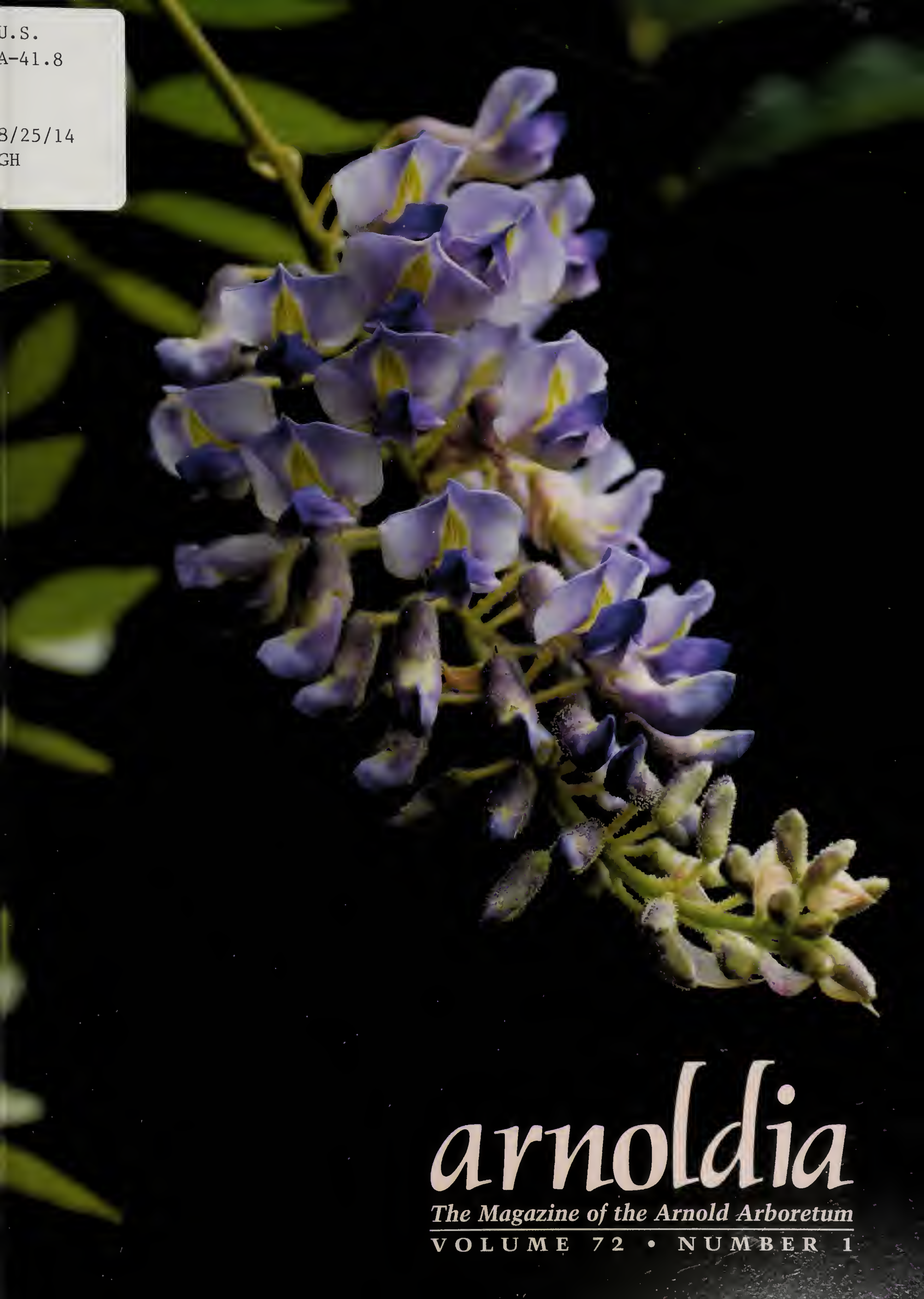

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Front cover: Flowers of a Kentucky wisteria cultivar (*Wisteria frutescens* var. *macrostachya* 'Blue Moon'). Photo by Nancy Rose.

Inside front cover: Gentiana dolichocalyx is one of 117 *Gentiana* species in China's Hengduan region. This specimen was growing in Zoigê Marsh, southwest of the city of Ruoergai—the marshes in this area are among the most extensive in the world and contain many rare plants. Photo by David E. Boufford.

Inside back cover: This centenarian London planetree (*Platanus × acerifolia*, accession 16595-B) provides summer shade at the Arboretum. Photo by Nancy Rose.

Back cover: A *Stellera chamaejasme* blooms in an alpine meadow in the Hengduan region. This species exhibits several strikingly distinct color forms, usually with one color restricted to a single geographic area. Photo by David E. Boufford.

CORRECTION TO "Untangling the Twisted Tale of Oriental Bittersweet" by Peter Del Tredici, *Arnoldia* Volume 71, Issue 3: On page 9, the image captioned "Portrait of Thomas Hogg, Jr." is instead a portrait of his father, Thomas Hogg, Sr. At right is a photograph of Thomas Hogg, Jr. (circa 1887), courtesy of the LuEsther T. Mertz Library of the New York Botanical Garden.

Seeing the Lianas in the Trees: Woody Vines of the Temperate Zone

Stacey A. Leicht-Young

STACEY A. LEICHT-YOUNG

Without a support structure to climb, this American wisteria (*Wisteria frutescens*, accession 1414-85) stretches laterally and spills over a rock wall in the Arboretum's Leventritt Shrub and Vine Garden.

In the forests and edge habitats of temperate North America, there is a group of woody plants that is well recognized but often overlooked by both the casual observer and scientific researcher alike. These woody plants are generally described as "vines," but are more accurately called lianas. The ability of lianas to grow and climb in all directions, not just taller and wider like the better-known trees and shrubs, makes them a unique group of plants worthy of further study and appreciation.

What is a Liana?

In the simplest sense, lianas are woody vines. The term liana is better known from tropical climates where they are more abundant. By def-

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Virginia creeper (*Parthenocissus quinquefolia*), a common North American liana, climbing up a tree trunk.

inition lianas (and herbaceous vines) are plants unable to support themselves; to grow upwards, they require other plants or structures to support them. The advantage to using other plants for support is that lianas can invest resources into growing a large leaf area for photosynthesis without investing much into stem materials. A disadvantage is that when the support a liana is growing on falls down, it will also fall. However, because of their unique stem anatomy and elastic growth, they can most often resprout from their stems or roots, or simply grow along the ground until they encounter a new support. This flexibile growth habit is perhaps the defining element of lianas. The liana growth form is found in many different plant families, indicating that the climbing habit has evolved several different times. The result is a great diversity of liana species that grow worldwide in varied habitats.

Lianas of the North Temperate Zone

The highest diversity of liana species is in tropical areas where they can make up 25% or more of the total plant species in some forests. Lianas are much less prevalent in temperate North America, though; one estimate from North and South Carolina indicated that lianas constituted just 1.3% of the native plant species (Gentry 1991). Europe has even fewer native lianas than North America. However, southern temperate areas, such as southern South America and Eastern Asia have a higher diversity of species because of differing climate and different evolutionary history. For example, the genus *Celastrus* has only one native representative from North America (American bittersweet, *Celastrus scandens*) while China has at least 25 species

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Celastrus angulatus **is a bittersweet species from China with large leaves.**

MANY WAYS TO CLIMB A TREE

One of the most fascinating aspects of lianas (and herbaceous vines) is the many different methods by which they can climb trees, trellises, and even walls or rock faces. In fact, Charles Darwin was one of the first to publish on the many different mechanisms that vines use to climb objects (Darwin 1867). Although there is some variation in how these groupings are made, the general categories are root climbers, adhesive tendrils, tendrils, stem twiners, and petiole climbers.

Root Climbers

Root climbing lianas use adhesive adventitious roots to climb trees or rock faces. These roots can often look like bunches of hairs along the liana stems. These species grow close to the substrate they are attached to and sometimes form lateral branches that grow out and away from the main stem of the liana. Familiar temperate root climbing species include poison ivy (*Toxicodendron radicans*), trumpet creeper (*Campsis radicans*), climbing hydrangea (*Hydrangea anomala* ssp. *petiolaris*), woodvamp (*Decumaria barbara*), and the evergreens English ivy (*Hedera helix*) and wintercreeper (*Euonymus fortunei*).

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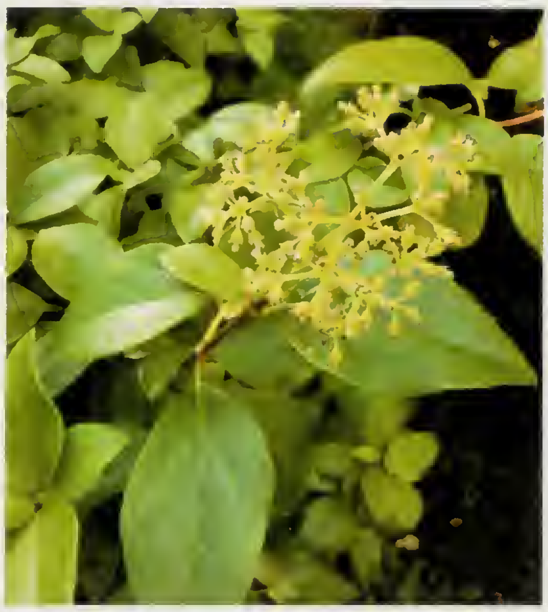

(Far left) Hairlike aerial roots of poison ivy attach the vine to the tree. (Left) The shiny, light green foliage of woodvamp (*Decumaria barbara*), a root-climbing species native to the southeastern United States.

Adhesive Tendrils

Like root climbers, lianas that have adhesive tendrils adhere to the tree or surface that they are climbing. However, it is not the roots that are doing the climbing in this case, but modified tendrils that have small adhesive pads at the tips. Adhesive tendril climbing lianas include Virginia creeper (*Parthenocissus quinquefolia*), which is one of the most common lianas in the forests of the Eastern United States; its relative, Boston or Japanese ivy (*P. tricuspidata*); and the showy-flowered crossvine (*Bignonia capreolata*), a species native to the southeastern and south central United States.

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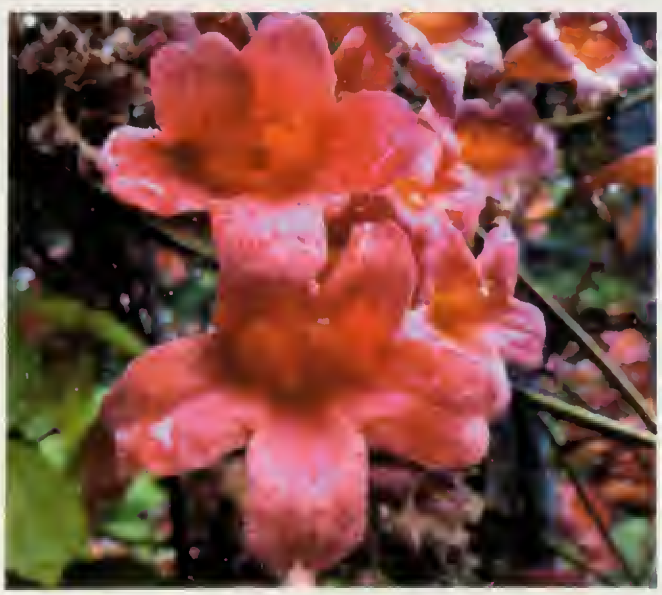

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(Left to right) Tendrils tipped with adhesive discs cling directly to supports; flowers of a crossvine cultivar (*Bignonia capreolata* 'Tangerine Beauty'); the unique leaves and adhesive tendrils of a wild crossvine climbing a white pine (*Pinus strobus*).

Tendrils

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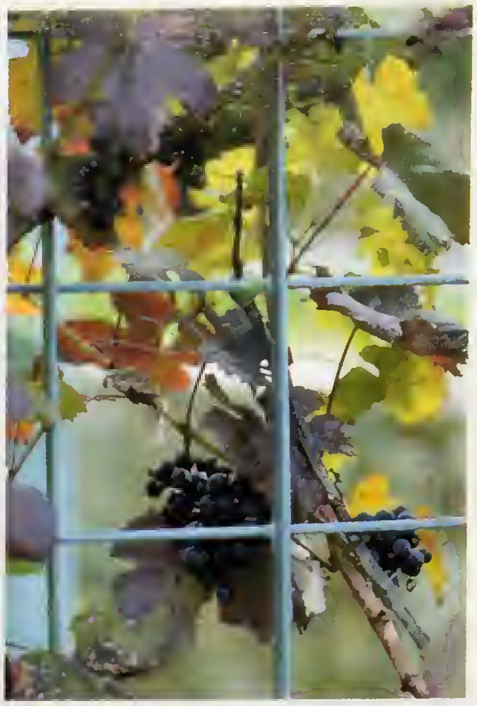

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Tendrils are structures that are formed through modifications of the stem, leaves, leaf tips, or stipules (outgrowths at the base of a leaf). Tendrils coil around small objects such as twigs, allowing the liana to climb. The most familiar temperate lianas that use tendrils are grapes (*Vitis* spp.) and porcelainberry (*Ampelopsis brevipedunculata*), another member of the grape family (Vitaceae). Greenbrier (*Smilax rotundifolia*) and other *Smilax* species use tendrils that are actually modified thorns to climb. Although members of the genus Smilax do not technically form woody stems (they are monocots, like lilies), they are often considered to be lianas because their stems persist overwinter and form leaves in the spring.

(Left) Grape tendril. (Above) Crimson gloryvine (*Vitis coignetiae*) is grown as an ornamental for its red to purple fall foliage.

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Stem Twiners

Stem twining lianas, as the name describes, use their stems to climb up objects by twining around them. They can also form somewhat self-supporting columns when many stems entwine. Stem twiners include bittersweets (*Celastrus* spp.) , vine honeysuckles (*Lonicera* spp.), wisterias (*Wisteria* spp.), chocolate vine (*Akebia quinata*), and supple-jack (*Berchemia scandens*), a lesser known native liana from the southeastern United States. Another species, the aromatic Chinese magnolia vine (*Schisandra chinensis*), is a stem twiner from one of the more ancient groups of flowering plants.

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Twining vines wrap around supports or even their own stems to climb. At left, entwined Oriental bittersweet (*Celastrus orbiculatus*) and Dutchman's pipe (*Aristolochia macrophylla*). Twining climbers include vining honeysuckles such as *Lonicera* × *heckrottii* 'Goldflame' (far left).

Petiole Climbers

Petiole climber lianas use their petioles (the small stalks at the base of leaves) to twine around objects in a manner similar to the tendril climbers. In temperate regions, clematis (*Clematis* spp.) is the most prominent petiole climber. There are hundreds of *Clematis* taxa including showy large-flowered hybrids as well as small-flowered species such as the white-flowered *C. virginiana, C. terniflora*, and *C. vitalba* that bloom in late summer or early fall.

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(Right) Twining petiole of *Clematis virginiana*. (Far right) Sweet autumn clematis (*C. terniflora*) is an Asian species that can escape cultivation and closely resembles the native virgin's bower (*C. virginiana*).

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Fox grape (*Vitis labrusca*), here showing characteristic matted white hairs on the underside of its leaves, is native to the eastern United States and is a parent species of the cultivated Concord grape.

The main reason cited for the lower diversity and numbers of lianas in the temperate zone is the presence of wide vessels in their stems. Vessels are part of plants' xylem tissue, which transports water from the roots to the leaves. In plants such as trees and shrubs, which are self-supporting, the wood structure is denser and has narrower vessels to provide structural support. Since lianas can have very long, flexible stems (because they use other plants for support), they have both very wide and very long vessels to move sufficient amounts of water to their large leaf canopy. However, there is a disadvantage to wide vessels. Large vessels, coupled with thin stems that do not provide much insulation, are more susceptible to the formation of air bubbles within them when temperatures drop below freezing. These bubbles are known as "freezing-induced embolisms." The embolism will block the flow of water through the liana stem, and potentially destroy the vessel if the air bubble is not dissolved back into the liquid when temperatures warm. If enough vessels are blocked, the liana cannot survive (Schnitzer 2005).

Temperate lianas do have adaptations to offset embolism. Some species, such as grapes (*Vitis* spp.), are able to use positive root pressure to push air bubbles out of vessels in early spring; this is why grape stems "bleed" when cut in the early spring. Other species, such as Oriental bittersweet (*Celastrus orbiculatus*), grow new xylem to replace any that was damaged by freezing in the spring (Tibbetts and Ewers 2000). In the far northern parts of its range in the United States and Canada, poison ivy (*Toxicodendron radicans*) grows as a low, trailing vine, not as the large, more exposed lianas seen in the Midwest and eastern United States (Schnitzer 2005). From a study of lianas in Chile, which has a southern temperate climate that experiences fewer continuous freezing days compared to northern temperate climates, lianas were found to have a mixture of large and small vessels, allowing transport of water in the small vessels even if the large ones became embolized (Jimenez-Castillo and Lusk 2013). Although the temperate zone has a lower diversity of lianas as a result of their susceptibility to embolisms, there are many liana species that do thrive in these habitats and contribute to forest dynamics.

The Ecology of Climbing Type

A liana's climbing method can provide information about the ecology of the species in natural settings (Carter and Teramura 1988). Root climbing and adhesive tendril climbing lianas can attach to supports of any size since they adhere to the surfaces they are climbing on. Often these species will grow in darker forest understories since they attach to larger trees that produce more shade. These species can also be seen growing up rock faces, and on

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Grape (*Vitis* sp., far left) climbing on American beech (*Fagus grandifolia*) in mature forest. Oriental bittersweet (light bark) using grape (dark bark) as a ladder to reach the canopy.

stone walls in gardens. Tendril climbers, stem twiners, and petiole climbers all need smaller supports to climb on since the stems or tendrils can only wrap around smaller diameter objects such as twigs. These species are most commonly observed in open forested habitats or along forest edges where there are small supports (e.g., shrubs and small trees) and higher light availability.

However, some of these species—most notably grapes and Oriental bittersweet—can employ other methods to reach the canopy in older forests with larger trees. Grapes often attach to trees when they are younger and continue to grow with them as the trees get taller, spreading across the canopy by means of their tendrils. This is why on a walk in the woods one can see very large grape stems scaling a tree straight from the forest floor to the canopy. Oriental bittersweet, on the other hand, can climb other lianas such as grapes to reach the canopy (this is called "laddering"), or it can "sit and wait" in the forest understory, growing along the ground until a gap forms from a tree fall, resulting in higher light and smaller diameter trees growing in the gap that it can climb (Leicht and Silander 2006). So, although lianas are more abundant in high light, disturbed habitats because of the higher availability of small supports to climb on, they can be present in old-growth forests as well (Leicht-Young et al. 2010).

North American Lianas and Their Asian Relatives

The liana floras of North America and East Asia have many genera in common. For example, *Wisteria*, *Clematis*, *Celastrus*, *Vitis*, and *Lonicera* all have Asian and North American species, but Asia has greater species diversity. Since North America and East Asia share similar latitudes, many liana species (and tree, shrub, and herbaceous species as well) were brought

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Japanese honeysuckle (left, *Lonciera japonica*), an invasive honeysuckle from East Asia, and trumpet honeysuckle (right, *L. sempervirens*), a native North American species.

from East Asia to North America for both practical (erosion control, wildlife forage) and horticultural (beautifying the landscape) purposes, mostly within the last 150 years. Many of these plant species have not spread because they are unable to move across the landscape via seed, were not planted in high numbers across a large area, or were constrained by climatic conditions (e.g., cold winter temperatures). But others have escaped from their original planting locations and become naturalized and sometimes invasive in the novel environment.

The very attributes of these Asian species that make them desirable horticultural species (e.g., drought tolerance, rapid growth, abundant flower or fruit production) in many cases "pre-adapt" them for naturalizing in the landscape in adverse conditions. Indeed out of the 12 liana species from East Asia that are listed on state invasive species lists, 11 were introduced for ornamental purposes while kudzu (*Pueraria montana* var. *lobata*) was planted extensively for erosion control (Leicht-Young and Pavlovic 2014). In addition, when plants are brought into a new geographic area they often escape from the herbivores and pathogens that kept them in check in their home range, thus allowing them to grow more prolifically in their new location where they lack these competitors. Invasive lianas are those species that have propagated beyond self-contained naturalized populations (such as through birds dispersing their seeds), and that have been observed to have negative effects on native ecosystems because of their high densities. These lianas have the attributes of other invasive plants, and because most lianas, native or non-native, can grow rapidly up and over objects, invasive lianas can be said to have a "perfect storm" of characteristics, and can cause widespread damage to native ecosystems. This damage includes outcompeting native vegetation, adding weight to tree canopies and increasing the probability of breakage or fall during wind or ice storms, and girdling trees by wrapping around the trunks and stopping the flow of water and nutrients to the tree. Some of the more damaging invasive liana species in the northeastern United States are Oriental bittersweet, Japanese honeysuckle, and porcelainberry. While some native lianas can also damage trees and vegetation, the high concentrations of invasive lianas in a given location can accelerate this process.

These invasive lianas are very challenging for natural areas managers to combat because they can resprout from their roots after they have been cut or treated with herbicide, and bird-dispersed fruits that move over long dis-

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Damage to tree trunk from Oriental bittersweet.

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Porcelainberry (*Ampelopsis brevipedunculata*), originally cultivated for its attractive multi-hued fruit, has escaped cultivation through bird dispersal of seeds and is now highly invasive in edge habitats throughout much of the Northeast and Mid-Atlantic regions.

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Japanese hydrangea vine cultivars (*Schizophragma hydrangeoides* 'Roseum [left] and 'Moonlight' [right]) cling to rock walls in the Leventritt Shrub and Vine Garden.

tances can reintroduce the plant to a treated area. Fortunately, due to both research and outreach efforts, the public as well as those working in the horticultural field are more aware of the negative attributes of these and other invasive plants, and they are rarely encouraged for plantings. It is important to note that although there are Asian species that have escaped from cultivation and become invasive, other species, such as climbing hydrangea (*Hydrangea anomala* ssp. *petiolaris*), Japanese hydrangea vine (*Schizophragma hydrangeoides*), and Chinese magnolia vine (*Schisandra chinensis*) have not been observed to escape garden settings.

Changes on the Way?

Non-native invasive lianas have changed the face of our native ecosystems by altering the makeup of species present in the environment and often competing with native species for resources and space. With global changes such as increasing temperatures and carbon dioxide (CO_2) levels along with increasing landscape fragmentation (e.g., hurricane damage [Allen et al. 2005]), the role that all lianas will play in these future ecosystems may become more prominent.

Evidence suggests that with increasing CO_2 lianas will grow more abundantly. Another interesting (but disturbing) change with increasing CO_2 is that poison ivy may contain more urushiol, the compound that causes the allergic reaction (Ziska et al. 2007). In tropical areas, there has been a documented increase in lianas that has been attributed to increasing CO_2 as well as increasing forest fragmentation (Schnitzer and Bongers 2011). This concept has been little explored in the temperate zone, but it could be expected that similar changes will be seen here as the risk of freezing-induced embolisms and severe frost damage from cold temperatures decreases with warming (such as the predicted expansion of kudzu into the northern United States). In addition, the prominence of secondary forests has increased, especially in regions like New England where young forests have grown up from abandoned agricultural land on the edges of developed areas. These disturbed secondary forests are ideal for liana

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Kudzu (*Pueraria montana* var. *lobata*) clambers up a sign post in Maryland.

growth because of high light conditions and the presence of small diameter supports. Thus, the combination of warmer temperatures, increasing CO_2, and habitat fragmentation may result in ideal conditions for an increase in the abundance and growth of temperate lianas.

Surprisingly little is known about the role lianas currently play in the ecology of temper-

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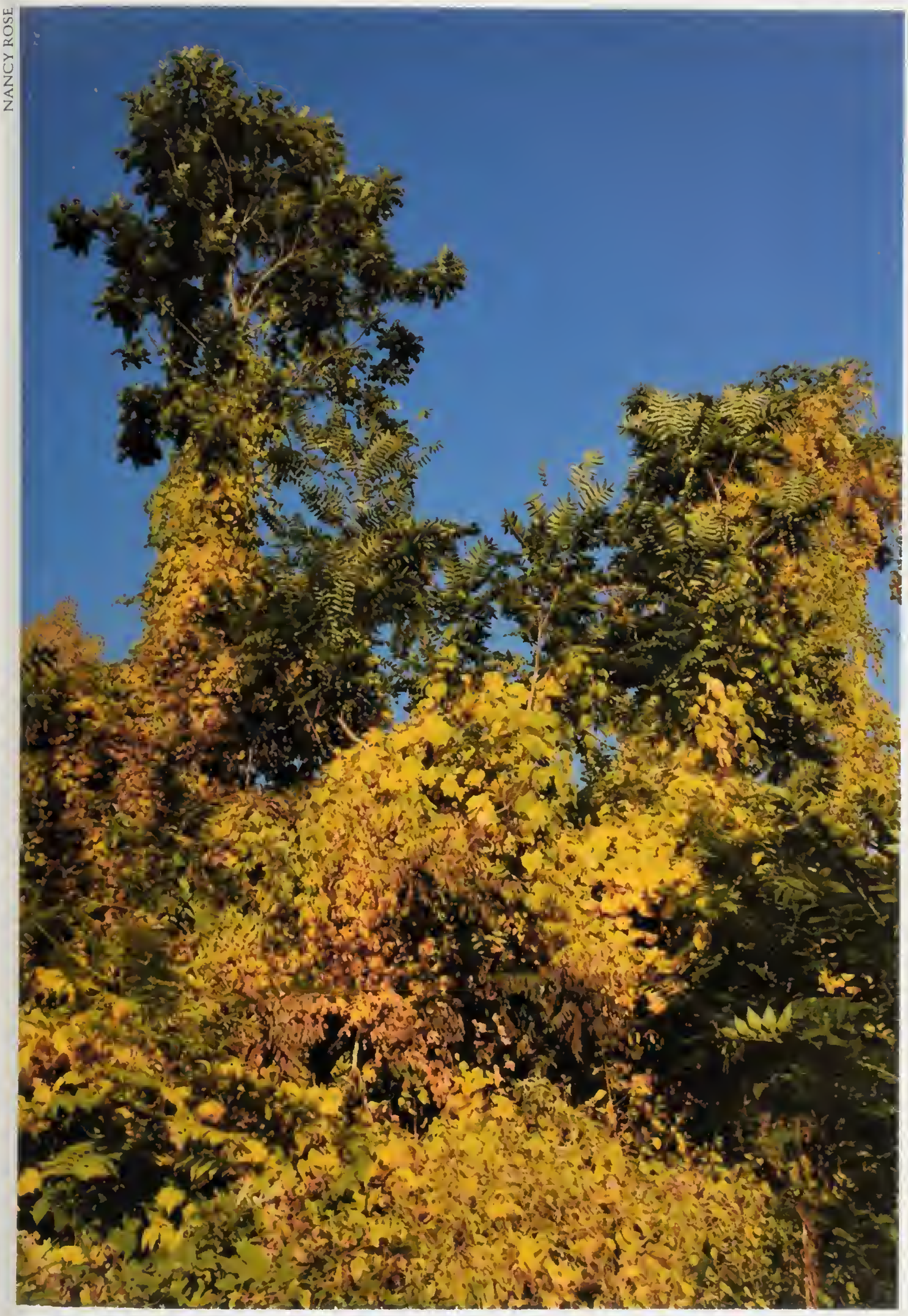
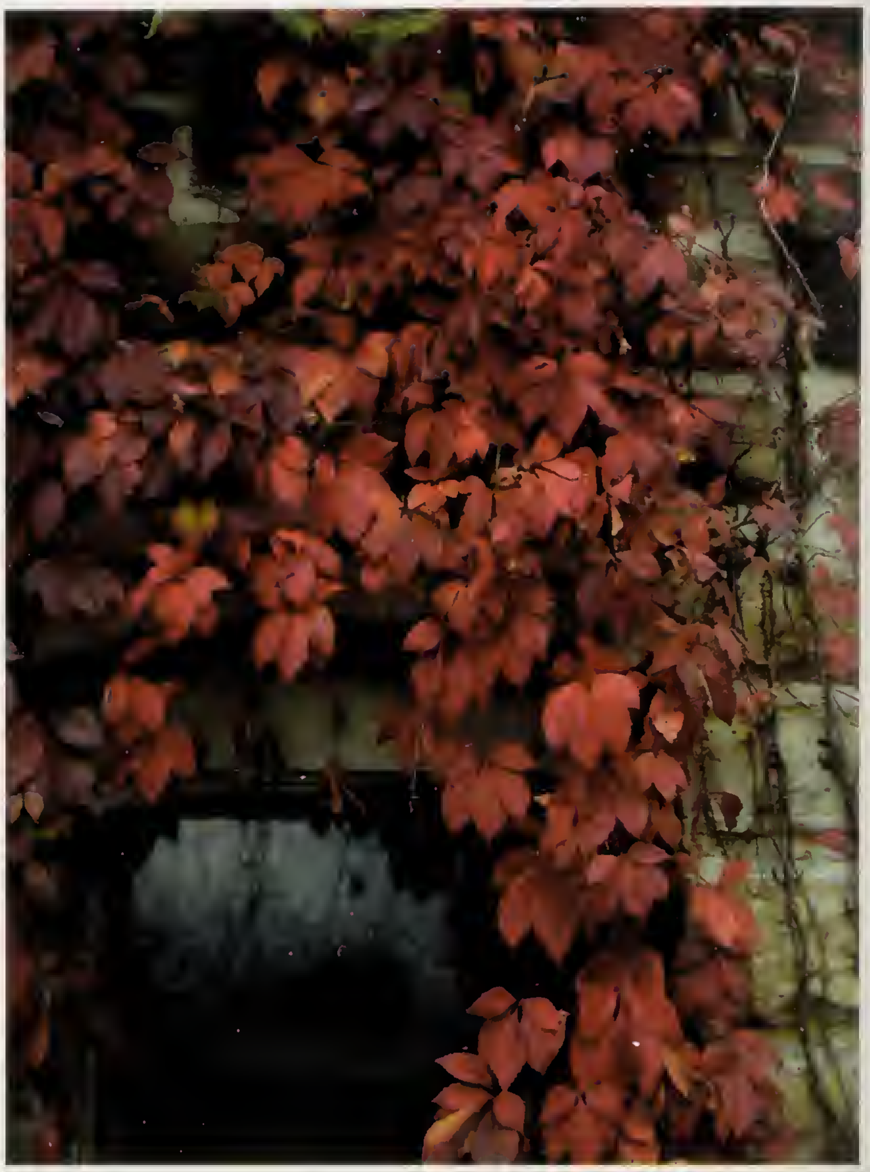


A tangle of wild grape (*Vitis riparia*) and Oriental bittersweet climbs trees in the Arboretum's Bussey Brook Meadow.

ate forests. We know from tropical studies and a handful of temperate studies that lianas compete with trees, not just in the obvious competition for light above ground, but also in the commonly overlooked root zone. In temperate species, researchers have found trees competing with liana roots show slower growth rates than those just competing above ground (Dillenburg et al. 1993). In addition, in seasonally dry tropical forests liana roots are able to tap deep water sources over a wide area, which allows them to continue to grow during drought while trees and shrubs often go dormant (Schnitzer 2005). From what we know about species like Oriental bittersweet, they can form extensive root networks that can compete with neighboring species and contribute to vegetative spread. Thus, roots likely contribute an important part in how lianas are able to successfully colonize and persist in competition with other plant species.

Intense competition from lianas above and below ground in high light situations, such as gaps in forests, may result in "liana tangles." These liana tangles can suppress the ability of trees to regrow into a forest gap or slow the succession of old fields to forests for many years. In temperate areas where the growing season is restricted to the warmer months, regrowth of trees and other species may be slowed for even longer. Additionally, as lianas grow up trees they put additional stress on them, resulting in a higher chance of tree fall. This cycle of lianas increasing the chance of tree fall and resprouting in newly formed gaps may have an important influence on the regrowth of subsequent secondary forests, especially after high-wind events or ice storms. These concepts have been studied to some extent in the tropics but need further observation and research in temperate habitats to increase understanding of how lianas contribute to the composition, structure, and ecosystem dynamics of temperate forests and what their future contribution may be in light of global climate change.

The next time you enjoy cascades of violet wisteria flowers on a pergola in the spring or see scarlet-leafed Virginia creeper on an autumn walk through the woods, consider the unique adaptations for growth that these and other lianas have made. By closely observing the fascinating species of temperate lianas that we often encounter we can better appreciate them and reflect on their important place in our ecosystem.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Virginia creeper (*Parthenocissus quinquefolia*) in fall color.

Literature Cited

Allen, B. P., R. R. Sharitz, P. C. Goebel. 2005. Twelve years post-hurricane liana dynamics in an old-growth southeastern floodplain forest. *Forest Ecology and Management* 218: 259–269.

Carter, G. A. and A. H. Teramura. 1988. Vine photosynthesis and relationships to climbing mechanics in a forest understory. *American Journal of Botany* 75: 1011–1018.

Darwin, C. 1867. On the movements and habits of climbing plants. *Journal of the Linnean Society of London Botany* 9: 1–118.

Dillenburg, L. R., D. F. Whigham, A. H. Teramura, and I. N. Forseth. 1993. Effects of below- and above-ground competition from the vines *Lonicera japonica* and *Parthenocissus quinquefolia* on the growth of the tree host *Liquidambar styraciflua*. *Oecologia* 93:48–54.

Gentry, A. H. 1991. The distribution and evolution of climbing plants. In F. E. Putz and H. A. Mooney (eds.) *The Biology of Vines*. Cambridge: Cambridge University Press. Pp. 3–52.

Jimenez-Castillo, M. and C. H. Lusk. 2013. Vascular performance of woody plants in a temperate rain forest: lianas suffer higher levels of freeze-thaw embolism than associated trees. *Functional Ecology* 27: 403–412.

Leicht, S. A. and J. A. Silander. 2006. Differential responses of invasive *Celastrus orbiculatus* (Celastraceae) and native *C. scandens* to changes in light quality. *American Journal of Botany* 93: 972–977.

Leicht-Young, S. A., N. B. Pavlovic, K. J. Frohnapple, and R. Grundel. 2010. Liana habitat and host preferences in northern temperate forests. *Forest Ecology and Management* 260: 1467–1477.

Leicht-Young, S. A. and N. B. Pavlovic. 2014. Lianas as invasive species in North America. In S. A. Schnitzer, F. Bongers, R. J. Burnham, and F. E. Putz (eds.) *The Ecology of Lianas*. In press.

Schnitzer, S. A. 2005. A mechanistic explanation for global patterns of liana abundance and distribution. *The American Naturalist* 166: 262–276.

Schnitzer, S. A. and F. Bongers. 2011. Increasing liana abundance and biomass in tropical forests: emerging patterns and putative mechanisms. *Ecology Letters* 14: 397–406.

Tibbetts, T. J. and F. W. Ewers. 2000. Root pressure and specific conductivity in temperate lianas: Exotic *Celastrus orbiculatus* (Celastraceae) vs. native *Vitis riparia* (Vitaceae). *American Journal of Botany* 87: 1272–1278.

Ziska, L., R. Sicher, K. George, and J. Mohan. 2007. Rising atmospheric carbon dioxide and potential impacts on the growth and toxicity of poison ivy (*Toxicodendron radicans*). *Weed Science* 55: 288–292.

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The Pawpaw, a Forgotten North American Fruit Tree

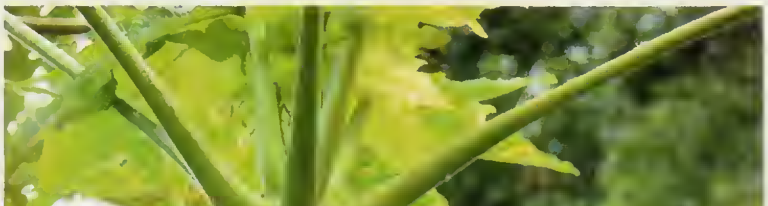
José I. Hormaza

The number of fruit trees native to North America is low compared to the many cultivated fruit species of Eurasian origin that currently form the basis for most fruit production in the New World. But there are a number of North American species with commercial possibilities, although many are neglected. Examples include a range of berries such as lowbush and highbush blueberries (*Vaccinium angustifolium* and *V. corymbosum*), cranberries (*V. macrocarpon*), huckleberries (*V. membranaceum*), American persimmon (*Diospyros virginiana*), American plum (*Prunus americana*), pawpaw (*Asimina triloba*), red mulberry (*Morus rubra*), and juneberries (*Amelanchier* spp.), most of them only available at a very small scale in some local markets. Among them, the pawpaw is probably one of the most interesting of the native North American fruit trees because of its exotic-tasting fruit and easy cultivation.

The History of Pawpaw

The earliest written report of pawpaw was made in 1541 by a Portuguese officer who was a member of Spaniard Hernando de Soto's expedition through the southeastern United States. He noted Native Americans growing and eating pawpaws in the Mississippi Valley region (Pickering 1879; Sargent 1890): "There is a fruit through all the country which groweth on a plant like Ligoacan [possibly a reference to lignum vitae, *Guaiacum officinale*], which the Indians do plant. The fruit is like unto Peares Riall ["pears royal"]; it has a very good smell, and an excellent taste" (Hackluyt 1609). Apparently, the name pawpaw was given to the tree by the members of the de Soto expedition for the resemblance of the fruits to the tropical fruit papaya (*Carica papaya*) that they already knew (Sargent 1890), papaya being a Spanish word derived from the Taíno word *papaia*. In some English speaking countries, such as Australia and New Zealand, the tropical papaya is also known as pawpaw, often resulting in confusion between the two species.

After this first report, pawpaw was described in records from additional explorations of the United States. One quote about the pawpaw in the northern United States is found in the so-called de Cannes memoir of 1690 (Pease and Werner 1934), probably written by Pierre Deliette, a French trader and colonial official who lived for several decades in Illinois: "There were other trees as thick as one's leg, which bend under a yellowish fruit of the shape and size of a medium-sized cucumber, which the



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The name "pawpaw" was apparently derived from papaya (*Carica papaya*), seen here, a tropical fruit that has a slight resemblance to pawpaw fruit.

5

savages call *assemina*. The French have given it an impertinent name. There are people who would not like it, but I find it very good. They have five or six nuclei [seeds] inside which are as big as marsh beans, and of about the same shape. I ate, one day, sixty of them, big and little. This fruit does not ripen till October, like the medlars." In 1709, John Lawson, a British explorer, reported in his book *A New Voyage to Carolina*—probably the first report of pawpaw in English—that "The Papau is not a large tree. I think I never saw one a foot through; but has the broadest leaf of any tree in the Woods, and bears an apple about the bigness of a hen's egg, yellow, soft, and as sweet as anything can well be. They [the Indians] make rare puddings of this fruit" (Lawson 1709). English naturalist Mark Catesby described and illustrated the pawpaw in his classic 1754 edition of *The Natural History of Carolina, Florida, and the Bahama Islands*: "The trunks of these trees are seldom bigger than the small of a man's Leg, and are about ten or twelve feet high, having a smooth greenish brown Bark. In March when the leaves begin to sprout, its blossoms appear, consisting each of six greenish white petals, the fruit grows in clusters of three, and sometimes four together; they are at first green, and when ripe yellow, covered with a thin smooth skin, which contains a yellow pulp, of a sweet luscious taste; in the middle of which lye in two rows, twelve seeds divided by so many thin membranes. All parts of the tree have a rank, if not a foetid smell" (Catesby 1754). In 1749, the Jesuit priest Joseph de Bonnecamps described the pawpaw: "Now that I am on the subject of trees, I will tell you something of the assiminetree, and of that which is called the lentil-tree. The 1st is a shrub, the fruit of which is oval in shape, and a little larger than a bustard's egg; its substance is white and spongy, and becomes yellow when the fruit is ripe. It contains two or three kernels, large and flat like the garden bean. They have each their special cell. The fruits grow ordinarily in pairs, and are suspended on the same stalk. The French have given it a name which is not very refined, *Testiculi asini*. This is a delicate morsel for the savages and the Canadians; as for me, I have found it of an unendurable insipidity" (Thwaites 1899).

Besides these early reports, it is known that George Washington planted pawpaws at this home, Mount Vernon, in Virginia (Washington 1785). Pawpaws were also among the many plants that Thomas Jefferson cultivated at Monticello, his home in Virginia (Betts et al. 1986); during his time as Minister to France he had pawpaw seeds (Jefferson 1786) and plants (Jefferson 1787) shipped to his friends in Europe. In September 1806, the members of the Lewis and Clark expedition subsisted almost entirely on wild pawpaws for several days. William Clark wrote in his journal : "Our party entirely out of provisions. Subsisting on poppaws. We divide the buiskit which amount to nearly one buisket per man, this in addition to the poppaws is to last us down to the Settlement's which is 150 miles. The party appear perfectly contented and tell us that they can live very well on the pappaws" (Lewis and Clark 1806). Daniel Boone and Mark Twain were also reported to have been pawpaw fans (Pomper and Layne 2005), and early settlers also depended partially on pawpaw fruits to sustain them in times of crop failure (Peterson 1991). Pawpaws are well established in American folklore and history (the traditional American children's song, "Way down yonder in the pawpaw patch," is still popular) and several towns, creeks, and rivers have been named after this fruit tree.

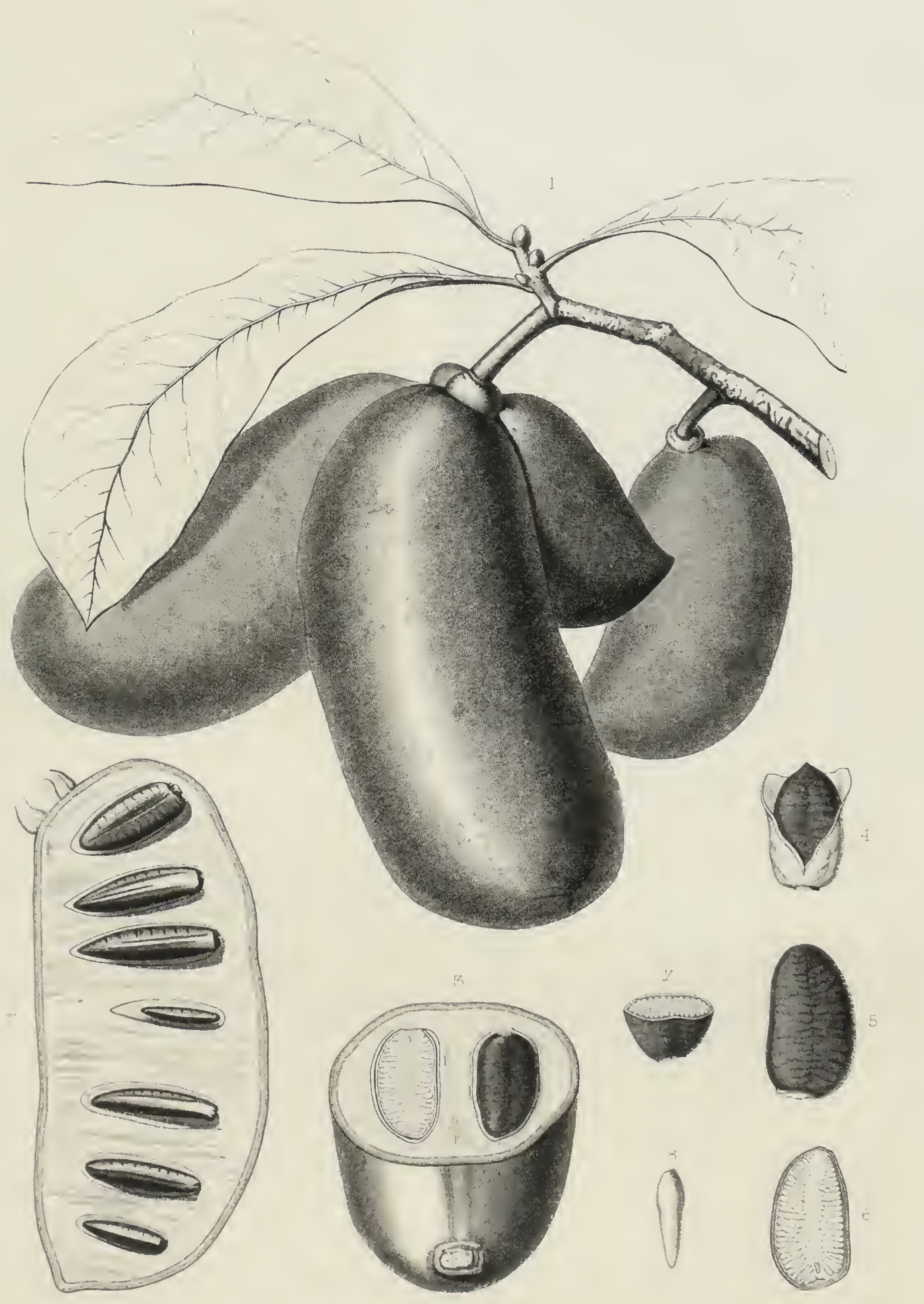
Taxonomy, Origin, and Dissemination

The first fossils of *Asimina* have been dated to the Eocene (about 56 to 34 million years ago) and the first clearly resembling *A. triloba* to the Miocene (about 23 to 5.3 million years ago) (Berry 1916). Janzen and Martin (1982) hypothesized that large fruits produced by some Central American plant species were dispersed by large mammals that were extinct by the end of the Pleistocene; they extrapolated this observation to North American plants that produce large fruits, such as the pawpaw. With the extinction of the fruit-eating megafauna, the range

Naturalist Mark Catesby used flower and fruit specimens preserved in alcohol to create his illustration of pawpaw, which may explain the lack of maroon flower coloration in this depiction. Image courtesy Missouri Botanical Garden, www.botanicus.org

Charles Edward Faxon's illustrations of *Asimina triloba* from Charles Sprague Sargent's *Silva of North America*, 1890.

Silva of North America Tab. XVI.



ASIMINA TRILOBA, Dunal

of the plant species dispersed by those animals started narrowing. Pawpaw probably survived thanks to its ability to easily reproduce vegetatively, producing numerous root suckers that form pawpaw patches in the wild (Barlow 2000, 2001). After the last ice age, humans could have become the new main vector dispersing pawpaw seeds and probably started the selection of plants with superior characteristics (Peterson 1991). Keener and Kuhns (1997) suggested that the northernmost distribution of the pawpaw into southern Ontario and western New York, Ohio, and Michigan was attributable to Iroquois population movements. Murphy (2001), however, argued against that hypothesis, suggesting instead that the spread of pawpaw could have been mainly by means of other mammals that seem to be able to eat pawpaw fruits, including raccoons, squirrels, opossums, foxes, bears, and white-tailed deer.

The North American pawpaw, *Asimina triloba* (L.) Dunal, is the northernmost representative of the mainly tropical and subtropical family Annonaceae, the largest living family within the order Magnoliales in the Eumagnoliid clade among the early-divergent angiosperms (Bremer et al. 2009). Annonaceae has more than 130 genera and 2,400 species (Couvreur et al., 2011), 900 of which are found in the Neotropics (Chatrou et al. 2004). Some of the tree species in the family such as cherimoya (*Annona cherimola*), sugar apple (*A. squamosa*), soursop (*A. muricata*), custard apple (*A. reticulata*), and atemoya (a hybrid between *A. cherimola* and *A. squamosa*) produce edible fruits, some of which were already used as a food source by pre-Columbian cultures in Central and South America (Popenoe 1989).

Pawpaw's scientific name has been changed repeatedly. Linnaeus first classified the pawpaw as *Annona triloba* in 1753. In 1763, Michel Adanson, a French naturalist, named the genus *Asimina* in his book *Familles naturelles des plantes*. The name *Asimina* is adapted from the native Algonquian word *assimin/rassimin/racemin*, via Cajun French *assiminier* (Chamberlain 1902; Gray 1886; Sargent 1890). Another North American native fruit, the American persimmon, also has the same root in its name, "min", the Algonquian word for fruit. However,


J. I. HORMAZA

The fruit of cherimoya (*Annona cherimola*).

in 1803 Michaux reclassified the pawpaw as *Orchidocarpum arietinum* and in 1807 Persoon reclassified it as *Porcelia triloba*. In 1817 Dunal renamed the species *Asimina triloba*. Torrey and Gray later moved the species to the genus *Uvaria*, but it was finally returned to *Asimina* by Gray in 1886 (Kral 1960). The current accepted nomenclature for the pawpaw is *Asimina triloba* (L.) Dunal.

The *Asimina* genus includes eight species native to North America (Kral 1960; Callaway 1990; Brett and Callaway 1992), four of which (*A. obovata* [Willd.] Nash, *A. pygmaea* [W. Bartram] Dunal, *A. reticulata* Shuttlw. ex Chapman, and *A. tetramera* Small) are found only in Florida, two (*A. incana* [W. Bartram] Exell and *A. longifolia* Kral) in Florida and southern Georgia, while *A. parviflora* (Michx.) Dunal reaches farther north, ranging from western Texas to North Carolina (Kral 1997). *Asimina triloba* is the most widespread of the eight species, indigenous to 26 states in the eastern United States, ranging from New York, and southern Michigan on the north, south to northern Florida, and west to eastern Texas, Nebraska, and Kansas (Callaway 1990). It is also present in Ontario, Canada (Fox 2012).

A Description of Pawpaw

The pawpaw is the only species in the *Asimina* genus that produces fruits of significant interest as a food source. It is, in fact, the largest edible fruit native to North America. It grows wild as a deciduous understory tree in hardwood forests with moist but well-drained and fertile soils in the eastern United States, often in large patches of the same genotype due to extensive root suckering (Kral 1960; Pomper and Layne 2005), although sometimes different genotypes can be found in the same patch (Pomper et al. 2009).

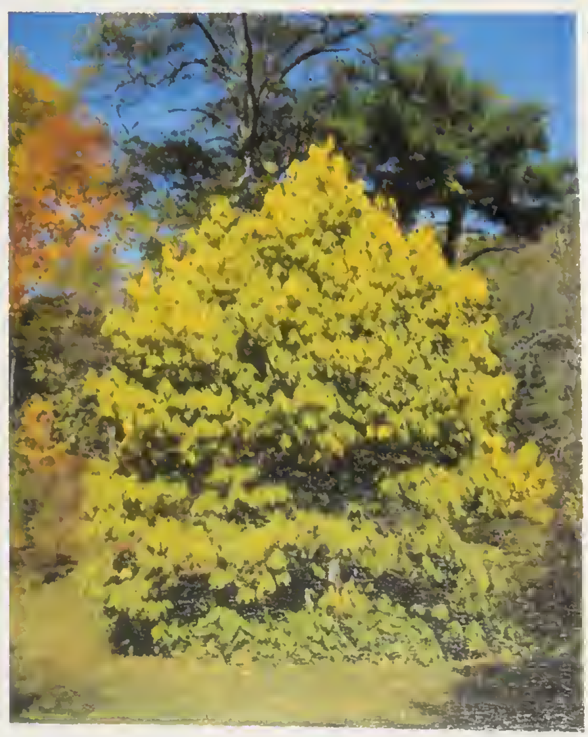
Pawpaw trees can reach up to 10 meters (32.8 feet) tall and typically have a pyramidal habit in sunny locations. Pawpaw can be grown successfully in USDA plant hardiness zones 5 through 8 (average annual minimum temperatures -20 to 20°F [-28.8 to -6.7°C]) (Kral 1960). Pawpaw flower buds are dark brown, pubescent, and occur singly on the previous year's growth (Kral 1960). The flowers are light green upon emergence, but gradually turn maroon, with a slightly fetid aroma. The mature flowers are

NANCY ROSE

A multitude of root suckers rise around the base of a pawpaw tree.

IN THE ARNOLD ARBORETUM there are currently four *Asimina triloba* specimens obtained from different sources:

- **The oldest accession is 12708-A, grown from seeds sent by E. J. Cole of Grand Rapids, Michigan, in February 1903; records show that it was growing in its current location in 1926.**
- **1222-79-A was collected from the wild as a plant by Arboretum staff members Jack Alexander and Gary Koller in Missouri in December 1979. It grew in the nursery for a few years and then was planted in the collection in 1986.**
- **143-94-B was collected as seed in Michigan in October 1993 by Tim Boland (current director of the Polly Hill Arboretum in Martha's Vineyard). The seeds were received in early 1994 and one of the seedlings was planted in its current location in 2003.**
- **205-91-A was collected as seed by staff members of the University of Guelph Arboretum (Ontario, Canada) in the floodplain of the Thames River in Middlesex County, Ontario. It was planted in the collection in 2003.**



MICHAEL DOSMANN

Asimina triloba accession 1922-79-A in autumn.

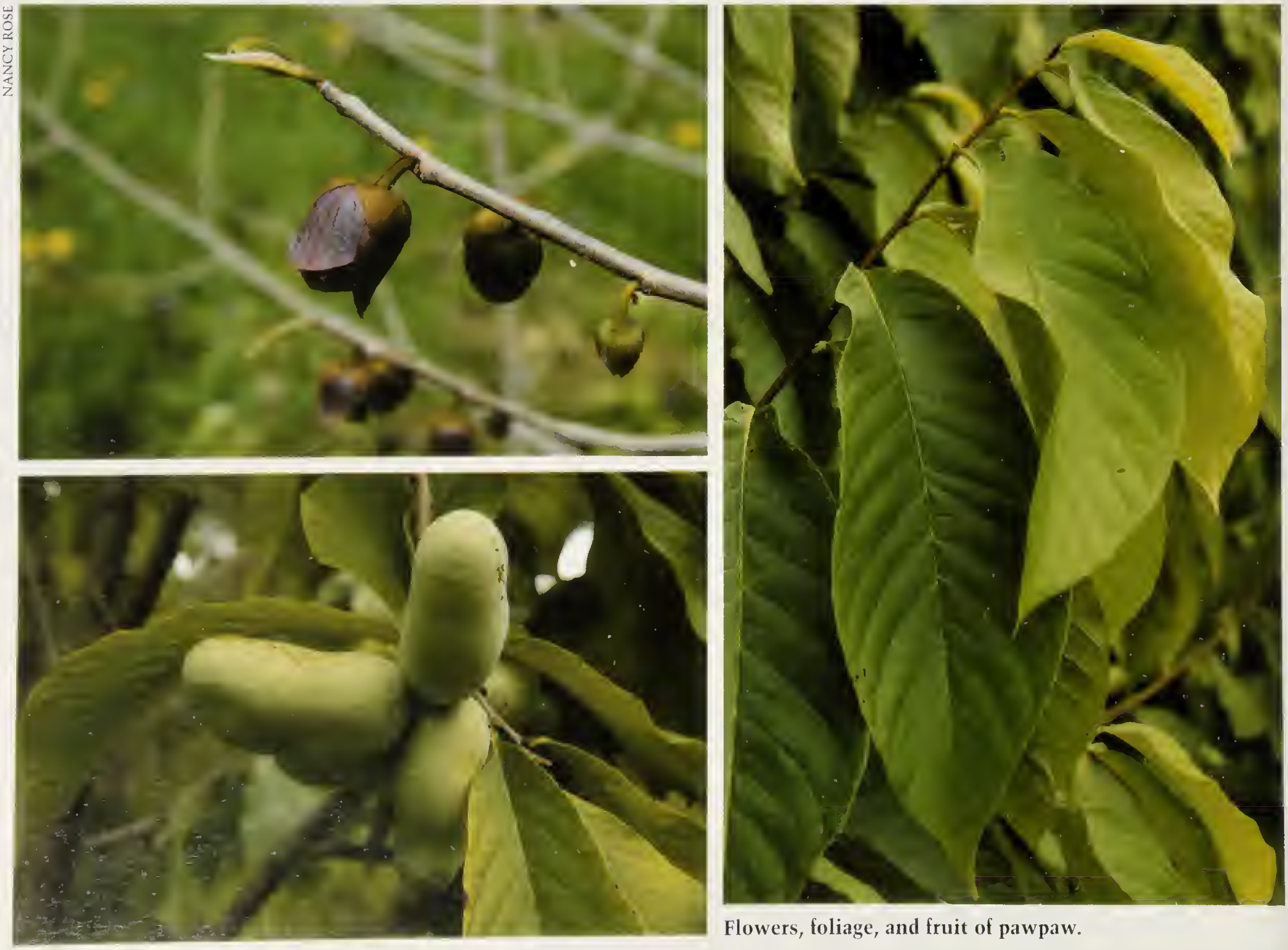
2 to 5 centimeters (0.8 to 2 inches) in diameter, with 3 outer petals, 3 smaller inner petals, and 3 sepals. Flowers emerge before the leaves have emerged and expanded.

The flowers have a globular androecium and a gynoecium with 7 to 10 simple, uniloculate carpels (Lampton 1957). As with other species in the Annonaceae, pawpaw flowers show protogynous dichogamy, that is, the stigmas are receptive before pollen is released from the anthers, which often prevents self pollination. Most pawpaw cultivars are believed to be self-incompatible (Pomper and Layne 2008).

The pawpaw fruits are botanically berries (Dirr 1990). The fruits are sweet, highly nutritious, have a pleasant but strong aroma, and have a unique exotic taste that resembles a combination of banana, mango, and pineapple (Pomper and Layne 2005). The pulp can be consumed both fresh and processed in different ways (ice cream, compotes, jam, pies, custards). The fruit can weigh up to 500 grams (17.6 ounces), with the average fruit weighing around 150 to 200 grams (5.3 to 7.1 ounces); there can be significant fruit weight differences depending on the genotype (Pomper and Layne 2005). The fruits have two rows of seeds with a total of 12 to 20 seeds that can be up to 3 centimeters (1.2 inches) long (Pomper and Layne 2008).

As with other Annonaceae species and other early-derived angiosperm families, pawpaws are primarily pollinated by flies and beetles that are attracted to the decaying smell and dark red color of the pawpaw flower; however, these pollinators are unreliable (Faegri and van der Piji 1971) and often of limited availability resulting in low fruit yields both in wild stands and in cultivation (Pomper and Layne 2008).

NANCY ROSE



Flowers, foliage, and fruit of pawpaw.

MEGAN MCCARTY

A female zebra swallowtail oviposits on an emerging pawpaw leaf.

Butterflies, Pawpaw, and Coevolution

The zebra swallowtail (*Protographium marcellus,* formerly *Eurytides marcellus*) is a beautiful black and white striped butterfly whose caterpillars feed exclusively on *Asimina* leaves. (The damage made to the leaves is reported to be negligible in pawpaw orchards [Pomper and Layne 2008]). Some compounds present in the pawpaw leaves (acetogenins, specific substances only found in species of the Annonaceae) are repellent to most insects and birds so the caterpillar accumulates them to avoid predation. These natural bioactive compounds present in the leaves, bark, and twigs of pawpaw and other species of the Annonaceae have shown some insecticidal and anti-tumoral properties (McLaughlin 2008). Of the seven swallowtail tribes, the Graphinii (to which the zebra swallowtail belongs) is one of the largest with about 150 species restricted to the tropics and subtropics except for two, *Iphiclides podalirius* and *Protographium marcellus* (the zebra swallowtail), that live in Palearctic and Nearctic regions, respectively (Haribal and Feeny 1998). The fact that both the zebra swallowtail and the pawpaw are the only members of their respective groups to live in temperate North America indicates that both species have coevolved and provides a neat system to study coevolution and adaptation to cooler climates.

The Current State of the Pawpaw

There was an increased interest in growing pawpaw as a crop at the beginning of the twentieth century; for example, in 1916 the American Genetic Association offered a $100 prize—$50 for the largest individual pawpaw tree and $50 for the tree—regardless of size—with the best fruit (American Genetic Association 1916). Yet in spite of its high potential through the years as a new high-value niche fruit crop, pawpaw is still only in the early stages of commercial production. The greatest current market potential for pawpaw is probably in local markets and direct sales to restaurants and other gourmet niche customers. Most pawpaw fruits are

Illustration of the exterior and interior of a pawpaw fruit painted by Royal Charles Steadman in 1924. From the USDA Pomological Watercolor Collection in the Rare and Special Collections of the National Agricultural Library in Beltsville, Maryland.

still collected from wild stands or produced in small family orchards. Current pawpaw production challenges have been reviewed by Pomper and Layne (2005) and include the need for new high-quality cultivars, pollination improvement, and postharvest issues; the shelf life of a tree-ripened fruit stored at room temperature is just 2 to 3 days, although under appropriate refrigeration conditions fruits harvested before fully ripening can be held up to 3 weeks while maintaining good eating quality. A number of high-quality pawpaw cultivars with large fruit (over 5 ounces) and heavy production have been selected since 1950 at Kentucky State University, which serves as a USDA National Clonal Germplasm Repository for *Asimina* species (Willson and Schmeske 1980; Pomper and Layne 2005).

Though pawpaws may never be as popular as apples or oranges, perhaps one day they'll at least make it out of the pawpaw patch and into the local grocery store. If you don't want to wait for that to occur, consider planting some pawpaw trees in your own backyard. This will give you the opportunity to taste an exotic fruit native to North America and, at the same time, perhaps enjoy the visit of zebra swallowtails.

References

American Genetic Association. 1916. Where are the best papaws? *Journal of Heredity* 7: 291–296.

Barlow, C. 2000. *The Ghosts Of Evolution: Nonsensical Fruit, Missing Partners, and Other Ecological Anachronisms.* New York: Basic Books.

Barlow, C. 2001. Anachronistic fruits and the ghosts who haunt them. *Arnoldia* 61: 14–21.

Berry, E. W. 1916. *The lower eocene floras of southeastern North America.* United States Geological Survey, Professional Paper 91, p. 90.

Betts, E. M., H. B. Perkins, and P. J. Hatch. 1986. *Thomas Jefferson's Flower Garden at Monticello,* 3rd edition. Charlottesville: University Press of Virginia.

Bremer, B., K. Bremer, M. W. Chase, M. F. Fay, J. L. Reveal, D. E. Soltis, P. S. Soltis, and P. F. Stevens. 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. *Botanical Journal of the Linnaean Society* 161: 105–121.

Brett, M. and D. J. Callaway. 1992. Our native pawpaw: the next new commercial fruit? *Arnoldia* 52(3): 21–29.

Callaway, M. B. 1990. The pawpaw (*Asimina triloba*). Kentucky State University Publications CRS-HORT1-901T.

Catesby, M. 1754. *The Natural History of Carolina, Florida and the Bahama Islands.* London.

Chamberlain, A. F. 1902. Algonquian words in American English. *Journal of American Folklore* 15: 240–267.

Chatrou, L. W., H. Rainer, and P. J. M. Mass. 2004. Annonaceae. In: D. W. Stevenson, S. V. Heald, N. Smith, S. A. Mori, A. Henderson (eds.). *Flowering Plants of the Neotropics.* Princeton, New Jersey: Princeton University Press. pp. 18–20

Couvreur, T. L. P., M. D. Pirie, L. W. Chatrou, R. M. K. Saunders, Y. C. F. Su, J. E. Richardson, and R. H. J. Erkens. 2011. Early evolutionary history of the flowering plant family Annonaceae: steady diversification and boreotropical geodispersal. *Journal of Biogeography* 38: 664–680.

Dirr, M. A. 1990. Manual of Woody Landscape Plants: Their Identification, Ornamental Characteristics, Culture, Propagation, and Uses. 4th ed. Champaign, Illinois: Stipes Publishing.

Faegri, K. and L. van der Piji. 1971. *The Principles of Pollination Ecology.* New York: Pergammon Press.

Fox, S. 2012. Picking up the pawpaws: the rare woody plants of Ontario program at the University of Guelph Arboretum. *Arnoldia* 69(3): 2–13.

Gray, A. 1886. The genus Asimina. *Botanical Gazette* 11: 161–164

Hackluyt, R. 1609. *A narrative of the expedition of Hernando de Soto into Florida. By a Gentleman of Elvas.* Published at Evora 1557. Translated from the Portuguese by Richard Hackluyt. London. http://archive.org/details/anarrativeofthee34997gut (accessed January 9th 2014).

Haribal, M. and P. Feeny. 1998. Oviposition stimulant for the zebra swallowtail butterfly, *Eurytides marcellus,* from the foliage of pawpaw, *Asimina triloba. Chemoecology* 8: 99–110.

Janzen, D. H. and P. S. Martin. 1982. Neotropical anachronisms: The fruits the gomphotheres ate. *Science* 215: 19–27.

Jefferson, T. 1786. From Thomas Jefferson to John Bartram, with Enclosure, 27 January 1786, Founders Online, National Archives (http://founders.archives.gov/documents/Jefferson/01-09-02-0201, ver. 2013-08-02). Source: *The Papers of Thomas Jefferson*; vol. 9, 1 November 1785–22 June 1786, ed. Julian P. Boyd. Princeton: Princeton University Press, 1954, pp. 228–230.

Jefferson, T. 1787. From Thomas Jefferson to John Banister, Jr., with enclosure, 7 February 1787," Founders Online, National Archives (http://founders.archives.gov/documents/Jefferson/01-11-02-0122, ver. 2013-08-02). Source: *The Papers of Thomas Jefferson*, vol. 11, 1 January–6 August 1787, ed. Julian P. Boyd. Princeton: Princeton University Press, 1955, pp. 121–122.

Keener, C. and E. Kuhns. 1997. The impact of Iroquoian populations on the northern distribution of pawpaws in the Northeast. *North American Archaeologist* 18: 327–342.

Kral, R. 1960. A revision of Asimina and Deeringothamnus (Annonaceae). *Brittonia* 12: 233–278.

Kral, R. 1997. Annonaceae. In: *Flora of North America*. Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford. Vol. 3, pp. 11–20.

Lampton, R. K. 1957. Floral morphology in *Asimina triloba* Dunal, development of ovule and embryo sac. *Bulletin of the Torrey Botanical Club* 84: 151–156.

Lawson, J. 1709. *A New Voyage to Carolina*. London. http://docsouth.unc.edu/nc/lawson/lawson.html (accessed January 9th 2014).

Lewis, M. and W. Clark. 1806. September 18, 1806, entry in *The Journals of the Lewis and Clark Expedition*, ed. Gary Moulton. University of Nebraska Press. 2005. http://lewisandclarkjournals.unl.edu/read/?_xmlsrc=1806-09-18&_xslsrc=LCstyles.xsl (accessed January 9th 2014).

McLaughlin, J. L. 2008. Paw Paw and cancer: annonaceous acetogenins from discovery to commercial products. *Journal of Natural Products* 71: 1311–1321.

Murphy, J. L. 2001. Pawpaws, persimmons, and 'possums: on the natural distribution of pawpaws in the northeast. *North American Archaeologist* 22: 93–115.

Pease, T. C. and R. C. Werner. 1934. *The French Foundations, 1680–1693*. Illinois Historical Collections, XXIII. Springfield: Trustees of the Illinois State Historical Library.

https://archive.org/details/frenchfoundation23peas (accessed January 9th 2014).

Peterson, R. N. 1991. Pawpaw (*Asimina*). *Acta Horticulturae* 290: 569–602.

Pickering, C. 1879. *Chronological History of Plants*. Vol. 1. Boston: Little, Brown and Company.

Pomper, K. W. and D. R. Layne. 2005. The North American pawpaw: botany and horticulture. *Horticultural Reviews* 31: 351–384.

Pomper, K. W. and D. R. Layne. 2008. *Asimina triloba*, pawpaw. In: J. Janick and R. E. Paull (eds.). *The Encyclopedia of Fruits and Nuts*. CAB International, pp. 62–68.

Pomper, K. W., J. D. Lowe, L. Lu, S. B. Crabtree, and L. A. Collins. 2009. Clonality of pawpaw (*Asimina triloba*) patches in Kentucky. *Journal of the Kentucky Academy of Sciences* 70: 3–11.

Popenoe, H. 1989. *Lost Crops of the Incas: Little Known Plants of the Andes with Promise of Worldwide Cultivation*. Washington, D.C.: National Academy Press.

Sargent, C. S. 1890. *Silva of North America*. New York: Houghton Mifflin.

Thwaites, R. G. 1899. *The Jesuit Relations and Allied Documents*. Travels and explorations of the Jesuit missionaries in New France 1610–1791. Vol. LIX. Cleveland: The Burrows Brothers Publishers.

Washington, G. 1785. Founders Online, National Archives (http://founders.archives.gov/documents/Washington/01-04-02-0002-0003, ver. 2013-08-02). Source: *The Diaries of George Washington*, vol. 4, 1 September 1784–30 June 1786, ed. Donald Jackson and Dorothy Twohig. Charlottesville: University Press of Virginia. 1978. pp. 96–111.

Willson, M. F. and D. W. Schmeske. 1980. Pollinator limitation, fruit production, and floral display in Pawpaw (*Asimina triloba*). *Bulletin of the Torrey Botanical Club* 107: 401–408.

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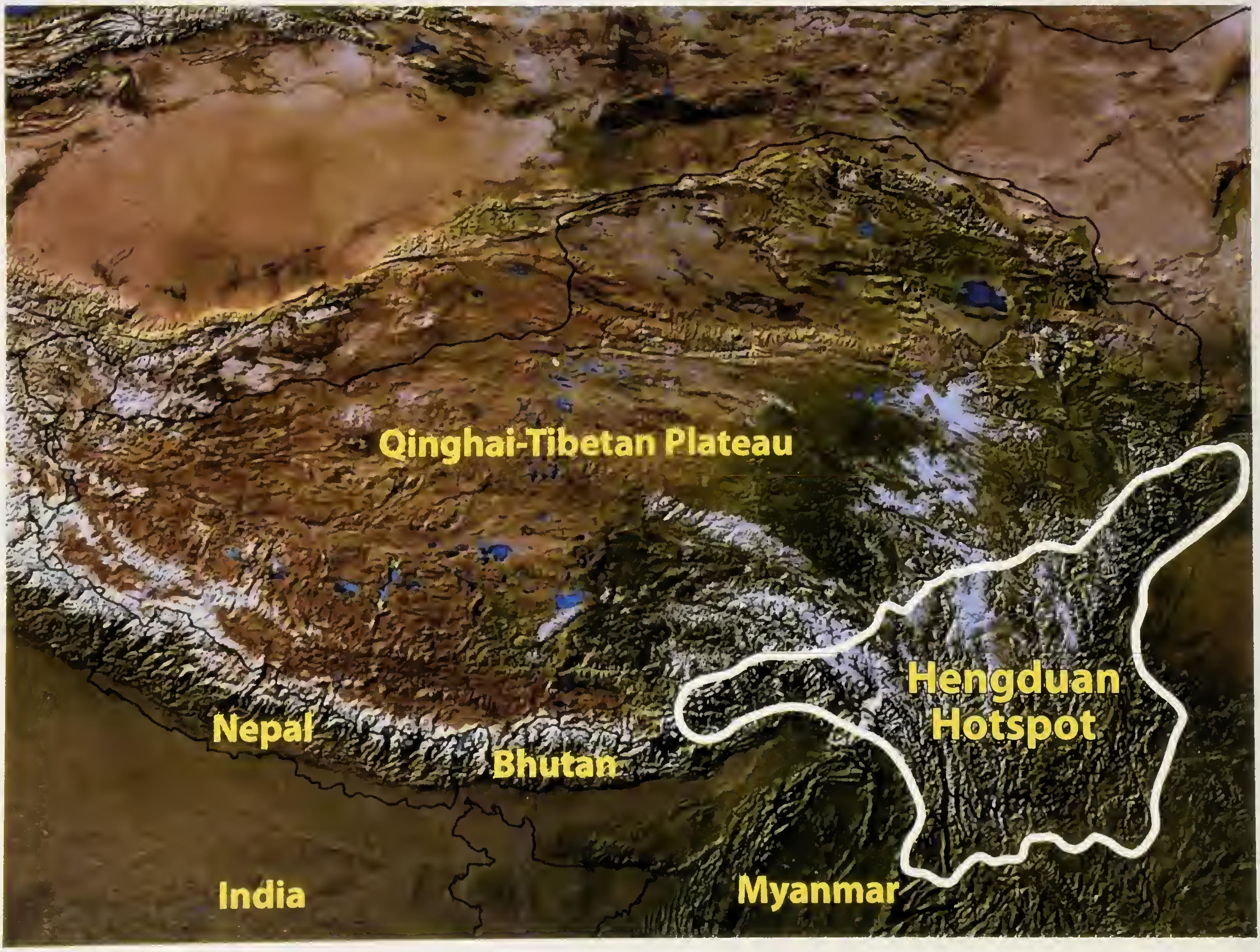
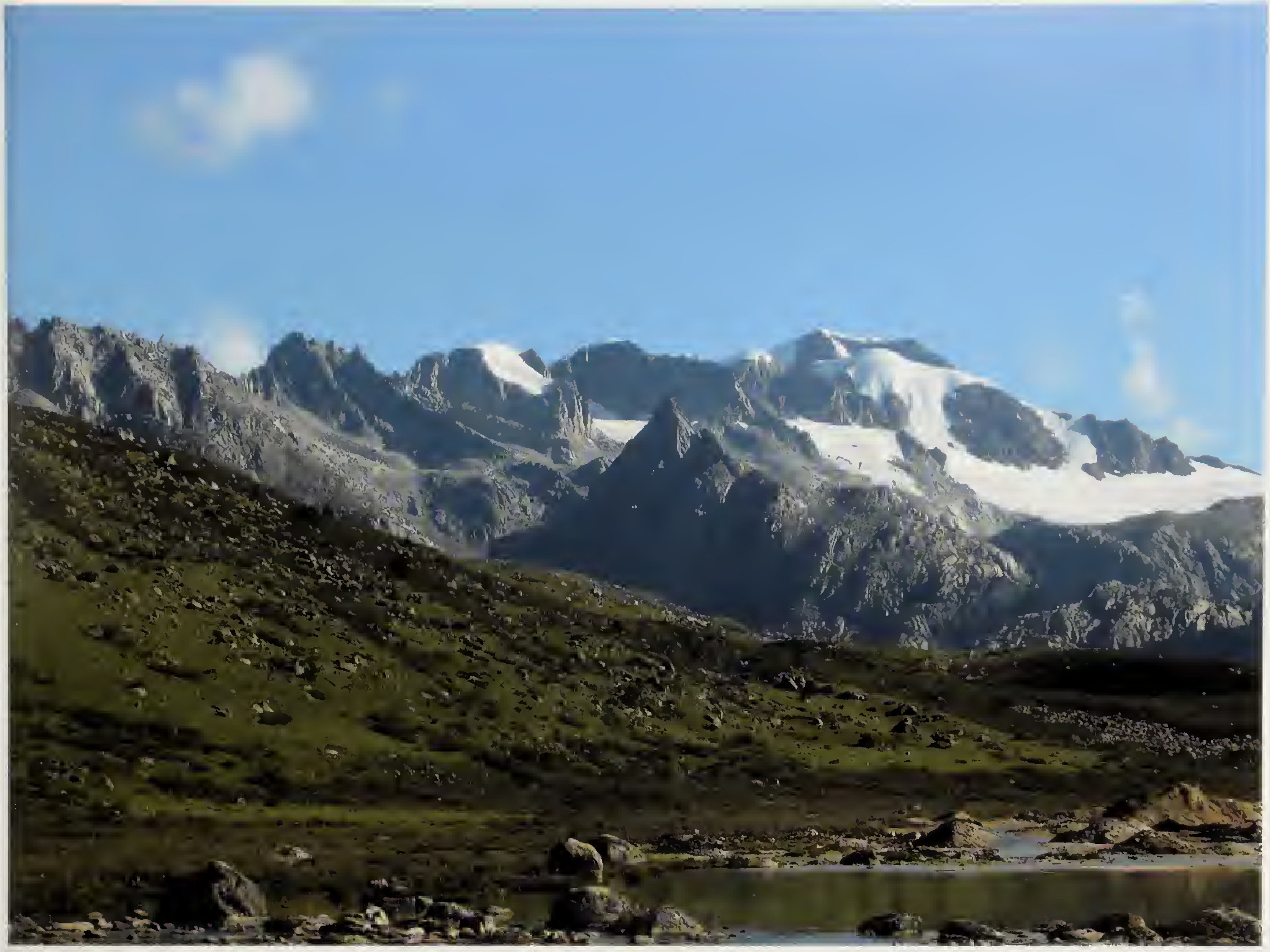
Biodiversity Hotspot: China's Hengduan Mountains

David E. Boufford

In southwestern China, in the southeastern corner of the Qinghai-Tibet Plateau, lies one of the world's 35 biodiversity hotspots: the Hengduan Mountains. This hotspot occurs at the juncture of mountain systems where precipitation can vary tremendously due to a combination of topography, climate, and hydrology. The terrain forms topographic channels that funnel seasonal monsoon rains up through the river valleys from the lowland tropics of southern China, India, and Myanmar (Burma) to the southeastern edge of the 5,000-plus-meter-high (16,400-plus-feet) Qinghai-Tibet Plateau. The region also receives vast amounts of water from the five major rivers that drain the plateau: the Yarlung Zangbo Jiang (which becomes the Brahmaputra in India and the Jamuna in Bangladesh); the Ayayerwaddy (Irrawaddy); Nu Jiang (Salween); Lancang Jiang (Mekong); and Jinsha Jiang (known in the West as the Yangtze, and





Sichuan, Batang Xian. A glacial lake lies at about 4,500 meters (14,764 feet) on the south side of the pass at Haizi Shan, surrounded by a *Kobresia* (bog sedge) meadow and with scattered dwarf *Salix* and *Rhododendron* on nearby slopes.

What's a Biodiversity Hotspot?

As defined by Conservation International, to qualify as a biodiversity hotspot a region must meet two strict criteria:

- It must have at least 1,500 vascular plants as endemics, which is to say, it must have a high percentage of plant life found nowhere else on the planet. A hotspot, in other words, is irreplaceable.
- It must have 30% or less of its original natural vegetation. In other words, it must be threatened.
- Around the world, 35 areas qualify as hotspots. They represent just 2.3% of Earth's land surface, but they support more than half of the world's plant species as endemics—i.e., species found no place else—and nearly 43% of bird, mammal, reptile, and amphibian species as endemics. (http://www.conservation.org/How/Pages/Hotspots.aspx)

by several different names in China: Tongtian He in Tibet, Jinsha Jiang from Qinghai through Yunnan, and Chang Jiang from the point where it enters Sichuan from Yunnan). The Nu Jiang, Lancang Jiang, and Chang Jiang have carved deep gorges through the region, and in some places flow less than 70 kilometers (44 miles) apart. The Huang He (Yellow River), not included within the Hengduan area, flows northeast from the Qinghai-Tibet Plateau, but its source is just one mountain range north of the source of the Tongtian He/Jinsha Jiang/Chang Jiang/Yangtze.

Extreme topographic relief is a characteristic feature of the Hengduan region. Hutiaoxia (Tiger Leaping Gorge), the gorge of the Jinsha Jiang between Yulong Xueshan (Jade Dragon Snow Mountain) and Haba Xueshan (Haba Snow Mountain), is at an elevation of around 1,900 meters (6,234 feet). Haba Xueshan on the northwest side rises to 5,396 meters (17,703 feet) and Yulong Xueshan on the southeast side rises to 5,596 meters (18,360 feet). The peaks of the two mountains are 21 kilometers (13 miles) apart.

To the north and west, the hotspot is bounded by the high, dry Qinghai-Tibet Plateau. On the east, the Hengduan region drops precipitously from over 3,000 meters (9,843 feet) to the low, flat, Sichuan basin at about 600 meters (1,969 feet). The southern boundary in Yunnan is at the 2,000 meter (6,562 feet) level of the Yunnan plateau (Boufford and Van Dijk 2000). The average elevation in the easternmost part of the Hengduan region is over 3,000 meters (9,843 feet) and nearly 5,000 meters (16,400 feet) in the west. The highest peaks are Gongga Shan (7,556 meters [24,790 feet]) in Sichuan and Namjagbarwa (7,782 meters [25,530 feet]) at the western end of the hotspot in southeastern Xizang.

(Top) *Carpinus cordata, Pinus, Helwingia japonica,* and *Rhododendron augustinii* (in bloom) on a rock outcrop on Motianling Shan, Baishui Jiang Nature Reserve in Gansu Province. (Bottom) The flowers of *Rhododendron augustinii.*

VEGETATION

Within the hotspot are numerous vegetation types, each with its characteristic floristic associations. On the east and southeast, the vegetation comprises mixed broadleaved deciduous and evergreen forests with such characteristic plants of central China and the Sino-Japanese Floristic Region as *Cercidiphyllum, Tetra-*

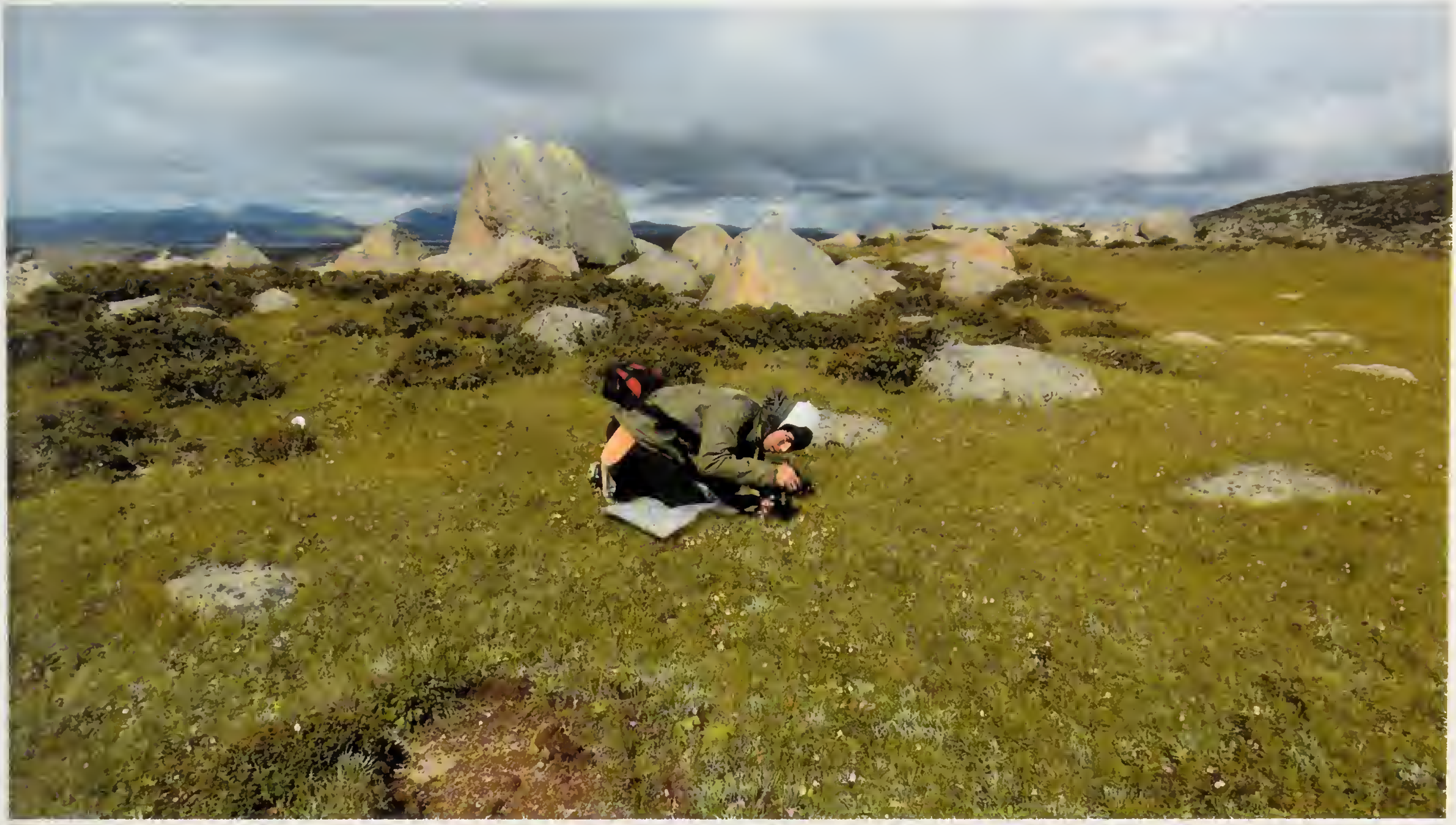
Sichuan, Litang Xian. North of Litang between Litang and Xinlong. A broad ravine with numerous side seepages and both moist and dry upland meadows, featuring the tall, yellow-bracted floral spikes of *Rheum alexandrae* (a rhubarb relative) and yellow-flowered *Pedicularis longiflora* var. *tubiformis* in the foreground along the stream.

centron, Acer (maple—45 species!), *Aesculus* (buckeye), *Tilia* (linden), several genera within Lauraceae (the laurel family), *Meliosma, Phellodendron* (corktree), *Evodia, Cornus* (dogwood), *Ostryopsis, Carpinus* (hornbeam), *Ostrya* (hophornbeam), *Betula* (birch), *Quercus* (oak), *Lithocarpus, Fagus* (beech), *Elaeocarpus,* and *Ailanthus* (Boufford and Ohba 1998). In formerly glaciated valleys and on higher slopes, *Abies* (fir), *Picea* (spruce), *Betula* and other boreal plants intermix with vegetation generally considered to be warm-temperate. Full grown, well-formed oak and fir trees reach an elevation of around 4,600 meters (15,092 feet) in some places and intermix with alpine meadows, scree slopes, and *Rhododendron* thickets. Herbaceous vegetation reaches to 6,000 meters (19,685 feet), although few plant specimens have been collected above 5,500 meters (18,045 feet).

The east and southeast portions of the Hengduan region are the best known, since they were easily reached by explorers and researchers coming up the Chang Jiang (Yangtze) or entering from Chengdu, about 100 kilometers (62 miles) away, or from Kunming. The forests on the eastern slopes also harbor some of the last surviving populations of giant panda, and China's best known and perhaps largest panda research station at Wolong Shan. About half of the Hengduan region within Sichuan was originally forested; the other half is part of what in China is called the Chuan-Zang-Gaoyuan (Sichuan-Xizang Plateau) (Sichuan Vegetation Study Group 1980; Wu 1988). Emei Shan (Mt. Omei), well-known as a center of plant diversity and for its many temples, is the best known and most thoroughly documented site within the Hengduan Mountains (Li and Shi 2007).

Above 3,500 meters (11,483 feet) is a rich mixture of alpine meadows, scree slopes, cliff faces, marshes surrounding glacial lakes, and other vegetation types generally dominated by a highly diverse flora of herbaceous plants and shrubs (Zhang et al. 2008). These intermix with conifer forests of primarily fir, spruce, and junipers in protected ravines and gorges. Rhododendron thickets are a conspicuous feature of the landscape, especially where Sichuan, Xizang, and Yunnan meet. They are best developed on sites protected from direct solar radiation, which can cause heating and drying of the soil, a phenomenon also noted on south-facing slopes in northern Myanmar (Burma) by Ward (1937). Alpine meadows, in the broad sense, typically dominated by species of *Kobresia* (bog sedges), are used for grazing throughout the region, particularly in the summer when herds of sheep, goats, and especially yaks are moved to higher elevations by the semi-nomadic Tibetan pastoralists. Most of the area is so heavily grazed that herbaceous plants survive only by growing

In Sichuan, just west of Gongya Xiang along the Serqu River. Three generations of Tibetan Buddhist pilgrims on a journey to Lhasa. At this point they were still 1410 kilometers (876 miles) from their destination with six months of walking to go.



Wang Qia photographing plants at Haizi Shan, an extensive cold, glaciated plateau with numerous lakes, ponds, and streams that often flow out of sight under the glacial debris.

up through the middle of shrubs, which offer some protection from the animals. The reason that so many herbarium specimens of herbaceous plants from these areas lack underground organs is because of the difficulty in extracting them from the middle of the coarse, frequently spiny shrubs in which they grow.

BIODIVERSITY

High diversity is generally associated with equitable, tropical climates. In contrast, the Hengduan region can experience snow, hail, freezing rain, and below freezing temperatures on any day of the year. Temperatures of -40°C (-40°F) and driving wind and snow are not unusual in the winter, yet plant diversity approaches that of the tropics. The vascular plant diversity is truly impressive, with as many as a third of China's vascular flora of 31,500 species growing just in the Hengduan regions. Of those, at least 3,500 species, including about 100 ferns and 20 gymnosperms, plus more than 30 genera of vascular plants, occur nowhere else in the world.

The diversity is also unusual in that a large proportion of species occur in relatively few, but characteristic, Hengduan genera: *Rhododendron* (226 species), *Pedicularis* (217), *Saussurea* (100+), *Ligularia* (70), *Cremanthodium* (38), *Anaphalis* (33), *Leontopodium* (25), *Artemisia* (55), *Gentiana* (117), *Primula* (113) *Saxifraga* (136), *Salix* (103), and *Corydalis* (89).

EARLY EXPLORATION

The first western explorers (and essentially the first naturalists) in the area were French missionaries who traveled to the remotest regions of China to convert the locals to Christianity (Kilpatrick 2014). Most were also trained in the natural sciences and were encouraged to collect and send specimens back to Paris. Among the most notable of these missionaries were Père Jean-Pierre-Armand David (1826–1900), the first westerner to send skins of the panda to Europe (in addition to many plant specimens); Père Jean Marie Delavay (1834–1895), who explored in western Yunnan and sent back thousands of plants specimens; Père Jean-Théodore Monbeig (1875–1914), who collected and was murdered in southeast Xizang; and Jean André Soulie (1858–1905), who collected in western Sichuan and southeast Xizang, where he, too, was murdered. The rich and varied collections of so many unusual plants arriving in Paris, when distributed to other herbaria in Europe, prompted the nurseries and scientific institutions of the day to send their own collectors to gather seeds and living plants for the garden trade and for science.

Western plant explorers including Joseph Rock (1885–1969), George Forest (1873–1932) and Ernest H. Wilson (1876–1930) visited parts of the Hengduan region, and Frank Kingdon-Ward touched its southern and western edges. From the 1920s to the 1940s, Chinese botanists including T. T. Yü (1908–1986), Ching Ren-Chang (1898–1986), K. M. Feng (1917–2007), C. W. Wang (1913–1987), W. P. Fang (1899–1983), and H. T. Tsai (1901–1981) made extensive collections along the southern and eastern edges of the area, but no comprehensive study of the entire region was undertaken until the Chinese Academy of Sciences organized a major multidisciplinary expedition to the area between 1973 and 1980. The findings from the expedition were published in *Vascular Plants of the Hengduan Mountains,* volumes 1 and 2 (Wang et al. 1993, 1994). Those two volumes provide detailed documentation on the plants of the area, not only those gathered on Chinese expeditions, but also specimens made by earlier Chinese and western collectors.

I and several colleagues have made numerous trips to document the biodiversity of the Hengduan region. Our own expeditions avoided areas where others had been, since the Harvard Herbaria are already richly represented by specimens from those areas. Instead, we focused on more remote regions and those that had been closed to the earlier explorers for various reasons.

THE FLORA

The Hengduan hotspot is botanically one of the richest temperate regions in the northern hemisphere. The high species diversity and endemism derives from the extremes of topography and climate, the island-like isolation of numerous high peaks and ridges, and the wide diversity of habitats they harbor. Broadleaved and coniferous forests, bamboo groves, scrub communities, savannas, meadows, prairies, freshwater wetlands, alpine scrubs, and scree slopes are among the broadly defined plant communities there (Sichuan Vegetation Study Group 1980). Because of the complex local geomorphology, the north-south orientation of the mountains, and the huge vertical differences in topography, vertical zonation of the vegetation is also well developed (Zhang et al. 2008). Areas between 1,000 and 3,000 meters (3,281 and 9,843 feet) provided conditions for humid mixed evergreen-deciduous broadleaved forests, xeric river valley scrub, and sclerophyllous evergreen broadleaved forests, depending on slope and moisture conditions. The drier formations are often characterized by introduced *Opuntia* (a cactus genus) on cliffs along the dry river gorges, making them reminiscent of a West Texas landscape.

Between 3,000 and 4,000 meters (9,843 and 13,123 feet) are subalpine coniferous forests dominated by *Pinus densata, Picea likiangensis,* other species of *Picea,* and *Abies squamata,* as well as by deciduous broadleaved species of *Betula* (birch), *Populus* (poplar), *Acer* (maple), *Quercus* (oak), *Prunus* (cherry), *Tilia* (linden), *Fraxinus* (ash) and *Sorbus* (mountain ash). Above 3,800 meters (12,467 feet) are alpine scrub and alpine meadows dominated by Cyperaceae (sedge family) members, particularly *Kobresia* (bog sedge). The subalpine scrub vegetation is dominated by shrubs of *Rhododendron, Juniperus, Caragana* (peashrub), *Artemisia, Salix* (willow), and a complex number of forms of *Dasiphora* (syn. *Potentilla*) *fruticosa* and *D. glabra.* Species of *Kobresia, Arenaria* (sandwort), *Bistorta, Aster, Saussurea, Pedicularis* (lousewort), various Apiaceae (carrot family), *Primula* (primrose), *Allium* (onion), *Cyananthus, Corydalis, Astragalus, Hedysarum* and *Oxytropis* dominate the alpine meadows.

On steep slopes at 4,500 meters (14,764 feet), the alpine scrub and meadows are replaced by alpine scree vegetation or by stony soils that provide habitat for numerous interesting endemic species of *Saussurea, Corydalis, Solms-laubachia* and other Brassicaceae (mustard family), and *Meconopsis* (a genus in the poppy family), or by high cold grasslands or high cold desert meadows where the major species are members of *Stipa, Kobresia, Carex, Arenaria, Bistorta* and *Artemisia.* The photos on the following pages provide just a small sample of the floristic richness of this unique and fascinating region.

Sichuan, Baiyu Xian, Zhandu Xiang. Mixed conifer-mixed broadleaved deciduous forests, with *Salix* (willow) growing near the stream, along a branch of the Ou Qu in Ase Gou (Ase Gorge).

References Cited

Boufford, D. E. and P. P. van Dijk. 2000. South-Central China. pp. 338–351, in R. A. Mittermeier, N. Myers, and C. G. Mittermeier, eds. *Hotspots: Earth's biologically richest and most endangered terrestrial ecoregions.* Mexico City: CEMEX/Agrupación Sierra Madre.

Boufford, D. E. and H. Ohba. 1998. *Sino-Japanese Flora: Its Characteristics and Diversification.* University Museum, University of Tokyo, Bulletin 37.

Eaton. D. A. R., C. B. Fenster, J. Hereford, S. Q. Huang and R. H. Ree. 2012. Floral diversity and community structure in *Pedicularis* (Orobanchaceae). *Ecology* 93(8) Supplement S182–S194.

Kilpatrick, J. 2014. *Fathers of Botany: Missionary-Botanists and the Western Discovery of Chinese Plants 1862–1914.* In press, to be published by Royal Botanic Gardens, Kew, and University of Chicago Press, autumn 2014.

Li, Z. Y. and L. Shi. 2007. *Plants of Mount Emei.* Beijing: Beijing Science and Technology Press.

Sichuan Vegetation Study Group. 1980. Sichuan Zhibei (Vegetation of Sichuan). Chengdu: Sichuan People's Press.

Wang, H. and D. Z. Li. 2005. Pollination biology of four *Pedicularis* Species (Scrophulariaceae) in northwestern Yunnan, China. *Annals Missouri Botanic Garden* 92: 127–138.

Wang, W. T., S. G. Wu, K. Y. Lang, P. Q. Li, F. T. Pu, and S. K. Chen (eds.). 1993. *Vascular Plants of the Hengduan Mountains.* Vol. 1, Pteridophyta, Gymnospermae, Dicotyledoneae (Saururacea to Cornaceae). Beijing: Beijing Science and Technology Press.

Wang, W. T., S. G. Wu, K. Y. Lang, P. Q. Li, F. T. Pu and S. K. Chen (eds.). 1994. *Vascular Plants of the Hengduan Mountains.* Vol. 2, Dicotyledoneae (Diapensiaceae to Asteraceae) to Monocotyledoneae (Typhaceae to Orchidaceae). Beijing: Beijing Science and Technology Press

Ward, F. K. 1937. *Plant Hunter's Paradise.* London: J. Cape.

Williams, P., T. Ya, Y. Jian, and S. Cameron. 2009. The bumblebees of Sichuan (Hymenoptera: Apidae, Bombini). *Systematics and Biodiversity* 7(2): 101–189.

Wu, Z. Y. 1988. Hengduan Mountain flora and her significance. *Journal Japanese Botany* 63: 297–311.

Zhang, D. C., Y. H. Zhang, D. E. Boufford, and H. Sun. 2008. Elevational patterns of species richness and endemism for some important taxa in the Hengduan Mountains, southwestern China. *Biodiversity Conservation* 18: 699–716. Published online 13 December 2008.

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WOODY PLANTS

A few of the woody plants of the Hengduan region, clockwise from upper left:

- The orange fruits of Tibetan sea-buckthorn (*Hippophae tibetana*).
- Immature cone of Prince Rupprecht larch (*Larix gmelinii* var. *principis-rupprechtii*).
- Flowers of *Clematis rehderiana,* named in honor of Alfred Rehder.
- Flowers of *Dipelta wenxianensis.*
- Young leaves of the shrub *Helwingia japonica* var. *papillosa,* which are cooked in oil with chopped garlic and eaten as a green vegetable.
- Fruits of *Eleutherococcus cissifolius,* a shrub in the aralia family (Araliaceae).

GENTIANACEAE

Gentians (*Gentiana*) and their relatives, notable for blue flower color, are characteristic of the Hengduan flora. Of the 248 species of *Gentiana* in China, 117 occur in the Hengduan region. Clockwise from upper left:

- *Gentianopsis contorta*
- *Gentiana crassicaulis*
- *Lomatogonium perenne*
- *Gentiana aristata*
- *Comastoma falcatum*
- *Gentiana atuntsiensis*

ASTERACEAE

The Asteraceae (aster or composite family) is another diverse plant group in the Hengduan region. *Saussurea, Ligularia, Cremanthodium, Anaphalis,* and *Leontopodium* (edelweiss) are among the most species-rich genera in the Hengduan region. Clockwise from upper left:

- *Saussurea stella* displays showy purple leaf bases.
- *Saussurea obvallata* has translucent bracts that form a protective globe around the small purple flowers within.
- These *Anaphalis* inflorescences feature pearly white bracts.
- *Cremanthodium humile* growing on a scree slope.
- The foliage of *Saussurea pilinophylla* is densely covered with soft hairs.
- Because it grows at elevations as high as 5,000 meters (16,404 feet), *Rhodiola crenulata* is believed to have special medicinal properties and is being extirpated by herb collectors throughout its range.

PEDICULARIS

Pedicularis has its main center of distribution in the Hengduan Mountain region, where 217 of China's 352 species occur. The plants are reported to be hemiparasitic, getting at least part of their nutritional needs from host plants. Despite many attempts, we have been unsuccessful in excavating the underground parts to find the connections with a host plant. While easy to recognize vegetatively as being a species of *Pedicularis,* the flowers are needed for identification to the species level. The beak (galea) and orientation of the corolla appear to be correlated with pollination by bumblebees (Eaton et al. 2012; Wang and Li 2005). The Hengduan region, with 65 species, is also the world's center of diversity for bumblebees (Williams et al. 2009). Clockwise from upper left:

- *Pedicularis stenocorys*
- *Pedicularis siphonantha* (two color forms within same population)
- *Pedicularis alopecuros*
- *Pedicularis kansuensis*
- *Pedicularis mollis*
- *Pedicularis armata* var. *trimaculata*

A Shady Character: *Platanus × acerifolia*

Nancy Rose

On hot, sunny summer days, visitors gravitate toward the Arboretum's magnificent old specimen trees whose dense, leafy canopies provide welcome shade. One such specimen is a centenarian London planetree (*Platanus × acerifolia*, accession 16595-B) growing in a prominent location near the juncture of Bussey Hill Road and Valley Road. This stately tree was accessioned in April 1891, received as a plant from Thomas Meehan and Son nursery in Philadelphia. With an age of about 125 years, it currently measures 31 meters (102 feet) tall, 24.5 meters (89 feet) wide, and has a trunk dbh (diameter at breast height) of 132.5 centimeters (52 inches).

London planetree was long considered to be a hybrid of Oriental planetree (*Platanus orientalis*) and American sycamore (*P. occidentalis*), though it required modern molecular analysis to prove this definitively. The species' exact origin and correct scientific name have been the subject of debate over the years. The parent species are from Eurasia and North America, respectively, so it was only through human transportation of germplasm between continents that they were able to hybridize. The first hybrid may have occurred at the Oxford Botanic Garden around 1670, though an origin in Spain has also been suggested. The first recorded binomial was *Platanus hispanica* in 1770, followed by *P. hybridus* in 1804, then *P. acerifolia* in 1805. Current references are split, with some listing *P. × acerifolia* (Ait.) Willd. and others *Platanus × hispanica* Mill. ex Münchh. as the accepted name.

Because of its hybrid nature, seed-grown London planetrees can be quite variable in growth habit, leaf shape, and fruit production. This is further compounded by potential backcrossing with either of the parent species. Mature London planetrees typically have a spreading crown and substantial trunk, and reach a height of 60 to 90 feet (18.3 to 27.4 meters) or more. The large (up to 10 inches [25.4 centimeters] wide) leaves have 3 to 5 lobes and are medium green with limited yellowish fall color. Male and female flowers are borne separately in globose inflorescences; the bumpy, tan, golf-ball-sized fruit holds multiple achenes. The fruit are usually borne in groups of 2 and may persist well into winter before breaking apart. London planetree's most notable ornamental feature is its thin, exfoliating bark that displays a camouflage-like pattern in shades of white, brown, and green.

A number of London planetree cultivars have been selected and vegetatively propagated; these cultivars are often preferred over seed-grown plants in landscapes where uniform tree shape and size is desirable. The species can be affected by several diseases including anthracnose, powdery mildew, and canker stain, so disease resistant cultivars have been especially sought after. The original "London" form (which lead to the common name) was likely a clonal selection, though "London planetree" is now widely used to denote the species as a whole.

Because of its large size and abundant leaf and fruit litter, London planetree is not ideal for many residential lots, especially small city lots. It is best reserved for sites where it can achieve its full stature, such as parks, public gardens, and campuses. London planetree is noted for its tolerance of heavy pruning and is often pruned and trained to limit crown growth, especially in Europe. Pollarding, a severe type of pruning that heads back growth to short, knobby limbs, is commonly practiced on London planetrees in European park and boulevard plantings. At the Arboretum, accession 16595-B and surrounding London planetrees have been allowed to grow in their natural, wide-spreading form, thus providing a shady haven during the dog days of summer.

Nancy Rose is the editor of *Arnoldia*.

arnoldia

The Magazine of the Arnold Arboretum
VOLUME 72 • NUMBER 2

Bessa del — J. N. Joly sculp

American Chesnut.

Castanea vesca

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Front cover: Flowers of a hybrid witch-hazel cultivar, *Hamamelis × intermedia* 'Jelena' (accession 462-65-A). Photo by Kyle Port.

Inside front cover: Illustration of American chestnut (*Castanea dentata*) from François André Michaux's *The North American Sylva,* Volume 3, published in 1819. Note that the illustration uses the old synonym *C. vesca* and an alternate spelling of the common name, "chesnut."

Inside back cover: The leaves of *Kalopanax septemlobus* accession 841-81-A, which grows near the Arboretum's Rehder Pond, developing bright greenish yellow fall color. Photo by Kyle Port.

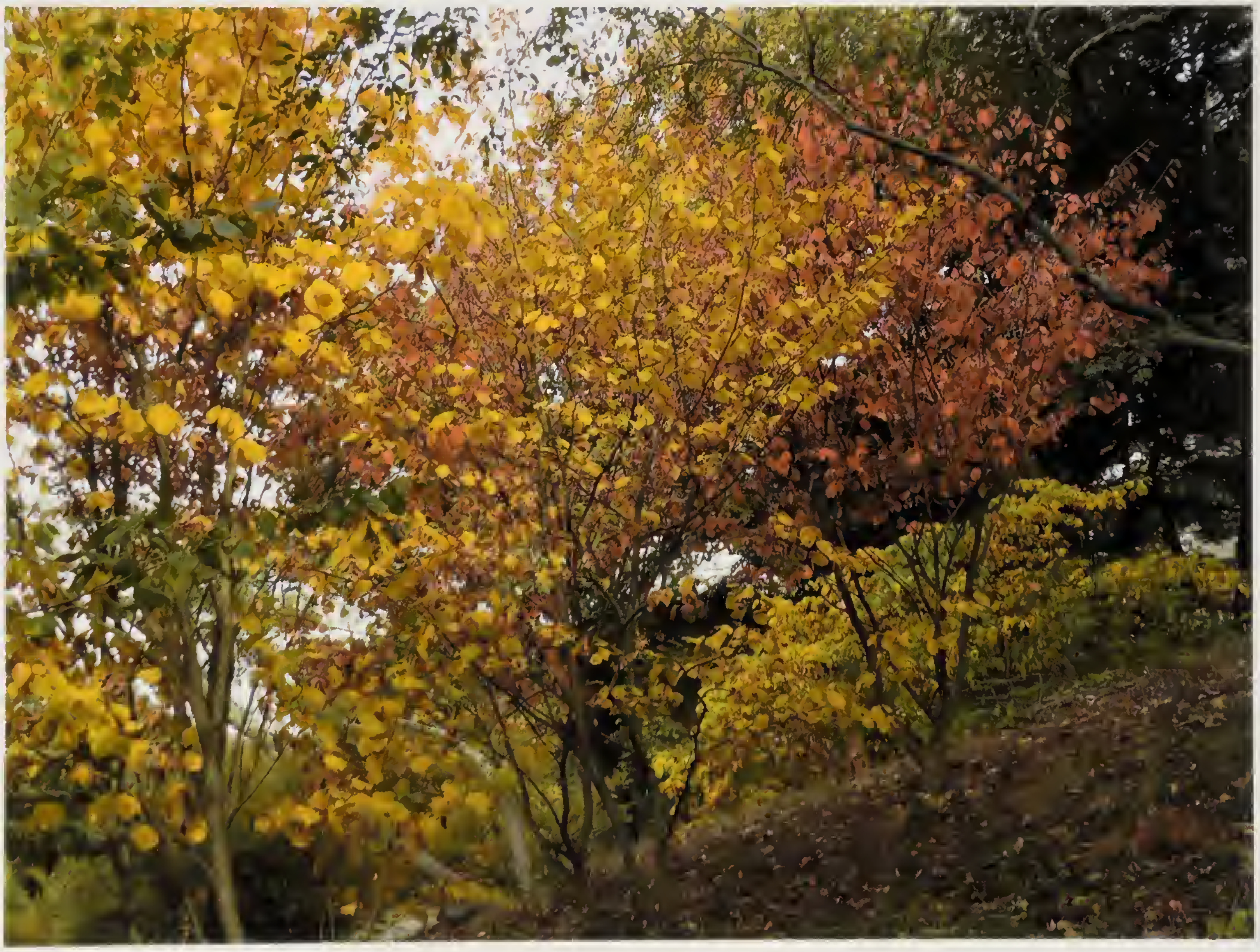
Back cover: Fall-flowering common witch-hazel (*Hamamelis virginiana*) blooms in a Minnesota garden. Photo by Nancy Rose.

Hamamelidaceae, Part 1: Exploring the Witch-hazels of the Arnold Arboretum

Andrew Gapinski

Hamamelidaceae, the witch-hazel family, includes approximately 30 genera representing around 100 species of deciduous trees and shrubs. Members of the family are found in both temperate and tropical regions of North and Central America, Eastern Asia, Africa, the Pacific Islands, and Australia. The Arnold Arboretum has a rich history with the family, from plant exploration to the naming and introduction of its members to cultivation. The Arboretum's Hamamelidaceae collection, which currently comprises ten temperate region genera, can be found in groupings throughout the Arboretum landscape. Specific locations

KYLE PORT

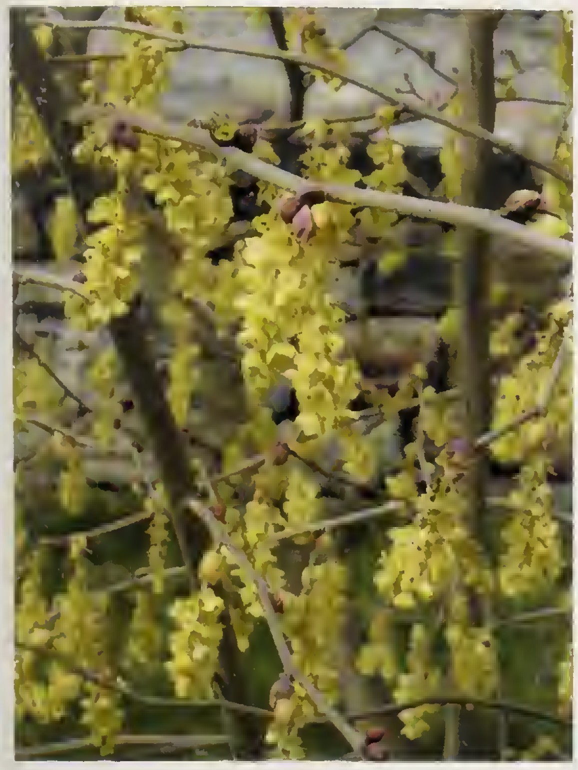


Many witch-hazels display attractive fall color; seen here, *Hamamelis* × *intermedia* 'Arnold Promise' (accession 380-94-C) with red orange foliage and *Hamamelis virginiana* f. *rubescens* (accession 527-92) with yellow foliage.

All In the Family

The Arnold Arboretum currently has living specimens representing these genera within Hamamelidaceae:

Corylopsis
Fortunearia
Fothergilla
Hamamelis
Liquidambar
Loropetalum
Parrotia
Parrotiopsis
Sinowilsonia
× *Sycoparrotia*



KYLE PORT (ALL)

Chinese winter-hazel (*Corylopsis sinensis*); American sweetgum (*Liquidambar styraciflua*); Large fothergilla (*Fothergilla major*)

include the area around the Hunnewell Visitor Center, the Leventritt Shrub and Vine Garden, scattered among the trees in the North Woods, on the edges of the hickory (*Carya*) collection, near the summit of Bussey Hill, and among the jewels of the Explorers Garden.

As autumn arrives at the Arboretum, the flowering season for the witch-hazel family begins, and will carry through until spring. Starting in October, common witch-hazel (*Hamamelis virginiana*)—a New England native—begins to bloom, the straplike yellow petals of its fragrant flowers extending on warm days and curling up when temperatures drop near freezing. This show can persist into December even as the snow begins to fall. Other members of the witch-hazel genus represent the earliest of bloomers, starting in January and lasting well into March—a remarkable sight in the depths of winter.

As the ground begins to warm in April, several species of *Corylopsis*—commonly called the winter-hazels—produce many pendulous clusters of bell-shaped yellow flowers. The fothergillas (*Fothergilla*) round out the family's flowering season in the Arboretum with their bottle-brush-like white blooms in May. Beyond the showy flowering of these genera, many are also aesthetically valuable for their unique foliage, vibrant fall colors, and, in the case of *Parrotia*, attractive exfoliating bark. Given these attributes, perhaps no other plant grouping holds greater ornamental potential and yet is so underutilized in today's landscape than the witch-hazel family. This two-part article explores various historical, taxonomic, and horticultural facets of Hamamelidaceae taxa in the Arboretum's collection. We begin with *Hamamelis*, the genus for which the family is named.

Hamamelis

> Whilst winter's hand is yet heavy on the land the Witch-hazels boldly put forth their star-shaped yellow blossoms but the native *Hamamelis vernalis* is over-shadowed by its more brilliant Chinese and Japanese relatives.
>
> Ernest H. Wilson, *Plant Hunting*, 1927

Witch-hazel (*Hamamelis*) is the most well-known Hamamelidaceae genus among gardeners and includes the only native New England representative of the family—*Hamamelis virginiana*, the common witch-hazel. There are two other North American species, *H. vernalis* (vernal or Ozark witch-hazel) and *H. ovalis* (big-leaf witch-hazel), and two Asian relatives, *H. mollis* (Chinese witch-hazel) and *H. japonica* (Japanese witch-hazel). All of these


KYLE PORT

Witch-hazel flower petals can furl and unfurl depending on air temperature. Seen here are flowers of *Hamamelis mollis* 'Princeton Gold'.


ANDREW CAPINSKI

A common witch-hazel (*Hamamelis virginiana*) in fall bloom, growing in Virginia's Shenandoah National Park.

Yellow flowers and yellow fall foliage blend on the branches of this common witch-hazel.

species are shrubs or small trees inhabiting temperate regions. They share characteristically narrow, straplike flower petals and capsulate fruit that is explosively dehiscent, capable of ejecting seeds as far as 10 meters (33 feet). Much work has been done to create hybrids (*H.* × *intermedia*) between the Chinese and Japanese species, resulting in the development of horticulturally desirable selections. Today these hybrids, as well as cultivars of *H. mollis*, are the witch-hazel family members most popular with American gardeners. Both the North American and Asian witch-hazels have a rich history, with fascinating stories of discovery and much horticultural potential.

North American Discoveries

Common witch-hazel has a wide-ranging native distribution along the east coast from Nova Scotia to Florida and west to the Mississippi River, petering out in the Ozarks. Its western limit runs from eastern Texas to Minnesota. It is commonly found in forest understories as a large multi-stemmed shrub. For non-gardeners, witch-hazel may be a familiar name not as a forest-dweller but for its use as a component in first-aid and skincare products. Native Americans used witch-hazel for its healing properties, and open-minded New Englanders soon recognized its potential. In 1866, the first commercial witch-hazel extract distillery was founded in Essex, Connecticut, by Thomas Newton Dickinson. Today, the distilling facility is located in East Hampton, Connecticut, and is the world's largest source of witch-hazel extract, still produced from witch-hazel wild-harvested from New England's woodlands.

The flowering time of common witch-hazel is definitely unique. Just as it seems that the last of the years' blooms have faded, *H. virginiana* comes into flower. Depending on the specimen in question, blooms start as early as October and can last into December. The species' fragrant flowers are composed of four yellow, straplike petals that furl and unfurl with the temperature swings of late autumn. In many cases, full bloom occurs when the plant's yellow fall foliage is still present, making it difficult to appreciate the flowers' full grandeur. This is viewed by some as an aesthetic fault of the plant, but to those who know what to look for, it is quite a remarkable display. With nothing else in bloom, the common witch-hazel has little competition for pollinators seeking a late season food source.

The Arboretum's largest concentration of *H. viriginiana* can be found in the North Woods, just past the *Aesculus* collection along Meadow Road, uphill from the short stretch of post-and-rail fence. A visit to explore this nook should be part of any autumn walk in the Arboretum. A bit farther down Meadow Road, at the northern end of Rehder Pond, is the Arboretum's oldest accession (14693-D) of common witch-hazel, wild-collected as a plant from western Massachusetts and brought back to the Arboretum in 1883 by Jackson Thornton Dawson, the Arboretum's first plant propagator.

Steps away from this specimen grows another one of the Arboretum's centenarian witch-hazels, *Hamamelis vernalis* accession 6099-D. Unlike common witch-hazel, the vernal witch-hazel, as the name suggests, flowers very early in the year (January through March). Although its geographic range overlaps with that of common witch-hazel, it only grows natively in the Ozark highlands of Missouri, Arkansas, and Oklahoma, and in small populations in Texas and Louisiana. A truly grand representation of the species, accession 6099-D was wild-collected as a seedling in Missouri and sent to the Arboretum in 1908 by Benjamin Franklin Bush under the consignment of Charles Sprague Sargent, the Arboretum's first director.

At the time of this plant's collection, *H. vernalis* had yet to be officially named and described by science, although, as herbarium records show, it was found growing in Missouri by Saint Louis botanist Dr. George Engelmann as early as 1845. Nonetheless, common witch-hazel was the only identified North American species at this point. In fact, Bush authored the 1895 publication *A list of the trees, shrubs and vines of Missouri* in which *H. virginiana* is mentioned as the sole representative of the genus. Sargent's 1890 publication *The Silva of North America, a description of the trees which grow naturally in North America exclusive of Mexico,* made the same conclusion.

The story of vernal witch-hazel's discovery begins with Sargent's and Bush's plant explorations in Missouri and Arkansas in September–October of 1907, the main goal of which was to search for new *Crataegus* (hawthorn) species. On October 8, 1907, the explorers collected a herbarium specimen in Swan, Missouri, of a *Hamamelis* in fruit, but lacking flowers; this certainly sparked their curiosity since it appeared dissimilar to the known fall-blooming species, *H. virginiana.* Returning to Boston, Sargent anxiously requested of Bush that he return to Missouri to collect seeds and flowering herbarium specimens that winter. In a letter to Bush dated January 22, 1908, Sargent wrote, "Are you doing anything about the flowers of that Southern Missouri *Hamamelis*? I am very anxious to get these this spring if possible and I am counting on you to do it, either through our friend at Swan or through your brother." Sargent received his first flowering vouchers of the suspicious witch-hazel on March 14, 1908, and wrote:

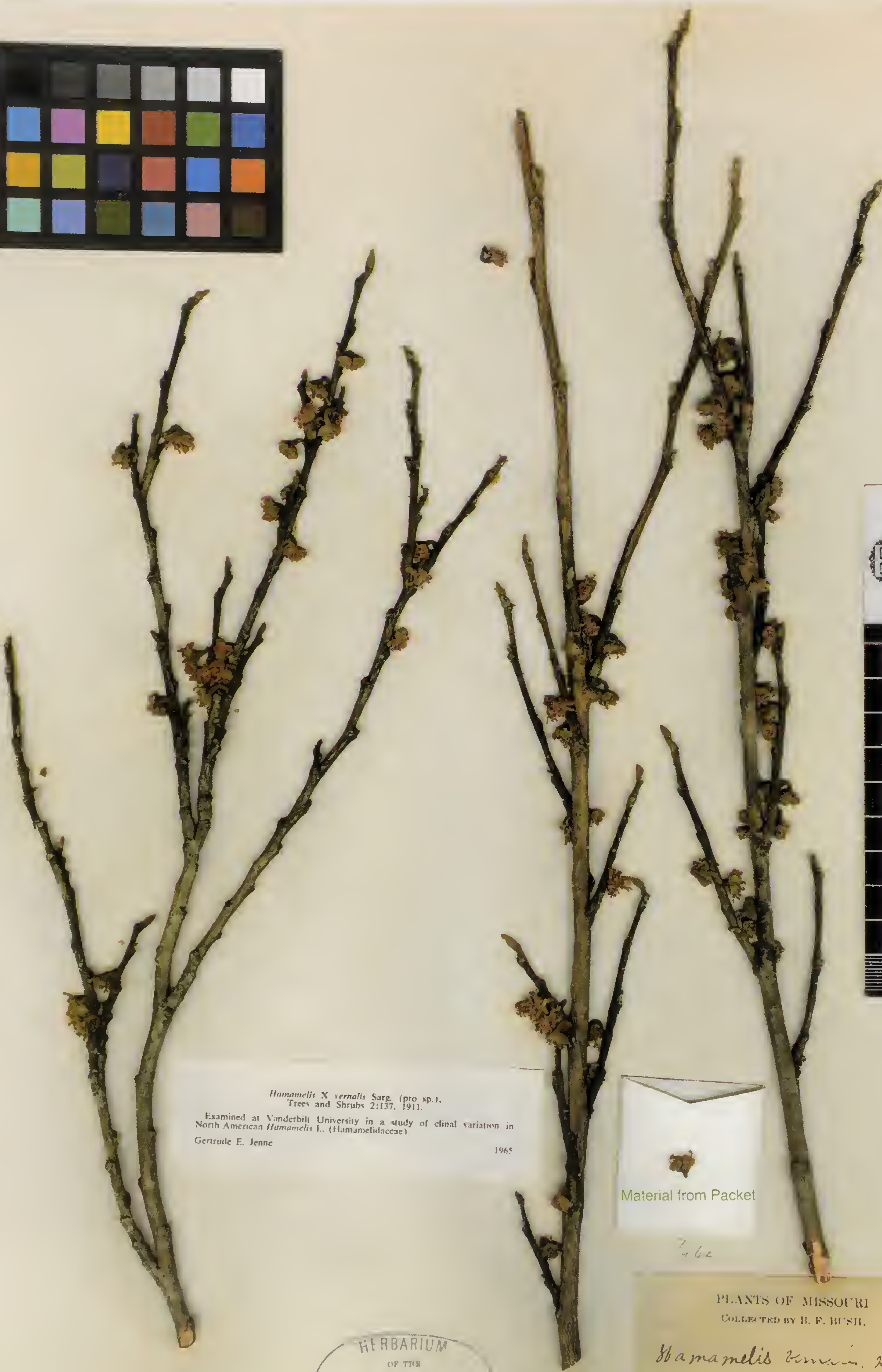

ROBERT MAYER

Flowers and old seed capsules of a 1908 accession of *Hamamelis vernalis* (6099-D) growing near Rehder Pond.

> Dear Mr. Bush:
>
> I am very much obligated for the *Hamamelis* specimens which arrived today. They were gathered a little too soon and if you had only put them in water a few days before pressing then the flowers would have fully expanded. I think there is no doubt, however, that this is an undescribed species. We want to describe and publish a figure of it in an early number of *Trees and Shrubs,* so I hope you won't "give it away" to anyone else ... We must manage to get some young rooted plants of the *Hamamelis* as none of the seeds we got last autumn were good. Apparently after they were gathered they were destroyed by the weevil ...
>
> Yours very truly,
>
> C. S. Sargent

Original October 8, 1907, herbarium voucher of *Hamamelis* sp. collected by B. F. Bush and C. S. Sargent in Swan, Missouri. This collection would lead to further investigation and the naming of a new North American witch-hazel species—*Hamamelis vernalis*—by Sargent in 1911. Note that the specific epithet "*vernalis*" was later added to the original description.


ARNOLD ARBORETUM
Vegetative specimen of *Hamamelis* from an area where *H.* X *vernalis* Sarg. and *H. virginiana* L. var. *virginiana* both occur. Positive determination uncertain, dependent upon floral structures.
Examined at Vanderbilt University in a study of variation in North American *Hamamelis* L. (Hamamelidaceae).
Gertrude E. Jenne 1965
Material from Packet
copyright reserved
cm 0 1 2 3 4 5 6 7 8 9 10
PLANTS OF ~~INDIAN TERRITORY~~ MISSOURI.
Hamamelis vernalis
Swan, Mo.
Oct. 8, 1907.
Taney Co.
Gravelly branches.
No. 4854A.
HERBARIUM OF THE ARNOLD ARBORETUM HARVARD UNIVERSITY
vernalis Sargent
Sargent, Trees & Shrubs 2: 137 (1911).
F. G. Meyer
18 Aug. 1992
U. S. NATIONAL ARBORETUM HERBARIUM, WASHINGTON, D. C.
THE HARVARD UNIVERSITY HERBARIA
00043430



Hamamelis X *vernalis* Sarg. (pro sp.).
Trees and Shrubs 2:137. 1911.

Examined at Vanderbilt University in a study of clinal variation in North American *Hamamelis* L. (Hamamelidaceae).

Gertrude E. Jenne

1965

Material from Packet

PLANTS OF MISSOURI

COLLECTED BY B. F. BUSH.

Hamamelis [illegible]

Swan, Mo.

Jan. 29, 1908.

Gravelly branches. No. 4915.

In October 1908, the Arboretum did receive and accession (6099) the rooted plants from Bush, as Sargent requested. Additional herbarium specimens of the wild plants in flower were received in February 1909 and are also held in the Harvard University Herbaria; they were undoubtedly sent to Sargent by Bush as he developed his new description of the species. In Sargent's 1911 publication, *Trees and Shrubs, Illustrations of New or Little Known Ligneous Plants,* he first described *H. vernalis* as a new species:

> The different species of *Hamamelis* offer no good morphological characters, the structure of the flowers, fruit and seeds being the same in them all. The plant, however, from southern Missouri, Arkansas and Louisiana is so distinct in its time of flowering, in the bright red color of the inner surface of the calyx-lobes, in the pale color of the under surface of the leaves, and in the amount and persistency of the pubescence on the leaves and branches that it appears desirable to distinguish it specifically from *Hamamelis virginiana.* The habit, too, of spreading by stolons into great thickets, and the fact that it grows so far as I have seen it only in the gravelly beds and margins of streams, also seem to separate it from the eastern species, which inhabits rich woodlands and upland pastures. In the color of the inner surface of the calyx-lobes and in its time of flowering *Hamamelis vernalis* resembles the Japanese species.

The individual specimen 6099-D from this original collection, which was planted and remains in its location near Rehder Pond, was first noted in bloom on January 15, 1913, by Ernest Henry Wilson, Arboretum plant explorer and "Keeper" of the Arboretum following Sargent's death in 1927. The news of the bloom was reported in the Arboretum's *Bulletin of Popular Information* that spring: "*Hamamelis vernalis* is an interesting plant with considerable decorative possibilities. It is a native of southern Missouri and, although the existence of a Witch Hazel in that part of the country has long been known, it has only recently been distinguished from the autumn flowering species of the northern states. This Missouri species flowered this winter in the Arboretum for the first time in cultivation and is still little known in gardens."


MICHAEL DOSMANN

Though not especially showy, the flowers of *H. vernalis* f. *tomentella* are notable for their fragrance.

In the 1920s, Alfred Rehder, renowned Arboretum taxonomist, described two variations (forms) of the species: *H. vernalis* f. *tomentella,* with pale, pubescent leaves, and *H. vernalis* f. *carnea,* with reddish petals. Specimens of both these forms (accessions 18885-A and 18886-A, respectively) can be found just north of the Hunnewell Visitor Center.

Astonishingly, almost one hundred years after Sargent named *H. vernalis,* a third species of North American witch-hazel was named. *Hamamelis ovalis,* known commonly as bigleaf witch-hazel, has a known range that is limited to a handful of counties in southern Mississippi and Alabama. It was discovered

Flowering specimen of *Hamamelis vernalis* sent from B. F. Bush to C. S. Sargent, at Sargent's urgent request following their collections in Swan, Missouri, the previous autumn. The flowers are only partially opened, as Sargent pointed out to Bush in his March 14, 1908, correspondence letter.

MICHAEL DOSMANN

This specimen of big-leaf witch-hazel (*Hamamelis ovalis*, accession 114-2009-A) displays the species' distinctive red flowers.

in July 2004 during a botanical inventory of a National Guard training site in Perry County, Mississippi. Officially described in 2006, this species has several distinctive traits including varying red petal coloration, musty floral scent, relatively large pubescent leaves, and the habitat in which it is found. Although known only to the far south, it carries the hardiest aspects of its relatives, growing remarkably well here at the Arboretum. Three specimens can be found planted in the collections, including accessions 113-2009-A and 114-2009-A in the Leventritt Shrub and Vine Garden. The latter of the two in particular expresses the large leaves for which the species is commonly named.

The potential horticultural merits of our native witch-hazels have long been recognized, yet remain underutilized. It is fairly rare to see these species grown in cultivation outside of botanic gardens and arboreta. Several cultivars of these species have been introduced, probably the most commonly seen being *H. vernalis* 'Autumn Embers', named for its noteworthy burgundy red fall foliage. Among the North American species and their variants growing at the Arboretum, there are three cultivars of vernal witch-hazel—'Lombart's Weeping', 'Orange Glow', and 'Sandra'—and one of common witch-hazel, 'Champlin' (synonym 'Champlin's Red').

Witch-hazels of Asia

In 1907–1908, as Sargent worked with Bush to describe *Hamamelis vernalis,* E. H. Wilson was collecting living plants and seeds of Chinese witch-hazel (*H. mollis*) in central China under the sponsorship of the Arboretum. Wilson wrote of his explorations:

> April 21, 1907
>
> Dear Professor Sargent,
>
> ... I visited a part of the mountainous region to the West-south-west of Ichang [Yichang], a part where I had not previously been. Reaching an altitude of about 7,000 feet, the woods in the mts. were still as dormant as in mid-winter, and the snow was still lying in the crevices. In the ravines & open valleys vegetation was advancing, and I made a collection of about 180 species of trees and shrubs ... Of shrubs, in the Mt. *Hamamelis mollis* was the most striking with its wealth of yellow flowers, on the low hills. *Loropetalum chinensis* [another member of the family] was a sight for the Gods ...
>
> With kindest regards,
>
> I am, Dear Professor,
>
> Faithfully and obediently yours,
>
> E. H. Wilson

Although still quite underutilized in our cultivated landscapes, the Asian witch-hazels and their hybrids have certainly received greater horticultural attention. Chinese witch-hazel is the least hardy of the species but is also the showiest, with bright yellow petals and red calyx-lobes, and fragrance well beyond the others. The previous season's leaves on *H. mollis* can be persistent, appearing dried out, brown, and obscuring the blooms even in late winter.

ANDREW GAPINSKI

This cultivar of Chinese witch-hazel (*Hamamelis mollis* 'Brevipetala') shows the species' trait of leaf retention.

KYLE PORT

This Japanese witch-hazel variant (*Hamamelis japonica* f. *flavopurpurascens*, accession 621-79-A) is notable for its multi-colored flowers.

It is found growing natively in the forests and thickets of central and eastern China. Japanese witch-hazel (*H. japonica*) differs from Chinese witch-hazel in several ways; it has a more flat-topped form, blooms slightly later, has cold-hardier flower buds, and its flowers have slightly longer and wavier petals but are often produced less abundantly and are muted in color. As the name suggests, *H. japonica* is endemic to Japan. The fall foliage color of both species can be quite spectacular.

Sargent himself collected seed of Japanese witch-hazel in 1892 as he explored the island's flora. He wrote observations of the encounter in his 1894 publication, *Forest Flora of Japan*:

> The Japanese *Hamamelis* ... is already an inhabitant of our gardens, where, unlike the American species which flowers in the autumn, it produces its orange or wine-colored flowers in March [*H. vernalis* had not yet been described]. *Hamamelis japonica* is one of the common forest-shrubs or small trees in its native country, where specimens occasionally occur thirty or forty feet in height, with stout straight trunks and broad shapely heads. In autumn the leaves turn bright clear yellow; but on one form which we found on Mount Hakkoda, near Aomori, with small thick often rounded leaves (*Hamamelis arborescens* of Hort., Veitch), they were conspicuous from their deep rich vinous red color. This may, perhaps, prove to be a second Japanese species.

As Sargent's observations in the wild suggest, the fall color can be quite variable, with combinations ranging from yellow to purple. None of the witch-hazel representatives from Sargent's 1892 voyage remain in the collections today, but a rather stately, vase-shaped specimen of *H. japonica* (accession 475-90-A) can be found growing in the Leventritt Shrub and Vine Garden.

As well, while none of the witch-hazels Wilson collected directly for the Arboretum remain in our collections today, the lineage of his 1907–1908 voyage lives on in a very significant way. On February 21, 1908, Wilson wrote Sargent detailing the contents of cases of plant material that he was sending to the Arboretum, and explained: "The uncertainty regarding the arrival of these plants in a living state makes

× *Hamamelis intermedia* Rehd.

HERBARIUM OF THE ARNOLD ARBORETUM
HARVARD UNIVERSITY

Hamamelis mollis Oliver

Seed, from #17601, Arb., 1928

Flowers with center and base of petals red brown

Cult. Arboretum. #1173-28-I

Coll. F. J. P. March 20, 1936

one anxious. Should fortune favor us and they arrive in a satisfactory condition you will possess many plants of more than ordinary interest and which are worth much from the scientific and arboricultural standpoint. If it fails we must try again on other lines." Two months later the cases did arrive, but the contents were in poor condition as he feared. Of the news, Wilson wrote "I need not enter into my feeling of bitter disappointment and vexation ... In slang language I was knocked all of a heap." Although the mortality in Wilson's early shipments to the Arboretum may have been high, some material did survive the journey. Among the survivors were seeds from *H. mollis* collected in Changyang Hsien, Hubei, under Wilson Collection Number 624, later becoming Arboretum accession 14691.


ARNOLD ARBORETUM

Flowers of *Hamamelis × intermedia* 'Arnold Promise' (accession 195-2005-A).

After accession 14691 had grown in the collections for a number of years, William Judd, propagator at the time, collected open-pollinated seed from this remarkable specimen of Chinese witch-hazel in 1928. The plant was growing in close proximity to other witch-hazels in the Arboretum's collections. Germinated the following spring, seven of the seedlings would eventually be planted in the collections carrying with them accession number 1173-28. Two of these original seedlings (1173-28-A and G) can still be found growing on the grounds today. In the years that followed, these plants were under careful observation, as several herbarium vouchers from the mid-1930s in the Harvard University Herbaria attest. Through such observations, it was determined that the open-pollinated nature by which the seeds were produced led to none of the seedlings being true *H. mollis*, but that they were in fact hybrids between *H. mollis* and *H. japonica*, displaying traits of both parent species. In 1945, Rehder named the hybrid *Hamamelis × intermedia*, given the "intermediate" traits of the parents exhibited in the new hybrid.

The Best of All in Flower

> Witch-hazels seem to be the true harbingers of spring ... However the Japanese witch-hazel has not proven an outstanding plant in bloom because the flowers are not profusely borne and mixed in color with some red, which detracts from the brilliance of the color display in early spring. On the other hand, the Chinese witch-hazel, long noted as a good and fragrant blooming plant, has proved disappointing many years in the Arnold Arboretum because the flower buds have been killed by cold winter.
>
> Donald Wyman, 1963

One of the Judd hybrid seedlings (accession 1173-28-B) had been planted beside the Hunnewell Building, and as it grew it was noted as exceptional among its siblings. In a plant records entry from March 24, 1959, Arboretum

Herbarium voucher taken March 20, 1936, by Ernest Jesse Palmer of one of the plants (1173-28-F) started from seeds of accession 14691 in 1928 by William Judd. Note that the original collection description was that of *Hamamelis mollis*, which was subsequently revised to read "× *Hamamelis intermedia* Rehd." once it was determined that the 1173-28 plants were in fact open-pollinated hybrids of *H. mollis* and *H. japonica*. Of this particular hybrid plant (1173-28-F), Donald Wyman noted in 1959 that it was "more japonica type" in reference to the traits typical of the hybrid's paternal parent (Japanese witch-hazel), including longer petals, an observation that can be seen in this voucher.

KYLE PORT

The specimen of 'Arnold Promise' witch-hazel (accession 396-69-A) that grows near the Hunnewell Building, seen in full flower during a snowstorm on March 8, 2013.

horticulturist Donald Wyman referred to it as the "best of all in flower." It captured all of the best floral traits of its maternal parent (*H. mollis*) with profusely borne, fragrant, bold yellow blossoms, as well as desirable characteristics of *H. japonica*, including better winter hardiness, larger petals, and less leaf retention through the winter. It also displayed signs of hybrid vigor, with a more upright form compared to its spreading parents. In the October 25, 1963, issue of *Arnoldia*, Wyman announced that a new clonal cultivar had been registered: *Hamamelis × intermedia* 'Arnold Promise'. He compared the plant to an "old friend," which could be observed out the windows of the library and herbarium and was known for its performance and counted on because it had been there a long time, yet was not "unusual" to the people who got used to enjoying it on a continuous basis. Only after several well-traveled visitors called special attention to the specimen was the plant considered for introduction. Although the original plant no longer graces the Hunnewell Building, a cutting taken from it in 1969 (accession 396-69-A) was grown out and planted near the original location in 1979. It survived a temporary relocation to the nursery in 1992 during the renovation of the Hunnewell Building and in 1995 it was returned to the same spot where it still thrives today. Though there are now

A handsome specimen of *Hamamelis mollis* 'Princeton Gold' (accession 338-2002-A) blooms at the edge of the Arboretum's Leventritt Shrub and Vine Garden.

ANDREW GAPINSKI

'Diane' is a *Hamamelis* × *intermedia* cultivar selected for its carmine flowers.

a great number of *H.* × *intermedia* cultivars that have been introduced to the horticultural industry, 'Arnold Promise' remains among the leaders in the garden world.

Along with the species accessions, the Arboretum's Asian witch-hazel holdings include a number of introduced cultivars. There are currently three Chinese witch-hazel cultivars in the collections: 'Brevipetala', 'Pallida', and 'Princeton Gold'. And in addition to the 14 'Arnold Promise' specimens that adorn the grounds, six other cultivars of *H.* × *intermedia* can be found throughout the landscape, including yellow-petaled 'Moonlight' and five others selected for their unique petal coloration in varying hues of red and orange: 'Diane', 'Feuerzauber', 'Hiltingbury', 'Jelena', and 'Ruby Glow'.

Continuing a Legacy of Discovery

Collection, evaluation, and scientific study of witch-hazels continues at the Arboretum. An accession of particular interest and value is a Chinese witch-hazel that was wild-collected in Wudang Shan, Hubei, China, as part of the 1994 North America–China Plant Exploration Consortium (NACPEC) expedition. One of the expedition's goals was to collect farther north in Hubei than Wilson ever had, with the hope of bringing hardier material into cultivation. The trip's

MICHAEL DOSMANN

The showy flowers of *Hamamelis mollis* accession 698-94-A, wild collected in China.

plant explorers, including former Arboretum Senior Research Scientist Peter Del Tredici, describe their discovery of a witch-hazel grove in fruit: "A little way beyond the *Zelkova* shrine, we found several plants of Chinese witch hazel ... loaded with unopened seed capsules. We were particularly pleased to collect this winter-blooming species, which has been gaining popularity in American gardens. After seeing so many plants without seed, it was a treat to find one in fruit, and we greedily collected every seed capsule we could find. The plants were growing on a dry, shady hillside near another plant in the witch hazel family, *Sinowilsonia henryi* ..." Two individuals from this collection (697-94-A and 698-94-A) can be found growing on either side of Meadow Road adjacent to the maple collection.

These and other *Hamamelis mollis* specimens are currently part of an investigation by Jessica Savage, a Putnam Fellow at the Arboretum, examining what allows Chinese witch-hazel and other precocious flowering plants to produce flowers early in the year before they develop new leaves. Plants that flower later in the season can use resources provided by their leaves to support their floral displays, but precocious flowering plants depend on nutrients stored in their stems. Her research will help us understand how plants like witch-hazel access the resources required for blooming and overcome the challenges of flowering, in some cases, while the ground is still frozen.

As I write this passage, Michael Dosmann, the Arboretum's Curator of Living Collections, is on an expedition in the Ozarks with several botanical colleagues. *Hamamelis vernalis* is on the group's list of targeted species for collection. The seeds and stories he brings back from his journey will most certainly add to the rich history of witch-hazel at the Arboretum and deepen our understanding of this exceptional genus.

References

Arnold Arboretum. 1913. *Bulletin of Popular Information.* No. 37.

Bean, W. J. 1973. *Trees and shrubs hardy in the British Isles*, 8th ed. Vol. 2. London: John Murray, Ltd.

Bush, B. F. 1895. *A list of the trees, shrubs and vines of Missouri.* Jefferson City, Missouri: Tribune Print. Co.

Connor, S. 1994. *New England natives: A celebration of people and trees.* Cambridge: Harvard University Press.

Del Tredici, P., P. Meyer, H. Riming, M. Cailiang, K. Conrad, and R. W. Thomas. 1995. Plant collecting on Wudang Shan. *Arnoldia* 55(1): 12–20.

Leonard, S. W. 2006. A new species of witch-hazel (*Hamamelis*: Hamamelidaceae) apparently endemic to Southern Missouri. *Sida, Contributions to Botany* 22: 849–856.

Meyer, F. G. *Hamamelidaceae.* 1997. In: Flora of North America Editorial Committee, eds. 1997. Flora of North America North of Mexico. New York and Oxford: Oxford University Press. Vol. 3: 362–367.

Rehder, A. 1945. Notes on some cultivated trees and shrubs. *Journal of the Arnold Arboretum* 26: 67–78.

Rehder, A. 1920. New species, varieties and combinations from the herbarium and the collections of the Arnold. *Journal of the Arnold Arboretum* 1: 254–263.

Rehder, A. 1928. New species, varieties and combinations from the herbarium and the collections of the Arnold Arboretum. *Journal of the Arnold Arboretum* 4: 29–31.

Sargent, C. S. 1894. *Forest flora of Japan: Notes on the forest flora of Japan.* Boston: Houghton, Mifflin and Company.

Sargent, C. S. 1890. *The Silva of North America*, Vol. 5. New York: Peter Smith (reprint 1947).

Sargent, C. S. 1913. *Trees and shrubs: Illustrations of new or little know ligneous plants.* Vol. 2. Boston: Houghton Mifflin Company.

Weaver, R. E. Jr. 1981. *Hamamelis* 'Arnold Promise'. *Arnoldia* 41(1): 30–31.

Weaver, R. E. Jr. 1976. The witch hazel family (Hamamelidaceae). *Arnoldia* 36(3): 69–109.

Wilson, E. H. 1927. *Plant hunting.* Vol. 2. Boston: The Stratford Company.

Wyman, D. 1963. New plants registered. *Arnoldia* 23(9): 111–118.

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Did American Chestnut Really Dominate the Eastern Forest?

Edward K. Faison and David R. Foster

"The American chestnut once comprised 25% or more of the Native Eastern Hardwood Forest." ***American Scientist*** **(1988)**

"Chestnut was perhaps the most widespread and abundant species in the Eastern United States since the last glaciation." ***USDA Forest Service Southern Research Station General Technical Report General Technical Report SRS-173*** **(2013)**

"Before the turn of the century, the eastern half of the United States was dominated by the American chestnut." ***American Chestnut Research and Restoration Project, SUNY College of Environmental Science and Forestry*** **(2013)**

Along with the bison and the passenger pigeon, the American chestnut forms an iconic triumvirate of the grandeur of the American wilderness and the devastation that human activity wrought upon it over the past three centuries. Just as the bison was the preeminent large mammal on the continent and the passenger pigeon the most abundant bird, so is chestnut often described as having dominated the eastern forest (or across its geographic range) prior to its destruction by an introduced Asian chestnut blight.

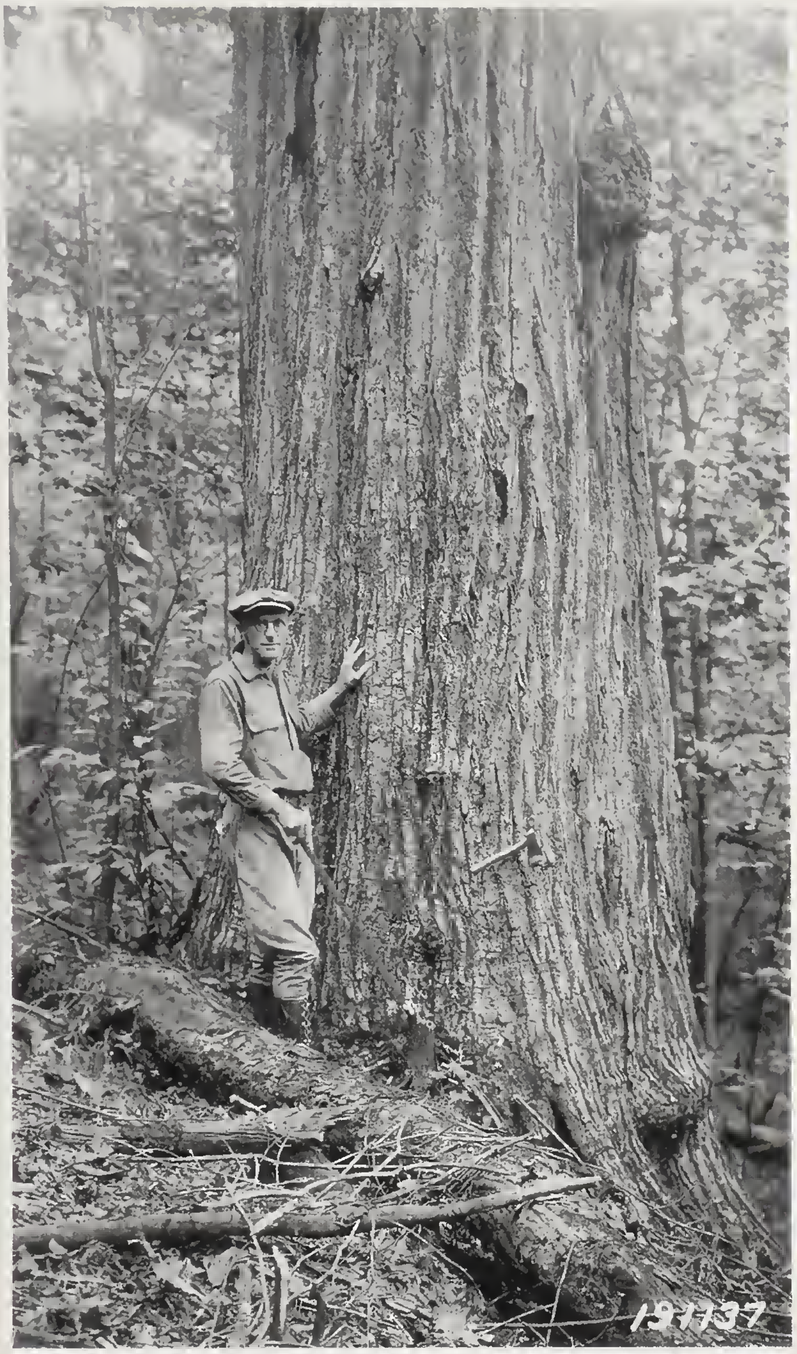
By all accounts chestnut was a magnificent and invaluable tree. It was among the fastest growing, tallest, and widest-trunked trees in the eastern United States. The strength, straight grain, and decay resistance of its wood made it ideal for framing, finished lumber, and fencing, and its regular production of nuts provided abundant food for native and European peoples, domestic livestock, and diverse wildlife. But was it really the dominant tree in the eastern forest?

Dominant species, in the words of forest ecologist E. Lucy Braun, are "those trees of the canopy, or superior arboreal layer, which numerically predominate." Given American chestnut's purported prior dominance in the eastern deciduous forest, we would expect the tree to have ranged widely across the East relative to other common tree species and to occupy a superior place in written accounts by early naturalists and explorers, early land survey records, forest surveys of the early twentieth century, and the paleoecological record. In fact, these sources reveal a very different story.

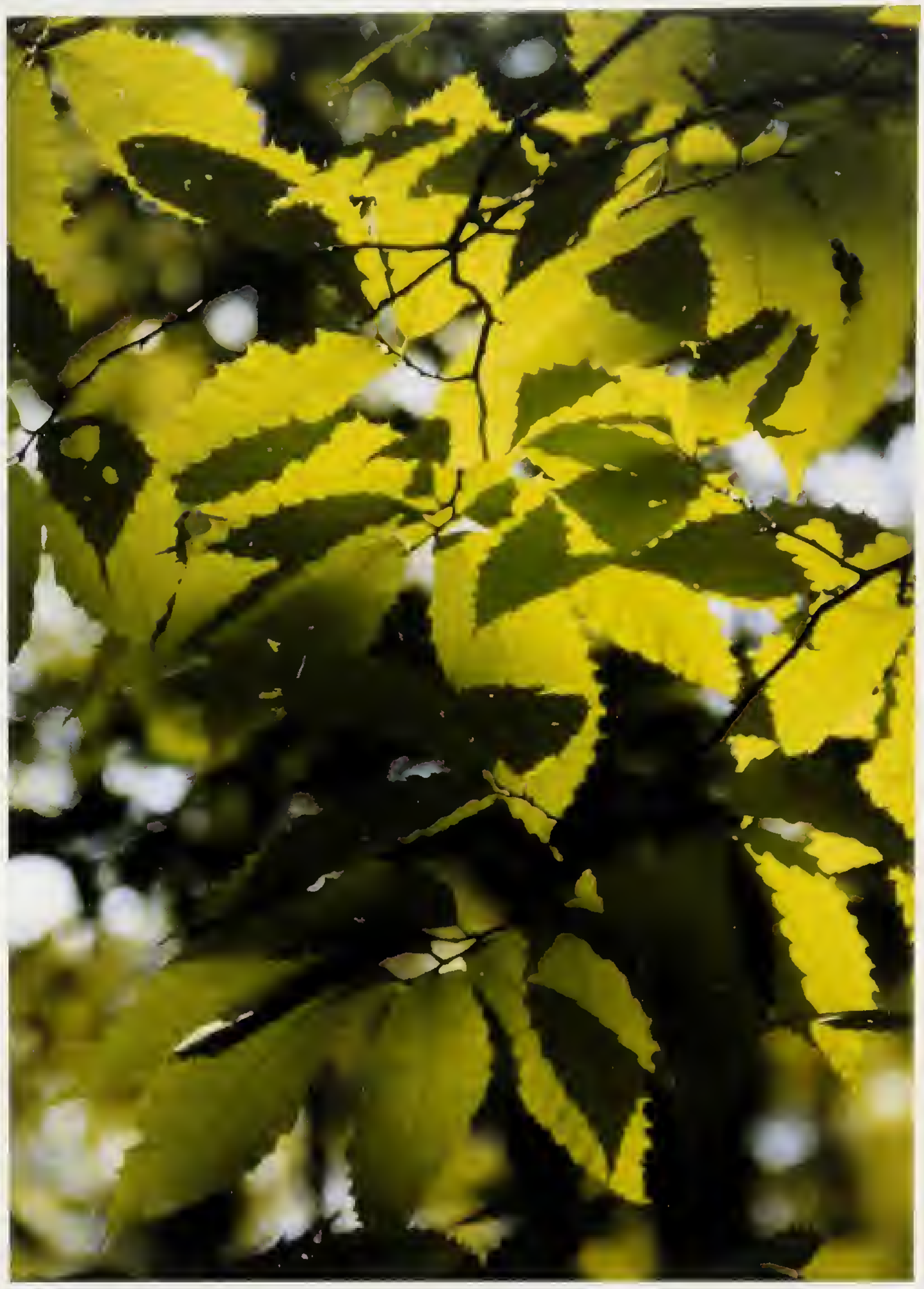
Accounts by Early Explorers and Naturalists

Accounts by foresters about chestnut's abundance at the turn of the twentieth century have been widely cited in the scientific and popular literature as evidence of the tree's former dominance. Descriptions of chestnut by naturalists and explorers at the time of European settlement, on the other hand, are rarely cited. Early written records must be used with caution, given that they were often written by non-botanists and provide a potentially biased assessment of previous forest conditions (Whitney 1994). Nonetheless, these descriptions—particularly if they correspond with other available lines of evidence—provide valuable eyewitness accounts of eastern forests prior to their widespread modification by Euro-

FOREST HISTORY SOCIETY, DURHAM, NC



DAVID R. FOSTER



(Left) A large American chestnut photographed in the Monongahela National Forest, West Virginia, in 1923. (Right) Foliage of American chestnut (*Castanea dentata*).

pean settlement. Below are selected quotations that reference chestnut and other species by some of the more important early explorers and naturalists in the Eastern United States.

John Smith, New England coast (early 1600s): "Oke [oak], is the chiefe wood, of which there is great difference in regard of the soil where it groweth; fir, pine, walnut, chestnut, birch, ash, elm ..., and many other sorts." (Smith 1616)

Colonel William Byrd, Virginia (1737): "chestnut trees grow very tall and thick, mostly, however, in mountainous regions and high land ..." (Bolgiano and Novak 2007)

William Bartram, northern Alabama–Mississippi border (late eighteenth century): "[we entered] a vast open forest which continued for above seventy miles ... without any considerable variation ... the forests consist chiefly of Oak, Hiccory, Ash, Sour Gum, Sweet Gum, Beech, Mulberry, Scarlet maple, Black Walnut, Dogwood, *Aesculus pavia, Prunus indica,* Ptelea, and an abundance of chestnut on the hills, with *Pinus taeda* and *Pinus lutea.*" (Bartram 1976)

Although these accounts represent only a very small sample of early observations, they offer some general patterns that are reinforced

A KILLER ARRIVES

Chestnut blight (*Cryphonectria parasitica*) was first discovered in 1904 in a stand of American chestnuts (*Castanea dentata*) in New York's Bronx Zoological Park, perhaps arriving on imported nursery stock of *Castanea crenata* from Japan. Subsequent investigation determined that the blight arrived in the late nineteenth century, as evidence suggested that American chestnuts on Long Island had been infected as early as 1893. The effects of the blight were immediate and devastating, often killing mature trees in 2 to 3 years. By 1906, the blight was detected in New Jersey, Maryland, and Virginia and continued to spread rapidly, reaching Pennsylvania in 1908 and North Carolina by 1923. All government efforts to contain or eradicate the blight failed, and ceased entirely by 1915. By the early 1940s the destruction of the American chestnut throughout its 300,000-square-mile range was complete.

The blight spreads by wind-borne fungal spores that invade the tree through cracks or injuries in the bark, killing the cambium and eventually girdling the tree. The roots generally survive the blight, however, and continue to produce sprouts that are eventually killed again before reaching reproductive age. In effect, the chestnut blight converted a once towering overstory tree into an understory shrub.

An American chestnut in Connecticut succumbing to chestnut blight, from the image collection *American Environmental Photographs, 1891–1936*, University of Chicago Library Special Collections.

A large white oak (*Quercus alba*) photographed near New Lenox, Illinois, from the image collection *American Environmental Photographs, 1891–1936*, University of Chicago Library Special Collections.

by many others not reported here, specifically that chestnut appears to have had a relatively restricted niche (mountainous) rather than being generally abundant throughout the landscape, and to have been secondary in importance to oaks (*Quercus*).

The Biogeography of Chestnut

The eastern deciduous forest spans approximately 926,000 square miles in North America, covering 13 entire states and substantial portions of 10 others from Maine to Minnesota and south to Texas and Georgia. This vast area is broadly united by a cover of deciduous or mixed deciduous-coniferous forest, but otherwise is far from uniform. Five climatic regions, twelve geomorphic regions, and five soil regions define this broad area. Climate, landforms, and proximity to the coast determine the frequency and type of natural disturbances (e.g., tornadoes, hurricanes, fires, ice storms) that influence a particular region, as well as the distribution and abundance of human populations and their disturbances such as tree cutting, agriculture, and the removal and introduction of wildlife. The physical environment and its associated natural and human disturbances, in turn, shape the vegetation.

For a tree species to dominate an area as broad and diverse as the eastern forest it needs to be an ecological generalist. Relative to other common species like white oak (*Quercus alba*),

DAVID LEE

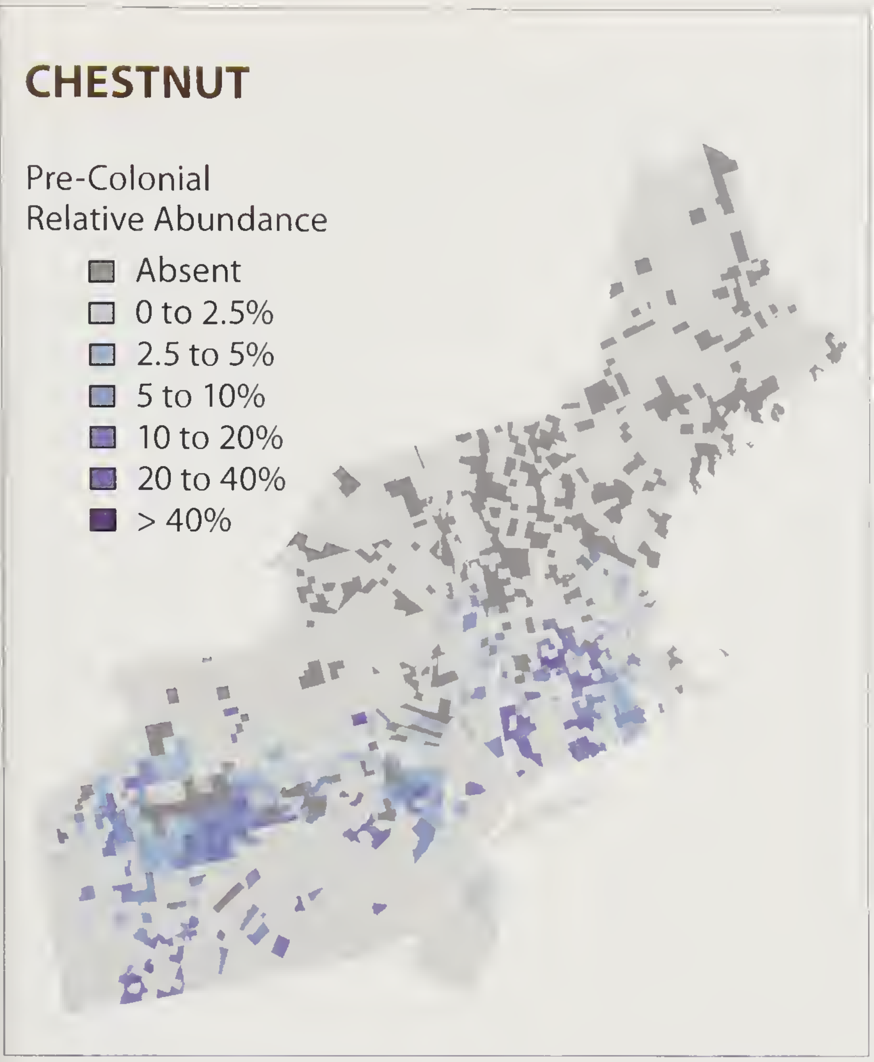
Sugar maple (*Acer saccharum*) leaves in autumn.

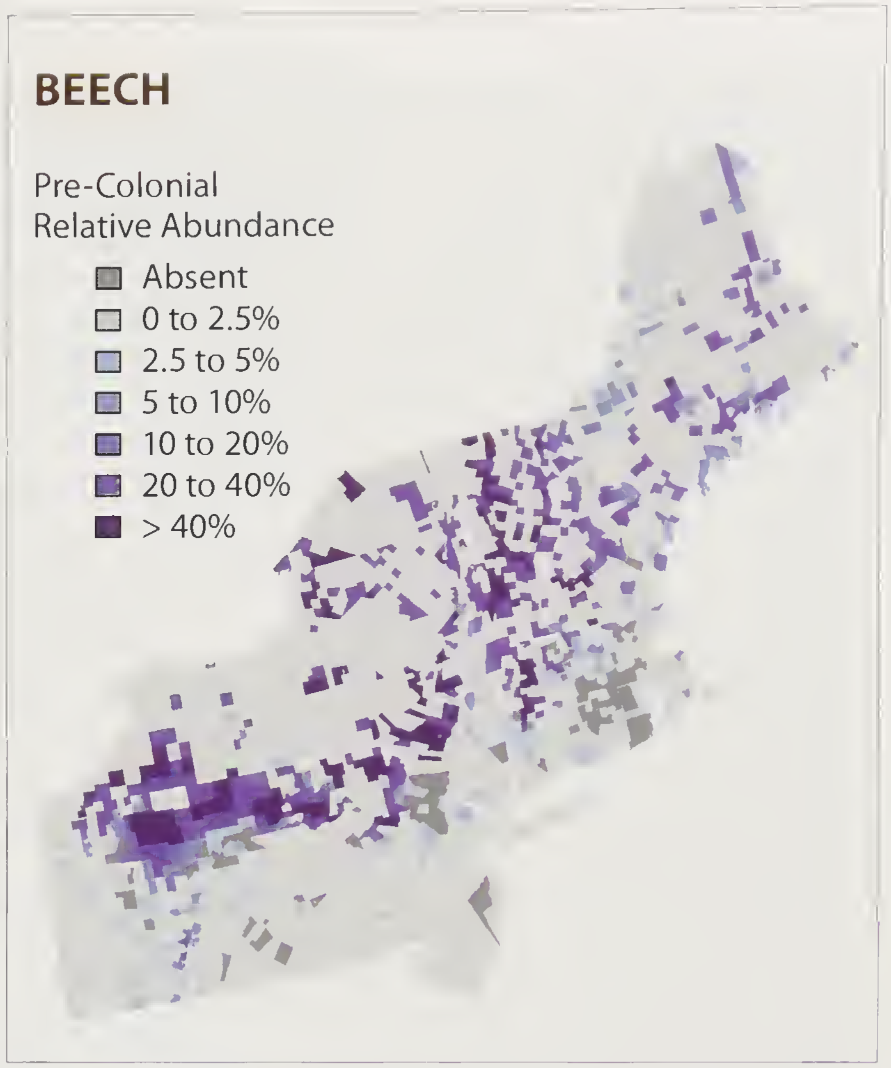
An impressive sugar maple (*Acer saccharum*) photographed near Golf, Illinois, from the image collection *American Environmental Photographs, 1891–1936*, University of Chicago Library Special Collections.

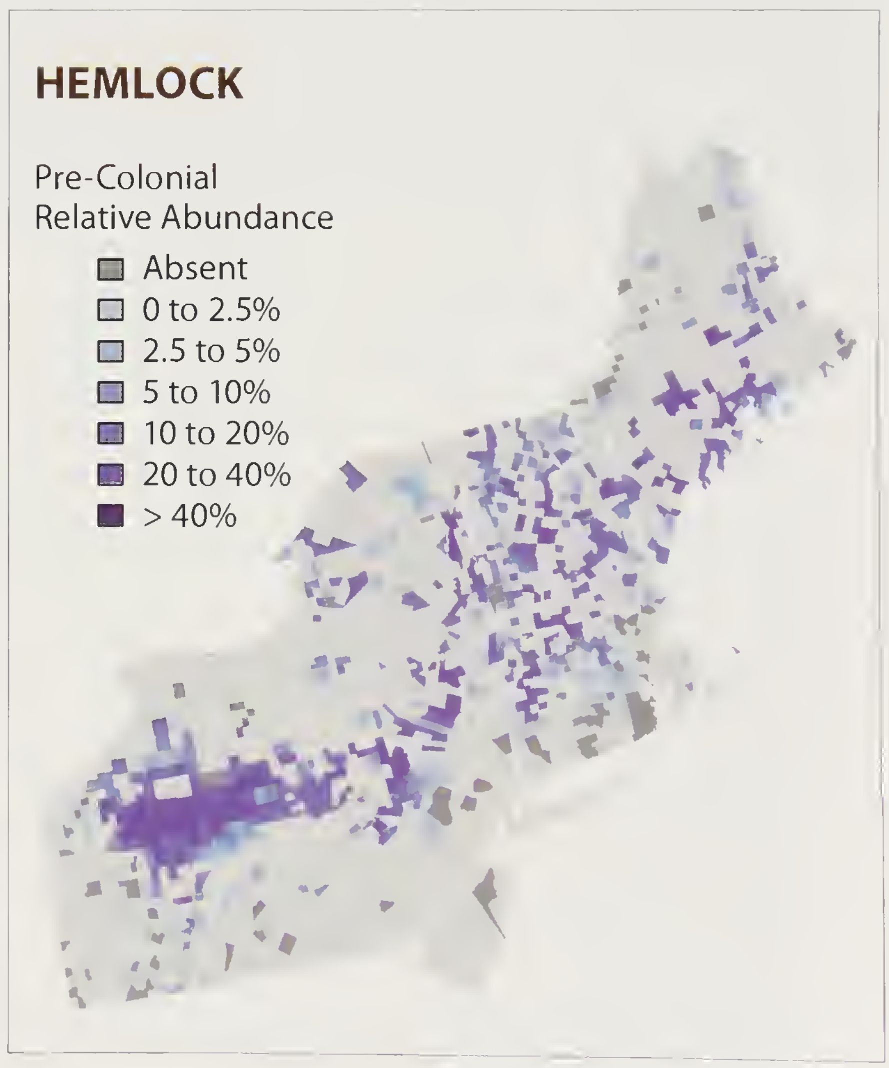
American beech (*Fagus grandifolia*), red maple (*Acer rubrum*) and sugar maple (*Acer saccharum*), chestnut had limited ecological amplitude. Chestnut has high water requirements relative to oaks and is restricted to moderate climates. Hence, it grew predominantly—as the early explorers noted—in sloping topography, particularly on moist, well-drained lower slopes and on some rocky ridges. Chestnut generally fared poorly on sandy coastal plains and outwash soils, clayey soils, saturated wetland soils, or calcium-rich sites. Much of the southeastern coast of the United States is dominated by sandy soils and therefore lacked chestnut altogether. Large areas of the midwestern section of the eastern forest have calcium-rich soils and relatively low rainfall and were thus also unsuitable for chestnut. In northern New England, northern New York, and upper Michigan, extremely cold winters were largely prohibitive to chestnut, which is susceptible to cold and frost damage. In sum, chestnut ranged across only about 309,000 square miles of eastern North America in the early twentieth century—about one-third of the Eastern forest. In contrast, sugar maple, red maple, white oak, red oak (*Quercus rubra*), American beech, and American basswood (*Tilia americana*) all have geographic ranges that exceeded chestnut's by at least a factor of three (Little 1971).

Witness Trees

Early land surveys conducted at the time of European settlement frequently utilized trees, known as witness trees, as corner posts and reference points, and surveyors often recorded each tree to genus or species. Compiled across counties, states, and regions, witness trees offer a formidable inventory of the forest composition that greeted the first European settlers. Early land survey data reveal that chestnut was far less abundant at the time of European settlement than the oft-quoted 25% of the forest. A recent paper by Jonathan Thompson, Charles Cogbill, and colleagues compiled witness tree data from over 700 townships from nine states in the northeastern United States. Their results show that chestnut comprised a mere 3% of trees in the region and never exceeded 25%







American chestnut abundance compared with American beech and eastern hemlock abundance in the Northeast at the time of European settlement as determined by early land survey data (Thompson et al. 2013)

of trees in a single town. In contrast, beech comprised 22% of trees across the region; oaks, predominantly white oak, 17.5%; and hemlock 11%.

Two decades ago, forest historian Gordon Whitney compiled maps of tree species abundance from land survey data across the midwestern United States. Data from about 100 counties or townships across eight states of the upper Midwest reveal that chestnut was never the dominant tree, comprising 5 to 15% of trees in a small section of Ohio and 0 to 4% of trees in the rest of the region. In contrast, beech and especially white oak were frequently the dominant tree, often comprising 25 to 65% of all trees. Limited early land survey data from the southern regions of the eastern forest also portray chestnut as a secondary species. Chest-

Dominant tree species and corresponding abundance and rank of American chestnut at the time of European settlement identified from early land survey data in the southeastern United States. Adapted from Abrams (2003).

Location	Dominant Tree Species and Abundance (%)	Chestnut Abundance (%)	Chestnut Rank	Reference
Eastern West Virginia – Ridge and Valley	White oak (33)	5	5	Abrams and McCay 1996
Eastern West Virginia – Allegheny Mts.	Beech (13)	6	8	Abrams and McCay 1996
Southern West Virginia	White oak (24)	12	2	Abrams et al. 1995
Northern Virginia	White oak (49)	0	NA	Orwig and Abrams 1994
Southwestern Virginia	Red oak (25)	9	3	McCormick and Platt 1980
Western Virginia	White oak (26)	5	5	Stephenson et al. 1992
Central Georgia	Pine, mostly loblolly and shortleaf (27) Post oak (18)	2	9	Cowell 1995
Northeastern Georgia	Pine (26) American chestnut (20)	20	1	Bratton and Meier 1998
Southcentral Tennessee	Post Oak (11)	2	11	DeSelm 1994
Northern Florida	Magnolia (21)	0	NA	Delcourt and Delcourt 1977
Southeastern Texas	Pine, mostly longleaf (25)	0	NA	Schafale and Harcombe 1983
Southeastern Louisiana	Magnolia (13)	0	NA	Delcourt and Delcourt 1974
Northeastern Louisiana	Pine, longleaf, shortleaf, and loblolly (24) White oak (11)	0	NA	Delcourt 1976
Eastern Alabama	Pine, 7 species (44) Post oak (12)	2	9	Black et al. 2002
Southern Arkansas	Black oak (18)	0	NA	Bragg 2003

A white oak (*Quercus alba*) in New Braintree, Massachusetts.

nut was the first-ranked species in only one of 15 locations, whereas white oak was the first-ranked tree in five of 15 locations (see Table on facing page).

Early Twentieth Century Forest Surveys

E. Lucy Braun conducted and compiled extensive forest surveys and observations across 120 counties of the eastern forest in the early twentieth century. Her data were predominantly gathered from "original" forests and thus fill in gaps in the witness tree studies, particularly in regions such as the Cumberland Mountains of Kentucky and the Blue Ridge Mountains of North Carolina and Tennessee. Although Braun acknowledged her unequal coverage of different regions, her work remains by far the most comprehensive assessment of the eastern deciduous forest, including American chestnut's abundance, at the time of the chestnut blight. Her surveys and data tables reveal that chestnut was a tree of surprisingly limited dominance. Chestnut was dominant (the most abundant canopy tree) in at least one survey in only 15 of the 120 counties (12.5%) sampled by Braun and others. Sugar maple, white oak, and hemlock were all dominant species in over 20% of the counties sampled, and beech was a dominant tree in over 40% of the counties sampled. In fact, Braun's data suggest that chestnut was not even the most abundant tree within its own geographic range: beech was a dominant species in at least one survey in almost half (48%) of the counties sampled in chestnut's range, whereas chestnut was a dominant tree in less than a quarter (23%) of the counties sampled.

American chestnut was spectacularly abundant in some locations. On north slopes in Joyce

Kilmer Memorial Forest in North Carolina, for instance, it comprised over 83% of the canopy trees, and on the slopes of Salt Pond Mountain in western Virginia, it made up 56 to 85% of the canopy trees (Braun 1950). Chestnut could also grow to enormous size. In a forest in Central Kentucky, Braun wrote that chestnuts, which comprised 22% of the canopy trees, were "by far the largest trees, about 5 feet d.b.h. (diameter at breast height)." But chestnut was far from the only tree to achieve such local dominance; beech, hemlock, sugar maple and white oak all achieved comparable abundances in other stand locations. In 1876, forester A. R. Crandall wrote the following in eastern Kentucky: "white oak has a wider range and greater development in numbers than any other species. In size it ranks with the largest of the hardwood trees …"

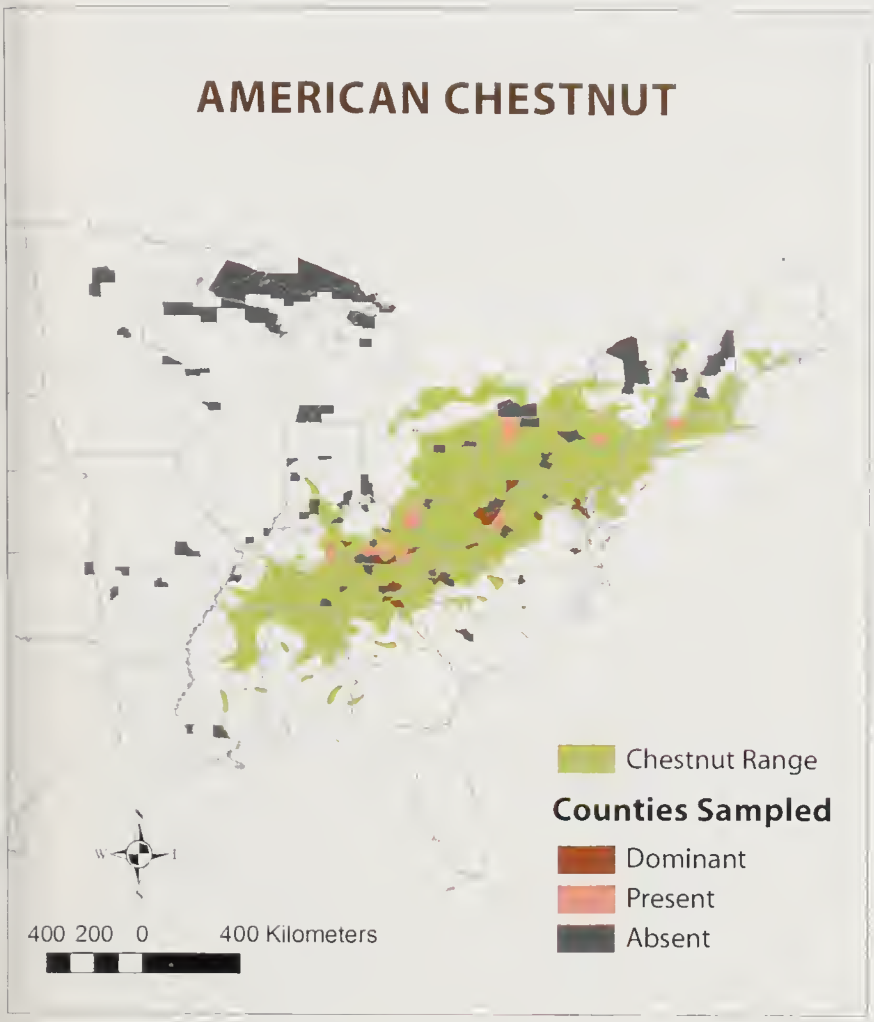
The Rise of Nineteenth Century Logging and Chestnut

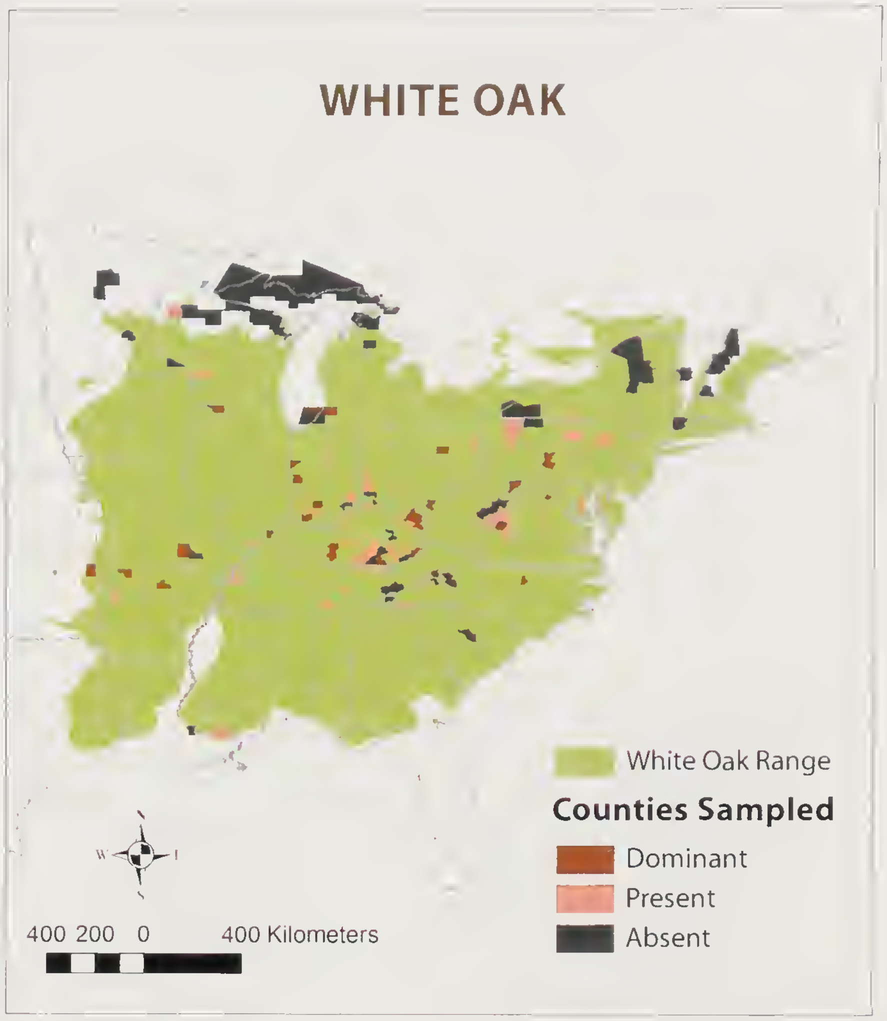
In its destructiveness and lack of legal control, nineteenth century commercial logging was similar to the unrestricted hunting that decimated the passenger pigeon and the bison. However, in an ironic twist to the story of American chestnut, this particular act of exploitation actually promoted chestnut to dominance in parts of its range where it hadn't been dominant before. Chestnut's remarkable

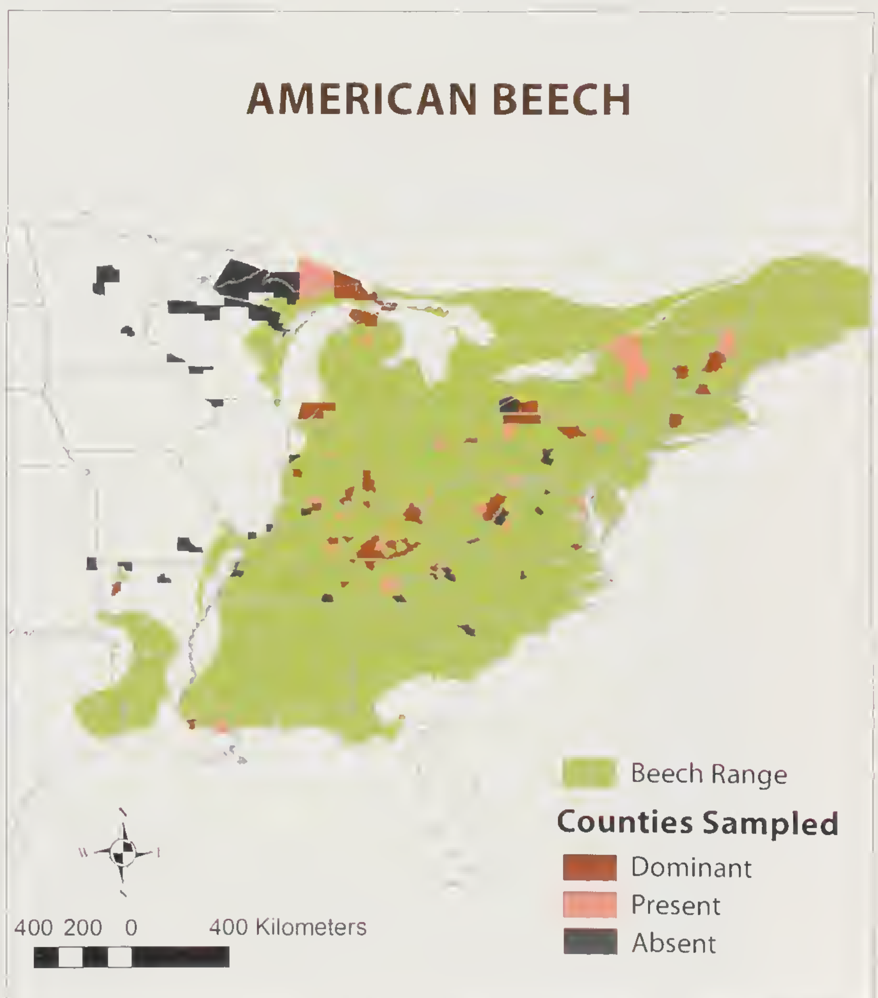
HARVARD FOREST ARCHIVES, HARVARD UNIVERSITY

A stand of American beech (*Fagus grandifolia*) in Harvard Forest's Pisgah Tract in New Hampshire, April 1930.

A ring of new shoots growing around the cut stump of an American chestnut, from the image collection *American Environmental Photographs, 1891–1936*, University of Chicago Library Special Collections.







American chestnut's geographic range and extent of dominance compared to that of white oak and American beech in the early twentieth century. Data compiled by Braun (1950).

ability to sprout vigorously from cut stumps, including those of large diameter and advanced age, made it better adapted to intensive logging than any other hardwood tree including oaks. As the early Connecticut foresters Hawley and Hawes (1912) wrote, "this sprouting capacity of the species is its strongest characteristic and the one by which with each successive cutting it gains in the struggle for existence with the rival inmates of the woodlot." Interestingly, chestnut's sprouting capacity was much more prominent in the Northeast than in the southern parts of chestnut's range. In heavily cutover forests of northern New Jersey and southern New England, chestnut increased from 5 to 15% of the forest during the early colonial period to an estimated 50% of the standing timber in Connecticut. Because Braun focused

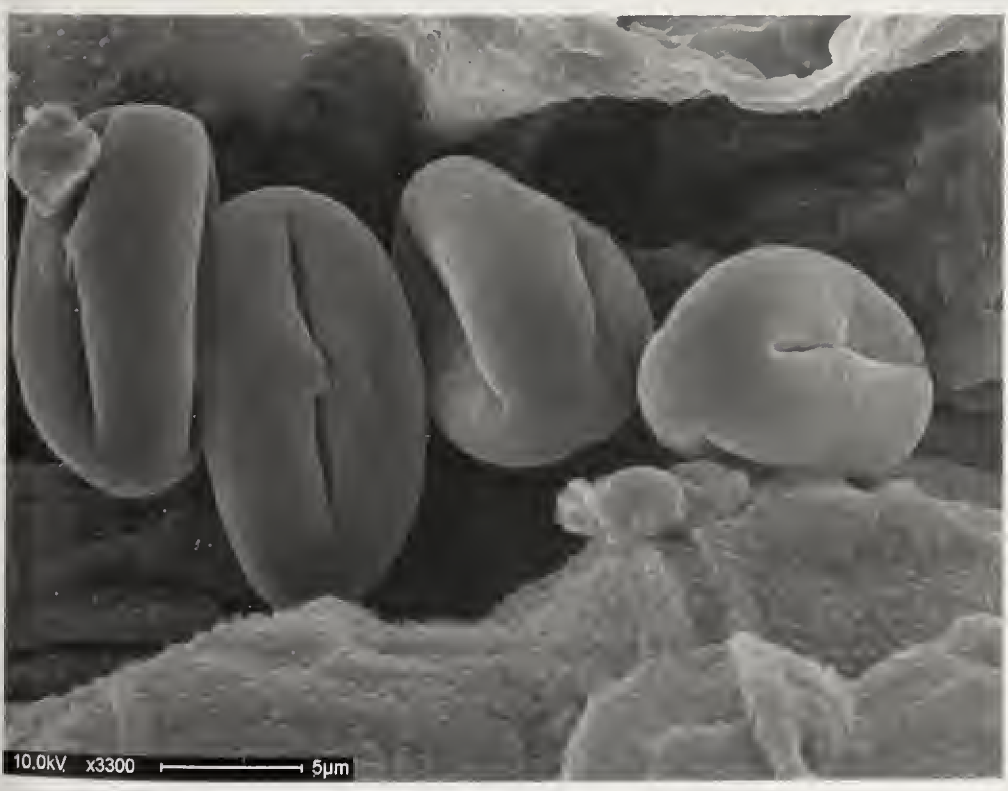
A stand of American chestnut in Big Creek Gap, Tennessee, from the image collection *American Environmental Photographs, 1891–1936,* University of Chicago Library Special Collections.

on "original" forests in her surveys, she largely avoided surveying the cutover southern New England region so her data probably underestimate chestnut's abundance in the Northeast. But it's important to remember that southern New England represents a small fraction of chestnut's range and the eastern forest overall.

The Last to Arrive: Chestnut Since the Last Ice Age

Fossil pollen records in the Eastern forest enable reconstruction of vegetation communities and tree species that have dominated forests over the past 15,000 to 50,000 years. In formerly glaciated areas such as the Northeast, pollen records provide a chronological record of recolonization of forest vegetation after glacial melt some 15,000 to 20,000 years BP (before present). In southern New England, ash (*Fraxinus*), birch (*Betula*), ironwood (both *Ostrya* and *Carpinus,* whose pollens are indistinguishable from each other), and oak arrived first, followed by maples; deciduous forests replaced coniferous forests about 9,000 years BP. Beech arrived about 8,000 years BP, and hickory about 6,000 years BP. Not until about 2,000 years BP does chestnut pollen appear in the sediment record, earning chestnut the distinction of being the last major tree species to recolonize the region after deglaciation (Davis 1983). When chestnut finally does appear in the sediment record, it generally doesn't exceed about 4 to 7% of the pollen types across the region with the exception of one record in northwestern Connecticut where it reaches 18 to 19% (Paillet 1991, Oswald et al. 2007). In contrast, oak pollen consistently comprises 40 to 60% of the pollen and beech 5 to 20%. Interestingly, chestnut does achieve great dominance (40 to 70%) at the stand scale in a few local New England pollen records (Foster et al. 1992, 2002), exemplifying the importance of spatial scale when considering the abundance of this species.

What accounts for chestnut's late arrival to New England? One possible reason is that the climate of the Northeast throughout much of the Holocene was too dry for chestnut. Other researchers have posited a lack of favorable well-drained germination sites in southern New England after deglaciation, or too much lime in the soil that took millennia to leach away. Chestnut is also self-sterile unlike many other trees that are self-fertile, and thus the chances of establishing new populations were much lower for this tree. Whether dispersal or environmentally limited, it is clear that



DANILO D. FERNANDO, SUNY-ESF

A micrograph of American chestnut pollen.

SPATIAL SCALE

Spatial scale refers to the size or extent of the area under consideration. A stand is a relatively small area of forest that is spatially continuous in structure and composition and is exposed to similar soil and climatic conditions. In paleoecology the size of the catch basin (e.g., lake, pond, swamp, or small hollow) determines the distance from which pollen in the sediments originates. Sediments from a small forest hollow will contain pollen from vegetation growing predominantly in the immediate stand (a "stand scale" investigation), whereas sediments from a large lake are dominated by pollen from the broader landscape up to 20 miles away.

chestnut was poorly adapted to recolonizing the deglaciated Northeast compared to other hardwood trees.

Chestnut had a much longer history in the unglaciated Southeast. Chestnut pollen appears in the pollen record as early as 16,000 years BP in Tennessee (Davis 1983). Although a few records show chestnut to be dominant or co-dominant with oaks during the Holocene in the North Carolina and Tennessee mountains, most of the records from the southern and central Appalachians analyzed by William Watts, Paul and Hazel Delcourt, and others reveal oaks to be dominant over chestnut. Still, comparisons between oak and chestnut pollen abundance should be undertaken with caution. Oak pollen grains are indistinguishable among species, and many are therefore combined into a single category of "oak" pollen. Chestnut, on the other hand, is the only species in its genus in the Northeast and is one of two species (the other is dwarf chinkapin, *Castanea pumila*) in the central and southern Appalachians. Oak pollen is wind dispersed and therefore is generally produced in larger quantities than is chestnut pollen, which is partially dispersed by insects. Hence, chestnut pollen is generally underrepresented in the pollen record, relative to oaks. Still, chestnut's relatively minor status in the pollen record is consistent with its secondary status in the witness tree data and in accounts by early settlers. In addition,

An illustration of dwarf chinkapin (*Castanea pumila*) from Mark Catesby's *The Natural History of Carolina, Florida, and the Bahama Islands, Volume 1.* This etching was first published in 1729.

chestnut's great abundance (40 to 45%) in a few southern Appalachian pollen records analyzed by the Delcourts and stand-level records from Massachusetts are consistent with twentieth century forest surveys in which chestnut achieved great dominance in some landscapes and topographic positions, but generally not at broader scales.

Concluding Thoughts

American chestnut was once a common tree species throughout its Appalachian Mountain range and a dominant species in parts of its central and southern range (primarily the oak-chestnut forest region). However, prior to European settlement, it was less dominant than white oak and beech and far less widespread than most other major tree species. With increasing timber harvesting in the nineteenth and early twentieth centuries, chestnut's dominance increased in the northern part of its range in heavily cut-over forestland. Still, the tree remained absent from fully two-thirds of the eastern forest, precluding it from ever being the dominant tree of this biome.

Revealing the truth about American chestnut's relatively limited place in the Eastern forest does not diminish the grandeur of this great tree, its historical importance to cultures of the central and southern Appalachians, and the great tragedy of its demise. Chestnut remains the flagship example of the potential dangers posed by introduced pathogens in our native forests. But we should be careful not to let a great tragedy and impassioned restoration efforts trump the available data when discussing the history of this tree.

References:

Abrams, M. D. 2003. Where has all the white oak gone? *Bioscience* 53: 927–939.

Abrams, M. D., D. A. Orwig, and T. E. DeMeo. 1995. Dendroecological analysis of successional dynamics for a presettlement-origin white pine–mixed oak forest in the southern Appalachians, USA. *Journal of Ecology* 83: 123–133.

Abrams, M. D., D. M. McCay 1996. Vegetation-site relationships of witness trees (1780–1856) in the presettlement forests of eastern West Virginia. *Canadian Journal of Forest Research* 26: 217–224.

American chestnut research and restoration project. 2014. http://www.esf.edu/chestnut/background.htm

Bartram, W. A. 1976. *Travels and Other Writings.* Princeton: Princeton University Press.

Black, B. A., H. T. Foster, and M. D. Abrams. 2002. Combining environmentally dependent and independent analyses of witness tree data in east-central Alabama. *Canadian Journal of Forest Research* 32: 2060–2075.

Bolgiano, C. and G. Novak. 2007. *Mighty Giants: an American Chestnut Anthology.* American Chestnut Foundation, Bennington, VT.

Bragg, D. C. 2003. Natural presettlement features of the Ashley County, Arkansas area. *The American Midland Naturalist* 149:1–20.

Bratton, S. P. and A. J. Meier. 1998. The recent vegetation disturbance history of the Chattooga River Watershed. *Castanea* 63: 372–381.

Braun, E .L. 1950. *Deciduous Forests of Eastern North America.* Caldwell, New Jersey: The Blackburn Press.

Burnham, C. R. 1988. The restoration of the American chestnut. *American Scientist* 76: 478–487.

Cowell, C. M. 1995. Presettlement Piedmont forests: patterns of composition and disturbance in central Georgia. *Annals of the Association of American Geographers* 85: 65–83.

Davis, M. B. 1983. Quaternary history of deciduous forests of eastern North America and Europe. *Annals of the Missouri Botanical Garden* 70: 550–563.

Delcourt, H. R. 1976. Presettlement vegetation of the north of Red River Land District, Louisiana. *Castanea* 41: 122–139.

Delcourt, H. R. 1979. Late quaternary vegetation history of the eastern Highland Rim and adjacent Cumberland Plateau of Tennessee. *Ecological Monographs* 49: 255–280.

Delcourt, H. R and P. A. Delcourt. 1974. Primeval magnolia-holly-beech climax in Louisiana. *Ecology* 55: 638–644.

Delcourt, H. R. and P. A. Delcourt. 1977. Presettlement magnolia-beech climax of the Gulf coastal plain: quantitative evidence from the Apalachicola River bluffs, north-central Florida. *Ecology* 58: 1085–1093.

Delcourt, P. A. and H. R. Delcourt. 1998. The influence of prehistoric human set fires on oak-chestnut forests in the southern Appalachians. *Castanea* 63: 337–345.

Delcourt, P. A., H. R. Delcourt, P. A. Cridlebaugh, and J. Chapman. 1986. Holocene ethnobotanical and paleoecological record of human impact on vegetation in the Little Tennessee River Valley, Tennessee. *Quaternary Research* 25: 330–349.

DeSelm, H. R. 1994. Vegetation results from an 1807 land survey from southern middle Tennessee. *Castanea* 59: 51–68.

Foster, D. R., T. Zebryk, P. Schoonmaker, and A. Lezberg. 1992. Post-settlement history of human land-use and vegetation dynamics of a *Tsuga canadensis* (hemlock) woodlot in Central New England. *Journal of Ecology* 80: 773–786.

Foster, D. R., S. Clayden, D. A. Orwig, B. Hall, and S. Barry. 2002. Oak, chestnut, and fire: climatic and cultural controls of long-term forest dynamics in New England, USA. *Journal of Biogeography* 29:1359–1379.

Hawley, R. C. and A. F. Hawes. 1912. *Forestry in New England*. New York: John Wiley and Sons.

Little, E. L., Jr. 1971. *Atlas of United States trees, volume 1, Conifers and Important Hardwoods*: Misc. Pub. 1146. Washington, D.C.: U.S. Department of Agriculture. 9 p., 200 maps

McCormick, J. F. and R. B. Platt. 1980. Recovery of an Appalachian forest following the chestnut blight or Catherine Keever—you were right! *American Midland Naturalist* 104: 264–273.

Orwig, D. A. and M. D. Abrams. 1994. Land-use history (1720–1992), composition, and dynamics of oak-pine forests within the Piedmont and Coastal Plain of northern Virginia. *Canadian Journal of Forest Research* 24: 1216–1225.

Oswald, W. W., E. K. Faison, and D. R. Foster. 2007. Post-glacial changes in spatial patterns of vegetation across southern New England. *Journal of Biogeography* 34: 900–913.

Paillet, F. L. 1991. Relationship between pollen frequency in moss polsters and forest composition in a naturalized stand of American chestnut: implications for paleoenvironmental interpretation. *Bulletin of the Torrey Botanical Club*. 118: 432–443.

Russell, E. W. B. 1987. Pre-blight distribution of *Castanea dentata* (Marsh.) Borkh. *Bulletin. Torrey Botanical Club* 114: 183–190.

Shuman B., P. Newby, Y. Huang, and T. Webb III. 2004. Evidence for the close climatic control of New England vegetation history. *Ecology* 85: 1297–1310.

Smith, J. 1616. *A Description of New England*. Electronic Texts in American Studies Libraries at University of Nebraska-Lincoln.

Stephenson, S. L., H. S. Adams, and M. L. Lipford. 1992. The impacts of human activities on the upland forests of western Virginia. *Virginia Journal of Science* 43: 121–131.

Thompson, J. R, D. N. Carpenter, C. V. Cogbill, and D. R. Foster. 2013. Four centuries of change in northeastern United States forests. *PLoS ONE* 8: e72540.

Wang, G. G., B. O. Knapp, S. C. Clark, and B. T. Mudder. 2013. *The Silvics of Castanea dentata (Marsh.) Borkh., American chestnut, Fagaceae (Beech Family)* Gen. Tech. Rep. SRS-GTR-173. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 18 p.

Watts, W. A. 1979. Late quaternary vegetation of central Appalachia and the New Jersey coastal plain. *Ecological Monographs* 49: 427–469.

Watts, W. A. 1980. The late quaternary vegetation history of the southeastern United States. *Annual Review of Ecology and Systematics* 11: 387–409.

Whitney, G. G. 1994. *From Coastal Wilderness to Fruited Plain: A History of Environmental Change in Temperate North America from 1500 to the Present*. New York: Cambridge University Press.

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Reading Tree Roots for Clues: The Habits of Truffles and Other Ectomycorrhizal Cup Fungi

Rosanne Healy

Here's something to ponder: The health and regeneration of grand old oaks (*Quercus*) and majestic pines (*Pinus*) is dependent on the well-being of tiny fungi that associate with the trees' roots. Such small organisms have a big role to play not only for oaks and pines but also for many other trees that rely on their fungal partners to get them through lean and dry times. An estimated 86% of plant species benefit from (or are even dependent on) fungal root associates that transfer water and nutrients to the plant in exchange for carbohydrates (Brundrett 2009). Carbohydrates from plants are the result of atmospheric CO_2 (carbon dioxide) fixation through photosynthesis and subsequent processes, which the fungi are incapable of doing.

The fungal root associates are the mycorrhizal (myco=fungus, rhiza=root) fungi. They can be roughly sorted into two types based on how they associate with the roots. One type is mostly invisible to us because their hyphae are inside the root (endomycorrhizae), and the other can be seen as a mantle surrounding the root tip (ectomycorrhizae). The endomycorrhizal fungi are root associates of the vast majority of herbaceous plants and certain tree species. This article focuses on ectomycorrhizal fungi, which grow mostly in association with trees rather than herbaceous plants. They make their presence known to us not only because we can see them on tree roots but also because we see their fruiting bodies, particularly from midsummer into fall here in New England.

NANCY ROSE

Trees such as the red oaks (*Quercus rubra*) and eastern white pines (*Pinus strobus*) seen here benefit from ectomycorrhizal fungi.

ALL IMAGES BY THE AUTHOR EXCEPT WHERE NOTED

The color and "furry" appearance of this ectomycorrhizal red oak root tip are from the fungal symbiont, a *Scleroderma* fungus.

The ectomycorrhizal root tips (top) and fruiting bodies (bottom, at several stages of maturity) of the basidiomycete fungus *Cortinarius armillatus*.

Which fungi are they?

Thanks to ever more ingenious methods of molecular fingerprinting of fungi, and a growing database of DNA sequences for fungi of all kinds, we now know much more about what species are involved in these relationships. The ectomycorrhizal fungi include some of the largest and most colorful of the fleshy basidiomycete fungi like *Cortinarius* and *Russula*, as well as prized edibles like the king bolete and chanterelle, and deadly poisonous species such as the death cap, *Amanita phalloides*. Far less is known about the cup fungi that form ectomycorrhizae, despite their long history of study.

The term "mycorrhiza" was coined by botanist Albert Frank in 1885 while he studied the relationship of *Tuber*, a truffle cup fungus, with its host tree roots in order to determine how to cultivate this gastronomically important fungus. He and his student, Albert Schlicht, discovered that the majority of apparently healthy plants that they surveyed in Germany had fungal root associates. Frank was the first to hypothesize that the fungi observed on roots were mutually beneficial with the trees rather than parasitic (Trappe 2005), a hypothesis that has since been borne out by many studies.

Most truffles, including the economically and gastronomically important *Tuber* species that interested Frank, are ectomycorrhizal. I have been studying *Pachyphlodes*, a common but generally ignored truffle genus, for the past 15 years. During these studies I collaborated with Harvard University Herbaria cup fungus experts Don Pfister and Matthew Smith (now at the University of Florida). We noticed that the asexual form of truffles, termed sporemats here, occur most abundantly on bare or nearly bare soil. This was consistent with reports that fruiting bodies of ectomycorrhizal Pezizales (the nomenclatural order for cup fungi) tend to occur in disturbed habitats such as dirt paths or roads in the forest (Petersen 1985). I am now working with Don Pfister to test the hypothesis that ectomycorrhizal Pezizales are more prevalent in managed rather than natural environments. To do this, we are comparing the ectomycorrhizal fungi on roots of red oaks (*Quercus rubra*) in the Arnold Arboretum with those on red oaks in Harvard Forest.

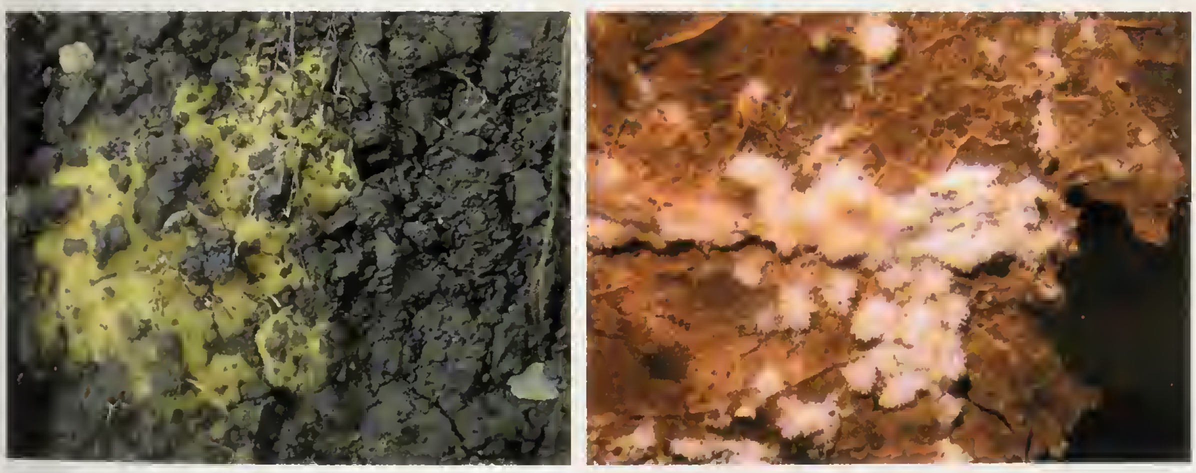
A Tale of Two Sites

Why choose these two sites for this study? There are some important differences between the Arboretum and the Harvard Forest. The Arboretum habitat is more like a residential area, where much of the understory is kept clear of non-cultivated plant life and the grass is kept short. The soil organic layer is comparatively shallow, and there is not much variety in the litter layer.

In contrast, the forests here in New England are characterized by an understory of regenerat-

RICHARD SCHULHOF

Research indicates that the ample foot paths, mowed lawns, and sparse understory in the Arnold Arboretum will favor Pezizales fungi on the root tips of the ectomycorrhizal trees.



Sporemats of truffle fungi *Pachyphlodes* sp. nov. (left) and *Tuber* sp. nov. (right).

An example of a sporemat and the truffle (*Pachyphlodes ligericus*) that its fungal barcoding sequence matches.

ing trees, native shrubs, vines, and herbs. The ground under the trees is covered by woody and leafy litter, and under that layer is a deep organic layer composed of roots, soil, and partially broken down organic matter that together form a dense mat that requires a knife to cut through it.

Compared to the forest habitat, there is not much in the Arboretum habitat to obstruct the passive transfer of fungal spores produced on the soil surface to roots and mycelia in or below the organic layer. This is possibly an important feature for the cup fungi because in order to fruit, the hyphae of outcrossing species such as *Tuber* must come in contact with a compatible mating type nucleus in another hypha. This is in contrast to most ectomycorrhizal basidiomycete species that form their mycelia with both nuclei soon after germination of their sexual spores. How do compatible mating types of truffles get together if the mycelia are underground? Perhaps the sporemats on the soil surface play a role in this event. If so, mating may be facilitated in an environment such as that found in the Arboretum over that found in a forest.

Ectomycorrhizal basidiomycete fruiting bodies (top) and their root tips (bottom) from (left to right) ***Amanita rubescens, Craterellus fallax,*** **and** ***Scleroderma areolatum.***

Let's explore that idea a bit. The sporemats are produced on the soil surface, presumably from the ectomycorrhizal roots below the soil surface. They in turn produce massive numbers of spores that are small, light colored, and thin walled, and therefore probably not designed to function as survival structures. We don't know what their function is, but it makes sense that they might be involved in the mating of truffles and other cup fungi that produce them. With this in mind, as part of the study of ectomycorrhizal communities, we also collected sporemats and fruit bodies in the vicinity of the trees we sampled from.

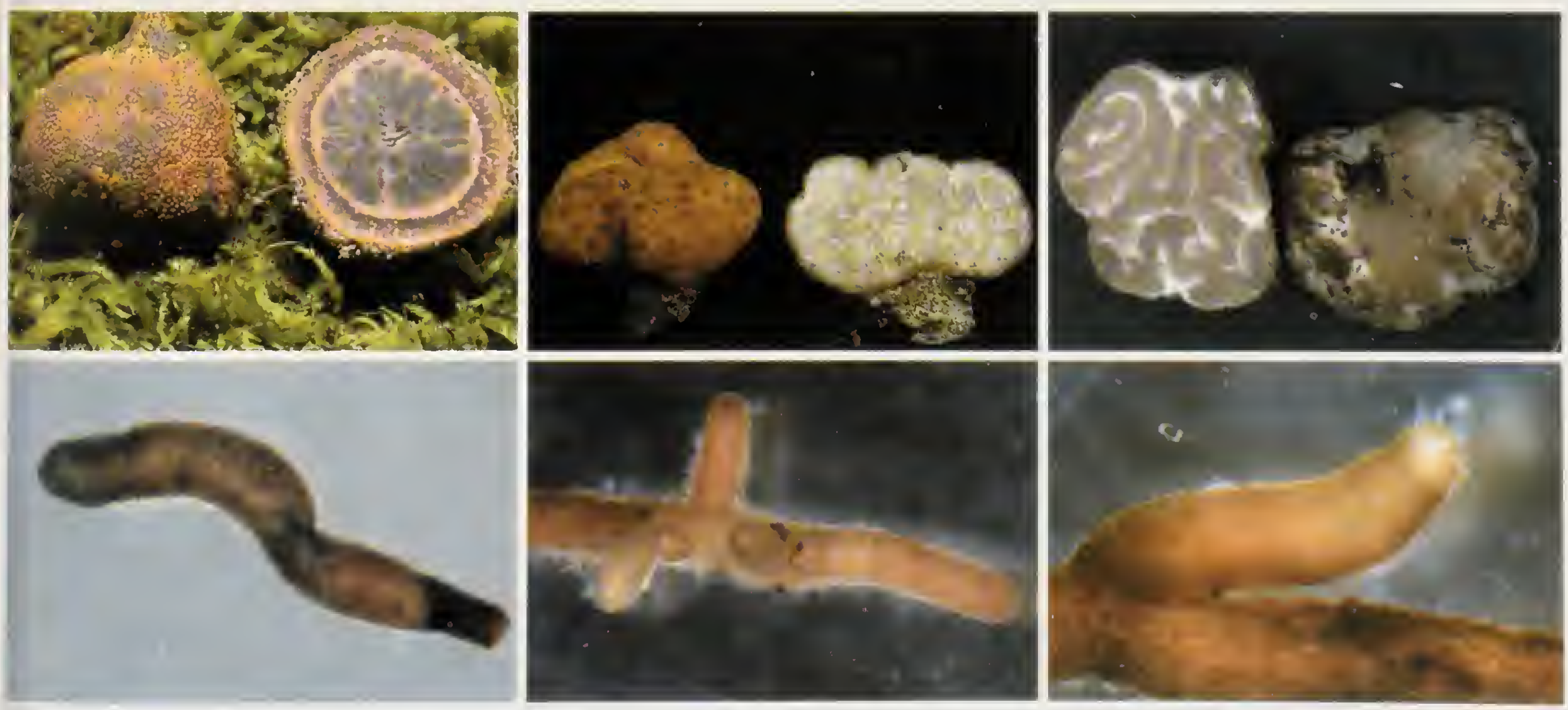
Fungus Findings

In order to determine what species are on the roots of the trees we sampled, we utilized a technique that yields the nucleotide sequence of the fungus genome from a nuclear region that is known to mutate quickly enough to show differences in nucleotides between species, but not so quickly that they differ much within species. This region of the genome is not a coding region, and therefore, the mutations have no known impact on reproduction. It is called the internal transcribed spacer region (ITS), and is one of the most useful for studying species limits in the fungi. In fact, this region was recently adopted as the first fungal bar code marker in the recently updated International Code of Nomenclature of algae, fungi and plants (McNeill et al. 2011). There is sufficient data from this genome region available in the National Center for Biotechnology Information (NCBI) that are deposited from national and international studies to be able to place most of the sequences from our study within a genus, and in some cases feel confident about the species, or to tell if it is likely an un-named (in NCBI) species. We can also compare our sequences with others in NCBI from a geographic locality perspective, and thus analyze the likely origins of the fungi on the root tips in our study to decide whether they are native or non-native.

While our study is not yet complete, I would like to share several interesting vignettes that have come to light. Basidiomycetes were the most frequently sequenced from the root tips in both habitats with 59 molecular taxonomic units (MOTUs) from Harvard Forest and 56 MOTUs from the Arboretum, 17 of which overlapped in both sites. Some MOTUs could be matched to sequences in GenBank from described species or at least sequenced fruit bodies. *Russula* species were the most frequently sequenced in both habitats with 32 MOTUs. A number of our other sequences matched *Russula* sequences from a previous study by Don Pfister and Sylvia Yang, but not sequences of any described species. A distant second place for most commonly sequenced genus was *Cortinarius* (14 MOTUs) followed by *Lactarius* (9 MOTUs). Even less common (genus followed by MOTUs within parentheses): *Amanita* (4), *Boletus* (1), *Byssocorticium* (1), *Clavulina* (4), *Craterellus* (1), *Entoloma* (3), *Inocybe* (4), *Laccaria* (1), *Piloderma* (1), *Pseudotomentella* (1), *Scleroderma* (2), *Sistotrema* (1), *Strobilomyces* (1), *Tomentella* (7), *Trechispora* (1), and *Tylopilus* (1).

This *Russula* fungus (fruit body and root tip shown) has a sequence that matches root tips in this study, as well as root tips and fruit bodies from a 2006 study by Don Pfister and Sylvia Yang in which they determined that many *Russula* species are exploited by the Indian pipe plant, *Monotropa uniflora*.

Nearly equal numbers of Ascomycete MOTUs were sequenced from each site. However, there was little overlap in species. It is particularly interesting that the Pezizales had significantly greater species richness and number of root tips in the Arboretum (10 MOTUs) than in the Forest (3 MOTUs). The cup fungi detected on roots in the Arboretum included *Hydnotrya*, four species of *Pachyphlodes*, three species of *Tuber*, and two root tip sequences that have no match to a fruit body sequence. From Harvard



Ectomycorrhizal ascomycete fruiting bodies (above) and their root tips (below) from (left to right) *Elaphomyces muricatus*, *Pachyphlodes* sp. nov., and *Tuber separans*.

Fruiting bodies of *Leotia lubrica*, commonly known as jelly babies, were found in Harvard Forest.

The researchers sequenced this unusual blue sporemat, which may be *Chromelosporium coerulescens* or a related species.

The distinctive black ectomycorrhiza of a *Cenococcum* fungus.

Forest we detected *Leotia lubrica* (commonly known as jelly babies) and *Elaphomyces* (hart's truffle). Cup fungi detected included *Tuber separans,* and the same species of *Tuber* (species 46) as found in the Arboretum. We also recovered a sequence that matches that of a lovely blue sporemat for which no fruiting body is known. This sporemat may be *Chromelosporium coerulescens* or a close relative. *Cenococcum,* an ascomycete not known to make a fruiting body, but with a very characteristic black ectomycorrhiza was ubiquitous on roots in both habitats.

We collected a number of truffle sporemats on the soil surface in the Arboretum, but in Harvard Forest they were found on top of the leaf litter, and even on the lower trunks of trees. Although we know from other ectomycorrhizal root studies that these species colonize roots, few of their sequences were detected on the roots sampled in this study, and none of their fruiting bodies found. The only evidence of their presence using our sampling technique was their sporemats. This may be because the Pezizales tend to be patchy in their colonization of roots, so they could easily be missed during sampling. The fact that they developed on the surface of the substantial organic layer in the forest shows that the originating mycelium is capable of navigating through the root mat and litter layer from the root tip. Where do the spores from the sporemat go and to what purpose? We don't know. We now see that they are quite capable of being formed atop heavy woodland litter, but we don't know how efficient their dispersal and ultimate journey into the soil is in either a forest or arboretum-like setting.

A second mystery came to light when one of the *Tuber* species detected on roots of a native red oak in the Arboretum was nearly identical in sequence to a species native to Europe, *Tuber borchii.* To our knowledge, this species has never been detected outside of cultivation in North America. Hannah Zurier, a Harvard undergraduate, received a Microbial Sciences Initiative fellowship to (in part) attempt to reconstruct how this truffle came to reside in the Arnold Arboretum. She found the truffle

The fruiting body and root tips of the newly named *Tuber arnoldianum*.

again on the same tree, and is in the process of looking for it on other trees in the vicinity.

A third interesting story involves another *Tuber* species. We detected a species (termed "species 46" by Tuberaceae expert Gregory Bonito, a mycologist at the Royal Botanic Gardens in Melbourne, Australia) on the roots of several trees scattered throughout the Arboretum, as well as from one of the trees sampled in Harvard Forest. Our sequences match those for an undescribed species, known previously only from orchid root tips in New York and red oak root tips from an urban area in New Jersey. We were fortunate to recover some fruiting bodies from the Arboretum so that we will now be able to describe this taxon. The Arnold Arboretum staff has chosen the name *Tuber arnoldianum* for this truffle.

While data are still being gathered, enough has been analyzed at this point (985 root tip sequences from 24 trees in each site) that I expect the pattern of Basidiomycete to Pezizales MOTUs in the two sites to hold up. This pattern continues to support the hypothesis that Pezizales are more prevalent in managed woodland sites such as the Arboretum. We can't be certain of the determining factors for this pattern, but refining the experimental parameters will help to zero in on those factors that are correlative. The well documented history of each accessioned tree, the ease of access to the rich information regarding Arboretum vegetation, and the encouragement and support of research by the staff at the Arnold Arboretum and Harvard Forest make these sites ideal for helping to resolve some of the outstanding questions regarding the ecology of ectomycorrhizal cup fungi.

References

Brundrett, M. C. 2009. Mycorrhizal associations and other means of nutrition of vascular plants: understanding global diversity of host plants by resolving conflicting information and developing reliable means of diagnosis. *Plant Soil* 320: 37–77.

McNeill, J., F. R. Barrie, W. R. Buck,V. Demoulin, W. Greuter, D. L. Hawksworth, P. S. Herendeen, S. Knapp, K. Marhold, J. Prado, W. F. Prud'homme van Reine, G. F. Smith, J. H. Wiersema, N. J. Turland, eds. 2012. International Code of Nomenclature for algae, fungi, and plants (Melbourne Code), adopted by the Eighteenth International Botanical Congress Melbourne, Australia, July 2011. *Regnum Vegetabile* 154. Germany: Koeltz Scientific Books.

Petersen, P. M. 1985. The ecology of Danish soil inhabiting Pezizales with emphasis on edaphic conditions. *Opera Botanica* 77: 1–38.

Trappe, J. M. 2005. A. B. Frank and mycorrhizae: the challenge to evolutionary and ecologic theory. *Mycorrhiza* 15: 277–281.

Yang, S. and D. H. Pfister. 2006. *Monotropa uniflora* plants of eastern Massachusetts form mycorrhizae with a diversity of russulacean fungi. *Mycologia* 98: 535–540.

Rosanne Healy is a 2013–2014 Sargent Scholar at the Arnold Arboretum, with matching support from Harvard Forest, and is a post-doctoral researcher with Donald Pfister in the Harvard University Herbaria.

The Castor Aralia, *Kalopanax septemlobus*

Kyle Port

Kalopanax is a monotypic genus in Araliaceae, the ginseng family. The lone species, *K. septemlobus,* is a dominant tree in northeastern Asia (Japan, China, Korea, the Russian Far East) where it is valued for the ethnopharmacology of its plant parts and its timber quality. Across Korea, overuse has threatened some wild populations and there are now calls to protect the species.

Castor aralia is a large deciduous tree that can grow to nearly 100 feet (about 30 meters) tall and has an average trunk diameter of about 40 inches (about 100 centimeters). Its stems are armed with stout prickles that yield to thick, deeply furrowed bark with age. It has very large (to 14 inches [36 centimeters] in diameter), long-petioled, 5- to 7-lobed leaves that may turn brilliant greenish yellow in autumn. Castor aralia bears large, wide (to 12 inches [31 centimeters] in diameter) inflorescences with numerous small umbels of white flowers that open in August and September here, providing late season nourishment to an assortment of pollinators. Successful pollination yields abundant blue-black fruits that are retained into winter.

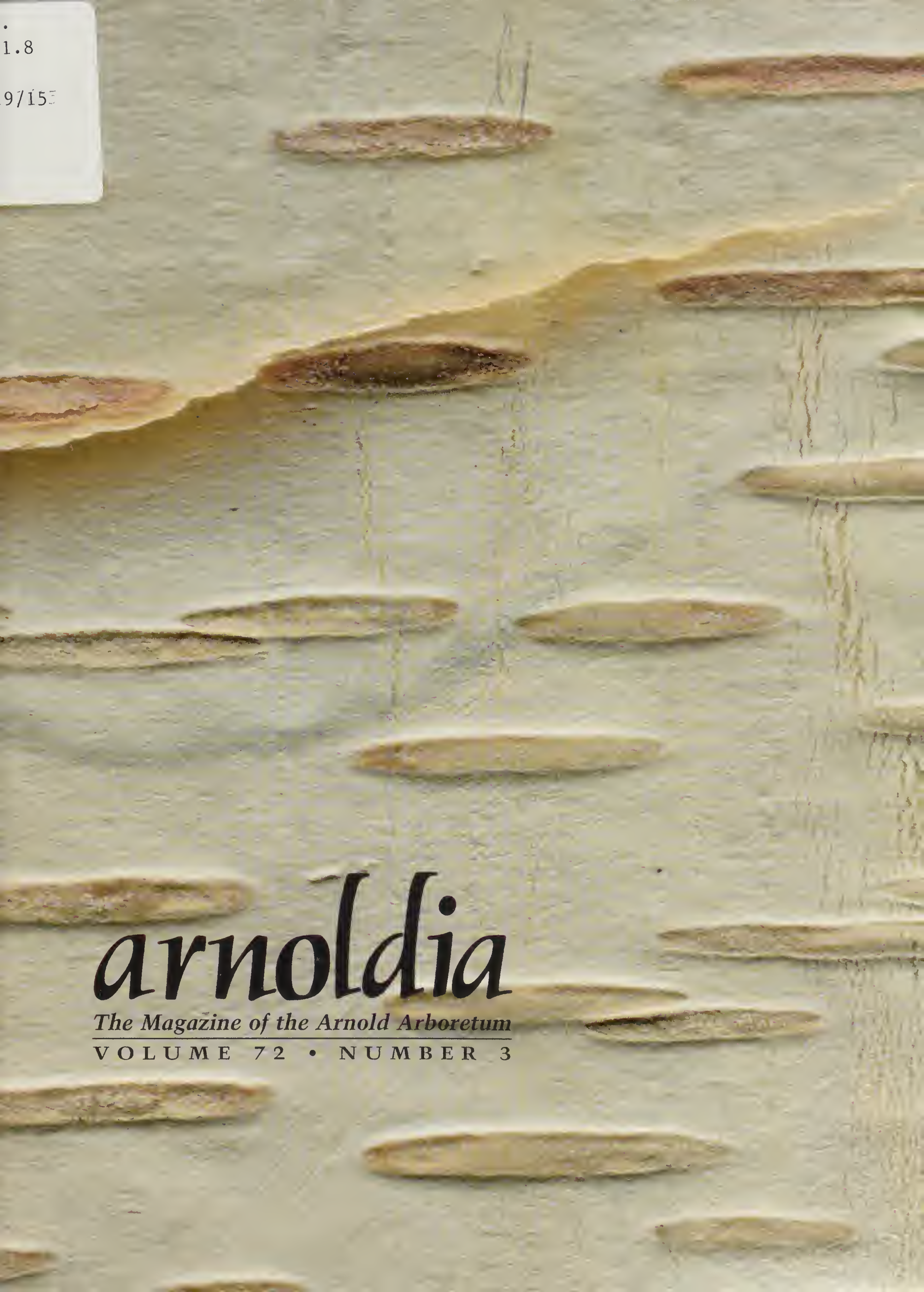
A single castor aralia plant was sent to the Arnold Arboretum in January 1881 by Alphonse Lavallée of Segrez, France. This inaugural specimen was accessioned as *Acanthopanax ricinifolium*—the species' accepted name at the time—and its accession card states only that it was "disposed of" in 1890. Intrigued by its characteristics and determined to cultivate specimens in Boston, Arboretum Director Charles Sprague Sargent collected seeds of the species on his first excursion to Japan in 1892. Two plants hailing from this collection thrive in the Arboretum today. Sargent's account of castor aralia in *Forest Flora of Japan* (1894) inspired additional collections, including J. G. Jack's 1905 seed collections at Lake Chuzenji (Chūzenjiko) and Sapporo, Japan. A total of 27 *Kalopanax septemlobus* accessions are documented in our curated databases and three plants currently grow in the permanent collections.

These handsome specimens grow on the eastern bank of Rehder Pond (accession 841-81-A) and near the paved summit path on Peters Hill (accession 12453-A and C). The younger specimen (841-81-A) was received as a seedling in 1981 from the United States National Arboretum, originating from seeds they received from China's Nanjing Botanical Garden. Growing without competition, its relatively uniform spread of 43 feet (13.1 meters) and height of 35.1 feet (10.7 meters) is remarkable. This specimen is marvelously tactile as the prickles around its 19.6 inch (49.8 centimeter) diameter trunk can still be felt when pressed. The two largest and oldest castor aralias on the grounds are those from Sargent's 1892 collection in Japan. Specimen 12453-A is 52 feet (15.8 meters) tall and has an astoundingly broad spread of 77 feet at its widest point; 12453-C is 34.7 feet (10.6 meters) tall and has a spread of 53 feet (16.1 meters).

In the July 19, 1923, issue of the *Bulletin of Popular Information,* Sargent wrote of castor aralia: "It is one of the most interesting trees in the collection and, because it is so unlike other trees of the northern hemisphere it is often said to resemble a tree of the tropics." The Arnold Arboretum subsequently distributed *Kalopanax septemlobus* seeds and plants to scores of researchers, institutions, nurseries, and hobbyists across the globe. Most prominently, it was among 10 taxa offered as a "reverse birthday present" in celebration of the Arboretum's centennial in 1972 and was included in institutional articles and listings of the best ornamental trees for the New England area.

Enthusiasm for castor aralia has since been tempered, however, as it has shown invasive tendencies in some areas, including the Arboretum grounds. Its fruits are readily consumed—and seeds subsequently dispersed—by birds; the Hokkaido Research Center in Japan documented 27 bird species feeding on *Kalopanax septemlobus* fruits across a 22 acre (9 hectare) site. Recognizing that dispersed seeds germinate in high percentages, we removed 7 accessioned castor aralias between 2010 and 2012. In addition, the practice of culling castor aralia seedlings from natural and cultivated areas of the Arboretum was formalized in our 2011 *Landscape Management Plan.* The conservation of taxa reported to be invasive is a topic of ongoing discussion here and at other botanical institutions. For the time being, don't miss the opportunity to study and marvel at a few of North America's oldest castor aralia here on our grounds.

Kyle Port is Manager of Plant Records at the Arnold Arboretum.



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Front cover: The bark of paper birch (*Betula papyrifera*) shows the prominent horizontal lenticels characteristic of many birch species. Photo by Paul and Eva Begley.

Inside front cover: A coalition of local parks organizations, including the Arboretum, worked with the Boston Parks Department to establish the Boston Park Rangers program in 1982. The program was based on the New York City Urban Park Rangers program, established in 1979; this slide of a New York City ranger was likely used in presentations aimed at rallying community support for the Boston program. Archives of the Arnold Arboretum.

Inside back cover: Native to the Mediterranean region, Montpellier maple (*Acer monspessulanum*) is noted for its small, leathery leaves and brightly colored samaras. Photo courtesy of Paulo Rocha Monteiro.

Back cover: The unique bark of cork oak (*Quercus suber*) is used to make cork stoppers, flooring, and other products. Photo courtesy of Amorim.

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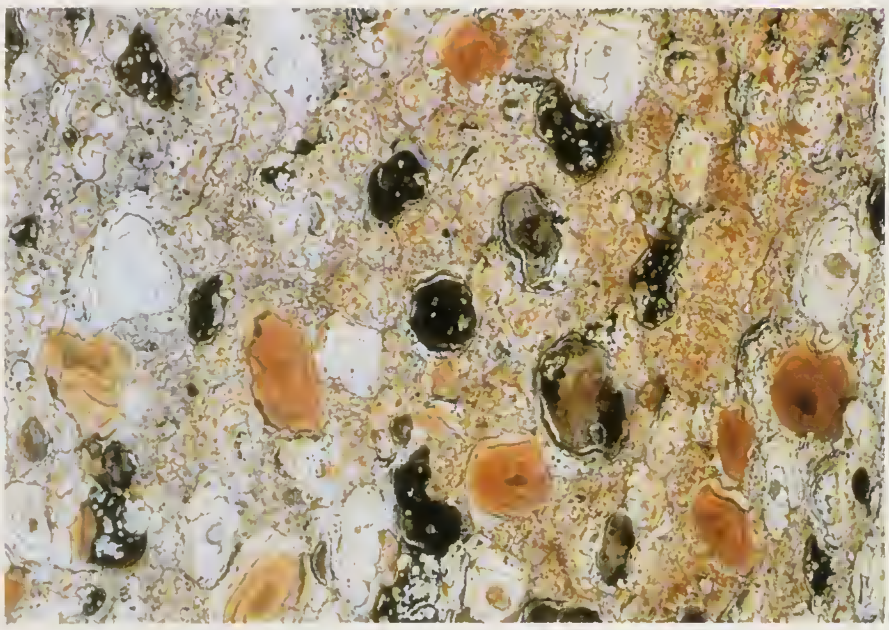
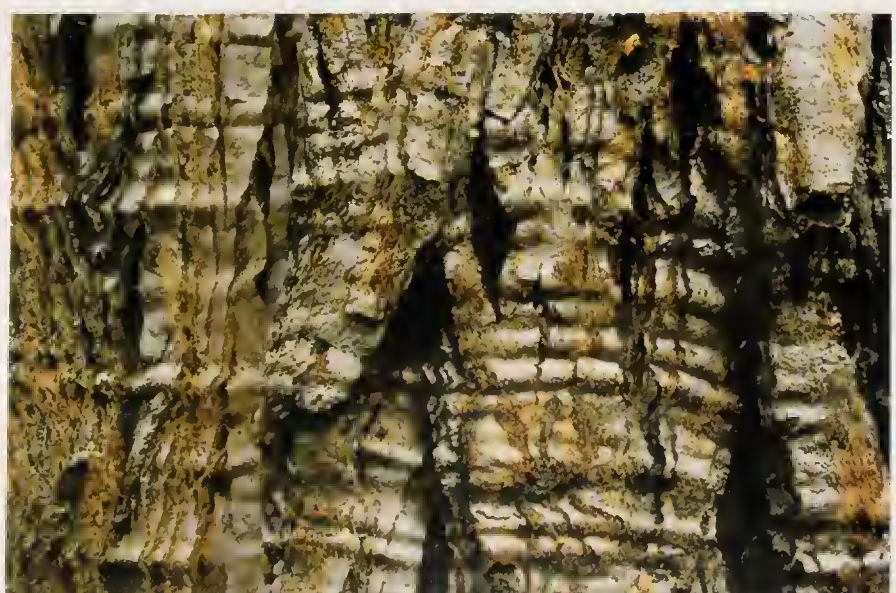
In the fading light of dusk, satiny bark curls on a greenleaf manzanita (*Arctostaphylos patula*) take on a purplish sheen.



The bark of whitebark pine (*Pinus albicaulis*) is much finer-textured than that of most pines and resembles an extreme close-up of an impressionist painting.



The trunks of giant sequoias (*Sequoiadendron giganteum*) are protected by thick layers of fibrous, fire-resistant bark.

Bark: From Abstract Art to Aspirin

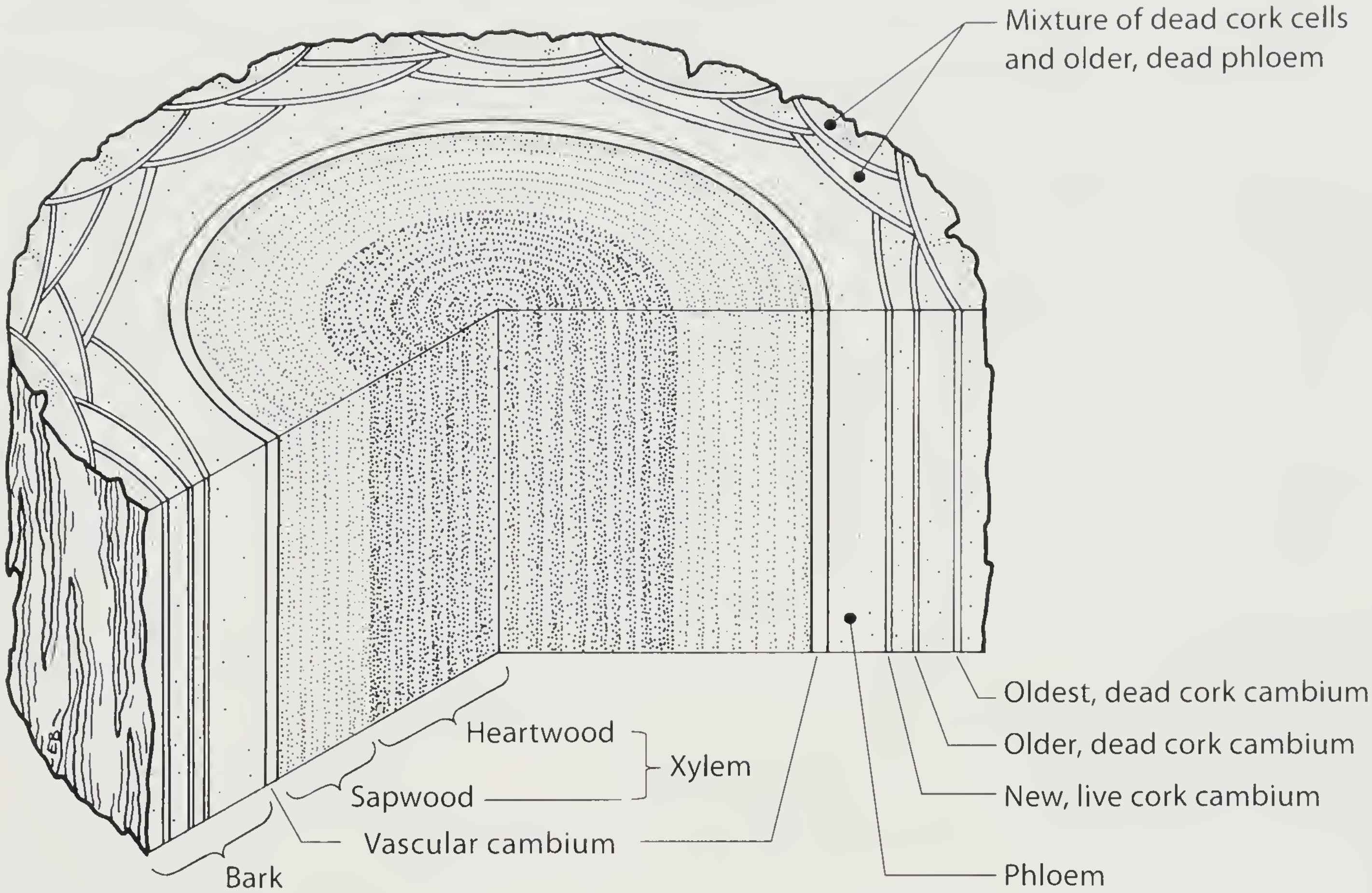
Eva Begley

To many people, bark is just the gray or brown stuff that covers tree trunks, but it's actually much more interesting than that. Woody dicotyledons and gymnosperms depend on their bark to keep insects and pathogens out. Bark also minimizes evaporation of water from trunks and branches. The fire-resistant bark of giant sequoia (*Sequoiadendron giganteum*) grows up to 18 inches [45.7 centimeters] thick and has allowed some individuals to thrive for more than 3,000 years. Cork oak (*Quercus suber*), native to southwestern Europe and northwestern Africa, can also survive forest fires thanks to its thick bark.

While functional for the tree, bark can be aesthetically pleasing for us. The bark of some trees shows surprising colors, including green, blue, and orange. It can be rough or smooth, stringy or flaky; it can peel away in long shreds or curl like chocolate shavings on an elaborate gateau. The textures and patterns in bark may remind you of abstract painting or sculpture, jigsaw puzzle pieces, or an old cable-knit sweater. Bark's charms are sometimes accentuated when festooned with lichens or providing a foothold for epiphytes.

Anatomy of a Tree

As a tree grows taller and adds more leaves and branches, its weight increases. To support the added weight, the trunk and branches grow in diameter. They do that thanks to a sleeve of almost-forever-young cells called the vascular cambium. During the growing season, these cells divide many times, mainly in a plane parallel to the surface of the trunk or branch. Cells produced on the inner side of the vascular cambium become xylem, which, as so-called sapwood, conducts water and minerals absorbed by the roots to the rest of the tree, then turns into the strong woody core of the tree—the heartwood, which is usually darker in color

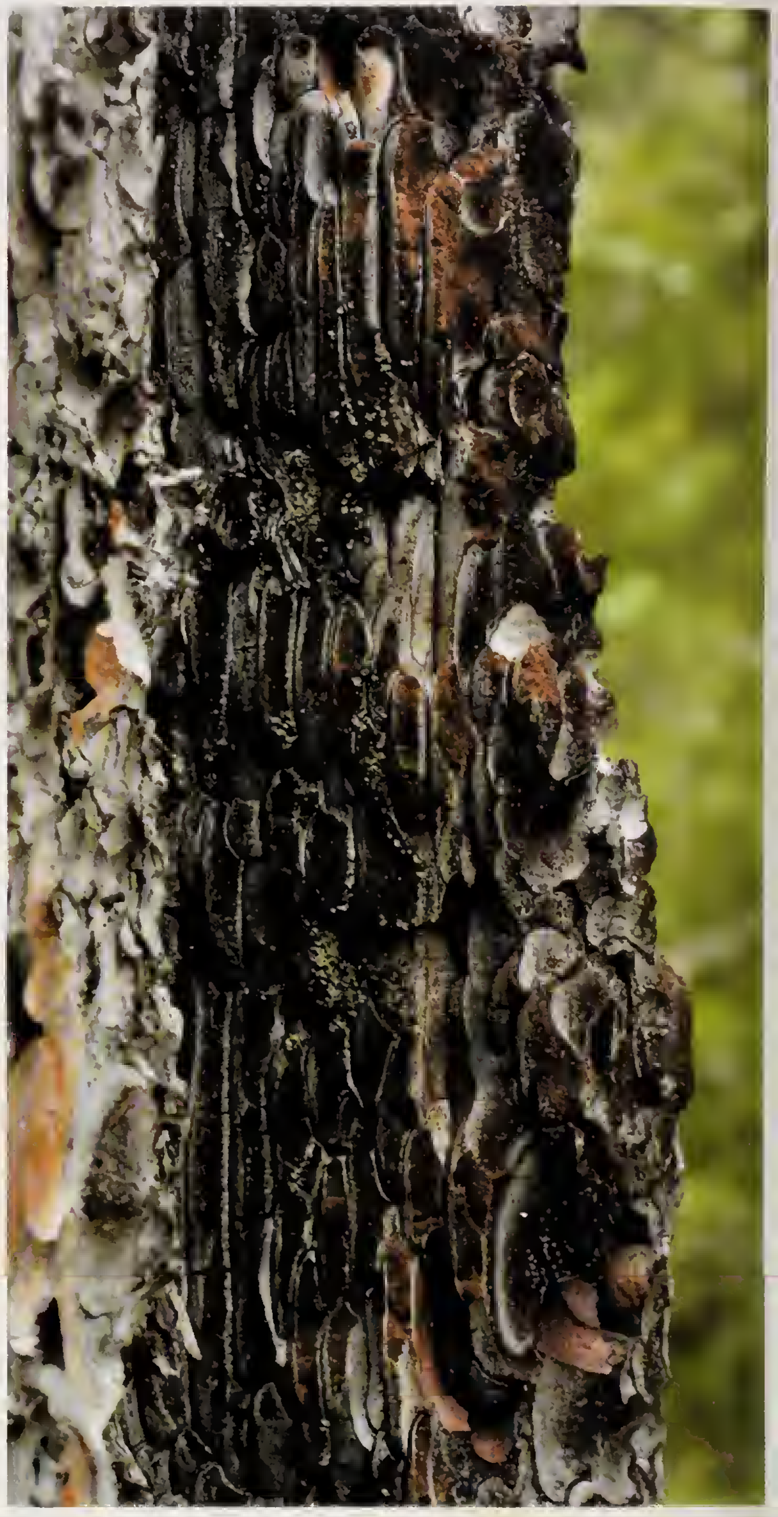


What Is Bark?

Botanists usually use the term "bark" to refer to everything outside the vascular cambium: phloem; phloem fibers; the innermost, live cork cambium and all its inner and outer derivatives; and older, dead cork cambia along with whatever else has accumulated outside the live cork cambium. The cork cambium and its products (that is, phellem and phelloderm) are collectively referred to as "periderm." The live, deeper-seated components of the bark are sometimes called "inner bark."

than the sapwood. Cells produced on the outer side of the vascular cambium become phloem, which conducts sugars and other carbon-based nutrients throughout the tree. In temperate climates, the xylem and phloem formed early in each growing season usually contain lots of relatively large cells; cells formed later in the growing season are smaller. As a result, the xylem and phloem are built up of concentric rings, each ring constituting one year's growth. Phloem rarely lasts more than a few years (more on that in a moment). Xylem, however, can last well beyond the life of the tree in the form of standing snags or downed wood, or as lumber in buildings and furniture. Similar processes take place in roots.

Once in a while, to keep up with the increasing girth of the tree, the cells of the vascular cambium divide in a radial plane. The phloem and most other cells outside the vascular cambium, though, have matured and aren't able to keep dividing or enlarging—they get stretched to the breaking point. That triggers the development of a new layer of squat, dividing cells, the cork cambium or phellogen, usually near the stem's surface. Like the cells of the vascular cambium, those of the cork cambium divide mainly in a plane parallel to the surface. (Interestingly, the cork cambium isn't necessarily active at the same time as the vascular cambium—the cork cambium seems to function more on an as-needed basis, perhaps in response

Front and side views of the bark of sugar pine (*Pinus lambertiana*). The crevices are deep enough to peer into and see the longitudinal arrangement of the bark plates formed by successive cork cambia.

to the damage caused by stretching and rupturing of cells around the perimeter of the trunk or branch.) The relatively few new cells formed on the *inner* side of the cork cambium, collectively called the phelloderm, usually stay fairly unspecialized; they may separate a bit, allowing some air circulation between them, and in some species they become photosynthetic, coloring the bark green. Far more new cells are produced on the *outer* side of the cork cambium; but except in a few aquatic or wetland plants, they stay tightly packed, with no air spaces between them. Unlike animal cells, each plant cell is enclosed by a wall composed primarily of cellulose. As the cell matures, its wall may be reinforced by additional layers of cellulose, or, in most cells in the xylem, by a strong, rigid substance called lignin. In the outer derivatives of the cork cambium, the cellulosic wall is lined by layers of a waterproof substance, suberin, sometimes alternating with sheets of waxes or lignin. Eventually, these outer derivatives die and their interiors become tiny gas-filled pockets, giving them a squishy feel: they have become phellem, commonly called cork.

Of course that isn't the end of the story, because in the meantime the vascular cambium continues increasing the plant's girth. Eventually, that first layer of cork also gets stretched excessively and starts to crack. In cork oak, occasional cell divisions in a radial plane allow the cork cambium to keep pace with the growth in girth, but more commonly the first-formed cork cambium dies and new cork cambium forms deeper in the trunk or branch, sometimes even in the outer, older part of the phloem. In some species, each new cork cambium forms a complete sleeve; other species produce many small, overlapping patches of cork cambium, a bit like curling shingles on an old roof. Often, these later cork cambia are initiated right underneath cracks in the tree's surface, like internal bandages, ensuring that no crack gets deep enough to damage the living interior of the tree. This process is repeated over and over throughout the life of the plant. Eventually, a complex structure is formed, with everything outside the innermost, most recently formed cork cambium either dead or dying.

Bark Variations

The texture of the bark depends largely on the shape and location of successive cork cambia and on the types of cells "trapped" between them. Chinese or lacebark elm (*Ulmus parvifolia*), for example, has many overlapping, irregularly shaped cork cambia fairly close to the surface. Trees with deeper-seated cork cambia have rougher, craggier bark, like northern red oak (*Quercus rubra*) and tulip tree (*Liriodendron tulipifera*). Layers of thin-walled cells, whether the inner derivatives of the cork cambium or part of the phloem, are structurally weak, so bark characterized by such layers is likely to flake or peel off easily. Phloem sometimes contains lots of long, skinny, thick-walled but pliable cells, called fibers; as old phloem gets incorporated into the bark, these fibers give it a stringy texture. In some pines, the outer derivatives of the cork cambium consist of alternating bands of suberized cork cells

The bark of lacebark elm (*Ulmus parvifolia*) has a jigsaw-puzzle-like pattern.

This Garry oak, also known as Oregon white oak (*Quercus garrayana*), has deeply creviced bark.

The bright green bark of palo verde (*Cercidium floridum*), a member of the legume family (Fabaceae), can be quite variably patterned; this particular tree shows kite-like shapes.

River birch (*Betula nigra*) is admired for its multicolored, dramatically peeling bark. Close examination reveals that each papery sheet is covered with the long transverse lenticels often found in the genus.

and short, heavily lignified cells, called stone cells, that harden the bark.

Layers of dead, waterproof cells are fine for protecting trees from bugs, desiccation, and other dangers, but they also hinder gas exchange. Like most living things, the live cells inside trunks and branches, including those of the vascular cambium and phloem, need oxygen. Lenticels provide the solution. They are small patches of loosely packed cells with lots of air spaces between them that the cork cambium produces here and there instead of dense arrays of cork cells. In some species, the lenticels are hidden at the bottom of cracks in the bark; in others, such as paper birch (*Betula papyrifera*), they form a prominent and characteristic part of the bark's appearance. Gases diffuse in and out through the lenticel's air spaces, allowing the live interior parts of the trunk to "breathe." Also, any green, chlorophyll-containing cells in the bark produce oxygen as a byproduct of photosynthesis. That oxygen gets snapped up by nearby, live, non-photosynthetic cells, which give off carbon dioxide, which their photosynthetic neighbors then use to produce more sugars—as neat a solution as any recycling system devised by engineers.

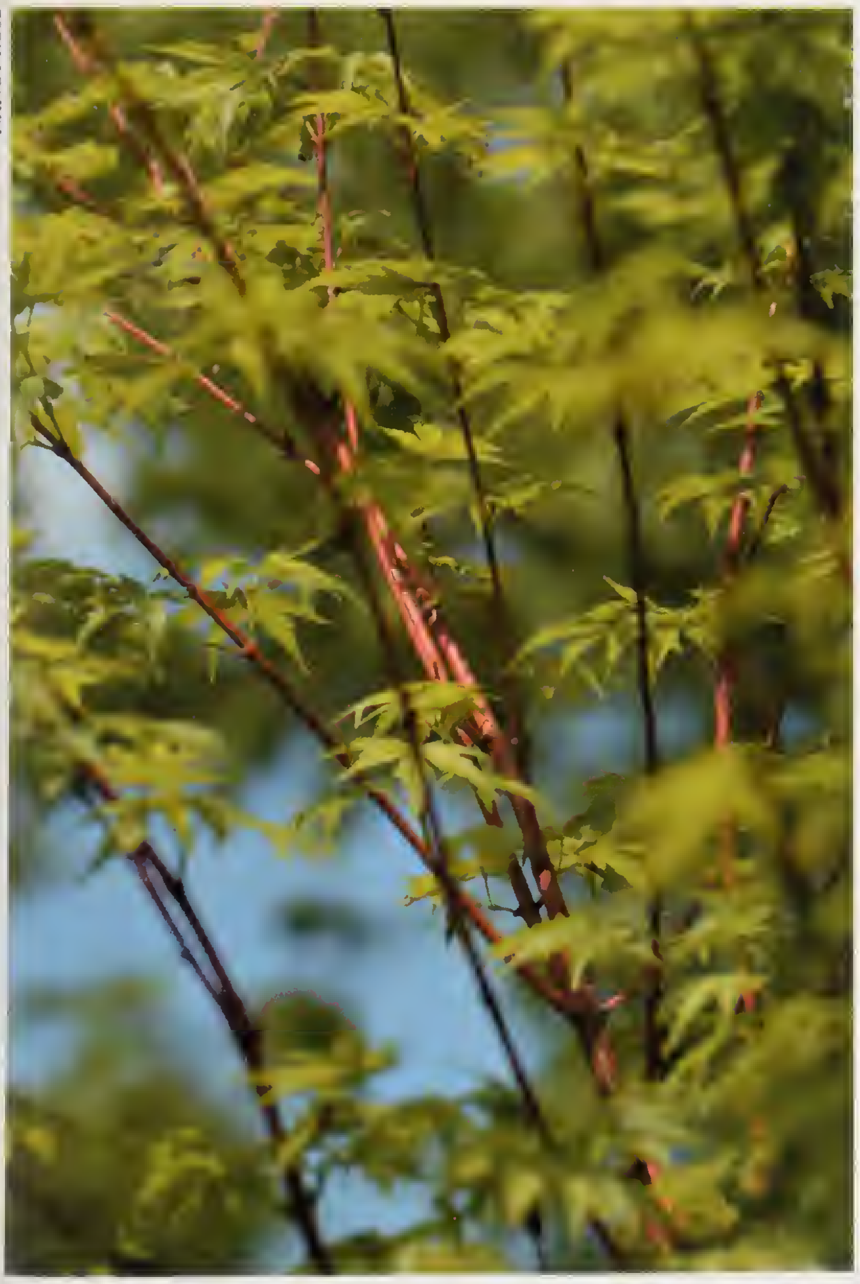
Different species of the same genus can have very different bark colors and patterns. Take the birches, for example. Sweet birch (*B. lenta*) has rather ordinary-looking gray bark, but paper birch and European white birch (*Betula pendula*) have smooth white bark with long, transverse lenticels. The lenticels of western water birch (*B. occidentalis*) form a similar pattern against a beautifully shiny, pinkish brown background, while in yellow birch (*B. alleghaniensis*) the background is yellowish brown or dark gray. River birch (*B. nigra*) is often grown for the tan, reddish brown, and dark gray sheets of bark that peel off its trunk in shaggy disarray. The maples are even more varied. Many have bark that is plain gray in color, albeit with various textures. But then there's the aptly named paperbark maple (*Acer griseum*) with peeling sheets of cinnamon colored bark, Father David's maple (*A. davidii*) with its characteristic vertical white squiggles on a bright green background, and coral bark maple (*A. palmatum* 'Sango-kaku'), a Japanese maple that adds color to winter gardens with its brilliant red branches.

Bark's appearance often changes with age, and it's common for the bark of twigs and young branches to differ from that of older limbs. An extreme example is European white birch, in which the rough, gray to almost black bark near the base of the trunk forms a stark contrast to the creamy white bark higher up. And in aspen (*Populus tremuloides*), wherever the trunk has been wounded, be it by fungal attack, natural abscission of the lower branches as the tree gets taller, a bear climbing the tree, or lonely sheepherders or bored teenagers carving their names into the tree, the bark becomes black and fissured, very different from the tree's normally smooth, pale bark.

Bark Beneficiaries

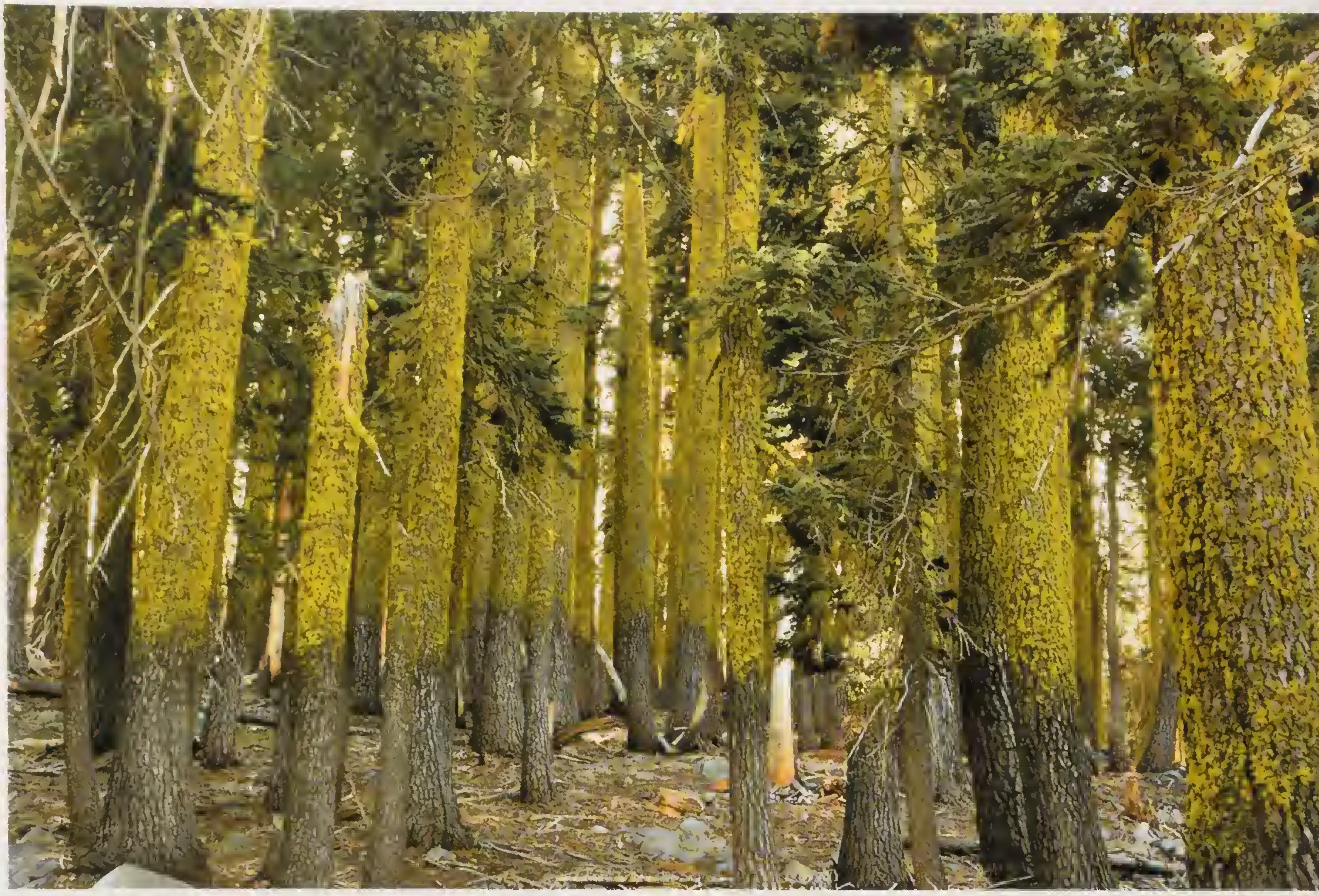
Thick bark has some obvious benefits to trees, but the cracks and fissures in that bark can also provide good habitat for other species. Especially on rough-barked trees, enough soil, organic debris, and moisture can collect to fill minute pockets in which lichens, mosses, and larger epiphytes such as ferns and orchids can get a toehold. Often, different species of lichens and mosses grow on the upper and lower surfaces of leaning tree trunks and large limbs.

NANCY ROSE



Younger branches of coral bark maple (*Acer palmatum* 'Sango-kaku') are bright red.

Black bears have left permanent calling cards on the trunks of this quaking aspens (*Populus tremuloides*).



The bark on the upper part of these old red fir (*Abies magnifica*) trunks is almost hidden by wolf lichen (*Letharia* spp.); the lichens don't grow below the average snow line in the grove.

Some mosses and lichens may prefer certain species of trees; for example, in the northern Sierra Nevada mountains, wolf lichen (*Letharia* spp.) usually seems to grow more luxuriantly on the trunks of red fir (*Abies magnifica*) and incense cedar (*Calocedrus decurrens*) than on the trunks of nearby seemingly equally rough-barked pines, though, the pines' *branches* sometimes bear dense chartreuse masses of this lichen.

Insects use the cracks and fissures in bark as places to hide; some feed on bark; others lay their eggs on or under the bark of dead or dying trees or trees stressed by drought. Collectively, these insects and their larvae provide a smorgasbord for insectivorous birds such as nuthatches, creepers, and woodpeckers. Sapsuckers (*Sphyrapicus* spp.), also members of the woodpecker family, drill horizontal rows of holes into the trunks of favorite tree species to feed on the nutritious inner bark and the sap that oozes out, along with insects caught in the flow. Subsequently, other woodpeckers, orioles, hummingbirds, warblers, and even some insects and mammals feed at these "sapsucker wells."

Nuthatches (*Sitta* spp.), gray jays (*Perisoreus canadensis*), and some species of woodpeckers cache nuts, seeds, and even dead insects by thrusting them into bark crevices, but acorn woodpeckers (*Melanerpes formicivorus*), native to the western United States and parts of Mexico, have raised the art of food storage to a new level. These social birds typically live in families of two to a dozen or more animals, and each family creates a communal acorn larder in the bark of thick-barked living trees, the bark or wood of standing snags, and even utility poles and fence posts. Acorns are stored in individual cubbyholes, each of which takes a total of about an hour to make although it's rarely finished in one sitting; typically, family members take turns drilling it over a period of a few days. A "granary tree" may have anywhere

Sapsuckers drilled multiple rows of holes in this white alder (*Alnus rhombifolia*). Extensive sapsucker drilling may partially girdle trees, which can eventually lead to the tree's decline.

Acorn woodpeckers constructed a granary in this valley oak (*Quercus lobata*). The tree is now dead, but the presence of a few remaining slabs of bark full of the distinctive holes indicates that the birds started their work while the tree was still alive or at least still had bark on it.

from one or two thousand to tens of thousands of acorn-sized cubbies, and each year the birds drill many more holes to replace those lost as limbs break off and old trees fall. In fall, the birds harvest ripe acorns from the branches of nearby oak trees (they rarely collect acorns that have already fallen to the ground), pry off the caps, and hammer the acorns into the predrilled holes. The flat end of the acorn, which provides a better surface for hammering, is almost always on the outside. If the first hole is too large or too small, the bird will try other holes until it finds one that is just the right size for a snug fit. The acorns provide an important food source for the family throughout the winter and early spring. Contrary to earlier belief, it seems that the birds feed directly on the acorns, not just on the insect larvae that sometimes infest them.

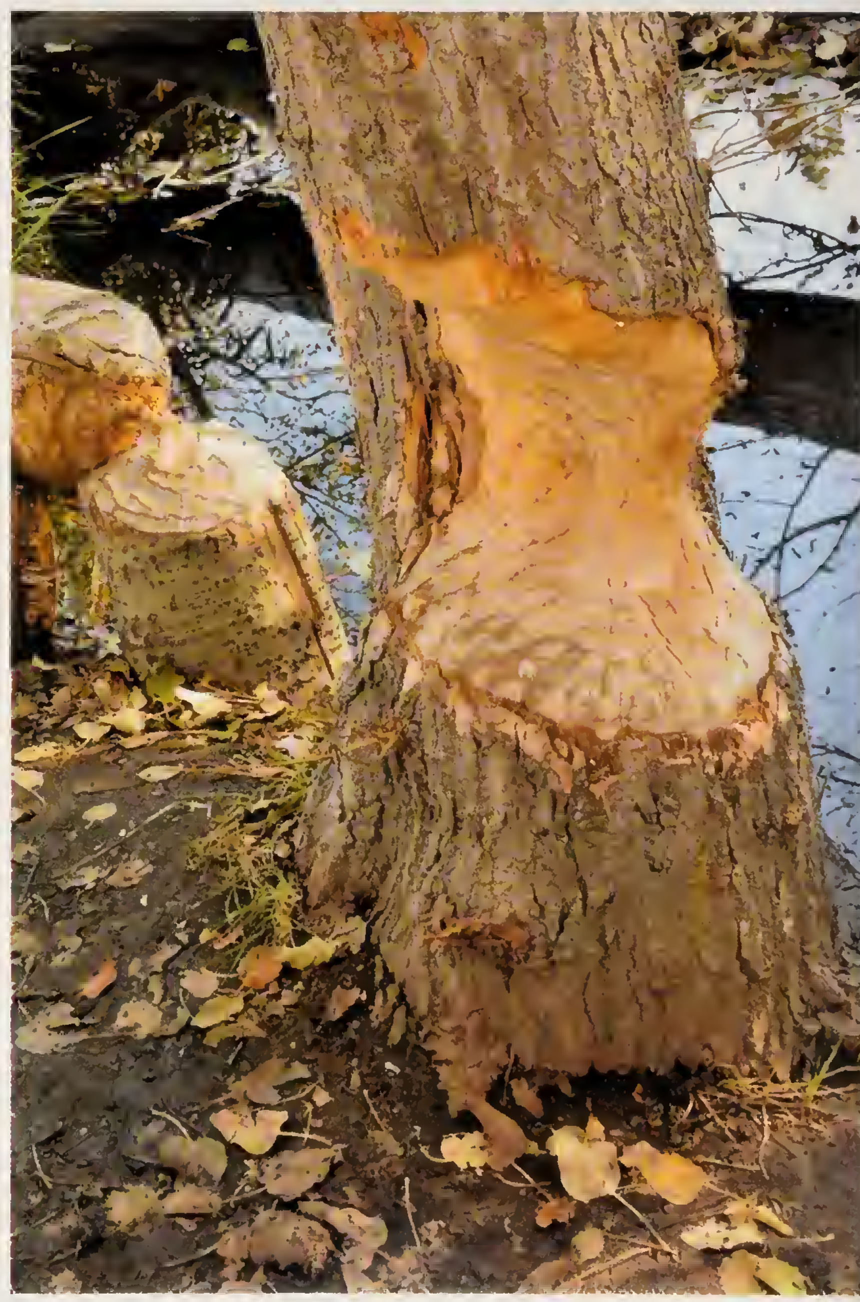
Some mammals feed directly on bark. Porcupines and snowshoe hares like conifer bark. Moose will eat bark in winter if nothing more to their liking is available. Beavers, on the other hand, love bark, especially aspen (which is abominably bitter to human taste buds), but also other *Populus* species, willows (*Salix* spp.), birch, red-osier dogwood (*Cornus sericea*), and other species. I've even seen conifers (specifically, lodgepole pine, *Pinus contorta* subsp. *murrayana*) felled by beavers. During the growing season, the animals eat the buds, leaves, and twigs of these plants as well as the bark. In winter, bark is their primary food. Since beavers can't climb trees to reach the goodies up in the canopy, their solution is to gnaw down the entire tree. They are amazingly efficient at this: I once watched a beaver scramble out of an Ozark river and up a steep bank to a young

Acorn woodpeckers drilled holes for various acorn sizes in this blue oak (*Quercus douglasii*).

maple, with a trunk diameter of maybe 4 to 5 inches (10 to 13 centimeters). Within moments the tree's crown was swaying wildly, and in less than five minutes the beaver had dragged the entire tree through thick undergrowth back into the water and was swimming away with it. The animals don't waste much: debarked trunks and branches are used to construct or reinforce the beavers' lodges and the dams that they are famous (or notorious, depending on your point of view) for building. And wherever winters are typically cold enough for ponds to freeze over, beaver families cache enough young branches each fall to last them through the winter, usually by jamming the butt ends deep into the mud at the bottom of the pond, sometimes by building floating rafts, placing already peeled logs and less-preferred foods such as alder on top of the raft and favorites like aspen and willow below so that the branches are easily accessible from underwater.

Canoes, Quinine, and Corks

Bark benefits people too. Leafing through Daniel Moerman's encyclopedic *Native American Ethnobotany,* I get the impression that Native Americans found the bark of just about every native tree species useful in some way, be it medicinally or to make baskets and other containers, rope, cloth, dyes, and many more items. In winter, the Lakota, Blackfoot, and Cheyenne fed their horses with cottonwood and aspen bark. Some tribes used slabs of bark as roofing material. In the upper Midwest the Ojibwe (also known as the Chippewa) stitched sheets of paper birch bark together with spruce roots



Beavers leave tell-tale signs wherever they fell trees.

The bark of cork oak (*Quercus suber*) is carefully hand-harvested. The bark regrows and can be harvested again in about ten years.

to waterproof their homes. In fact, so versatile is the bark of paper birch that it was used for everything from canoes to kitchen funnels; as Moerman puts it, "Nearly any kitchen utensil common to the white man could be duplicated in birch bark by the Ojibwe."

The homes and barns of North America's European settlers were often roofed with the bark of American chestnut (*Castanea dentata*). Some of those buildings might have been painted using brushes made by boiling basswood (*Tilia americana*) bark in lye, then pounding it to extract its hemp-like fibers, a technique the settlers learned from Native Americans who made rope, sewing thread, and woven bags from basswood bark. The settlers probably wore shoes made of leather processed with tannins extracted from hemlock or oak bark, and some of their clothes may have been dyed with quercitron, derived from the yellow-orange inner bark of the black oak (*Quercus velutina*). Alone or in combination with mordants or other dyes, quercitron can yield colors ranging from bright yellow to warm browns. It was used commercially until well into the twentieth century, when cheaper synthetic dyes were discovered.

Human health has also benefitted from certain chemical compounds in bark. To limit being incessantly munched by herbivores and damaged by insects, some plants produce chemical defenses. Some of these defenses are simply metabolic by-products, such as the calcium oxalate crystals that render the bark of some pines unpalatable to browsers. Others, such as various alkaloids, tannins, and cyanogens (which give cherry bark its distinctive bitter almond scent and cough-suppressing properties), require greater metabolic input and their synthesis consumes nutrients, but they provide valuable protection to long-lived plants. It's these same compounds that make the bark of some species medically useful.

Two of the most famous drugs we owe to bark are aspirin and quinine. The Greeks used willow bark extracts as long as 2,400 years ago to relieve pain; similarly, many Native American tribes used willow bark to treat colds, fevers, and headaches. In 1827, a French chemist, Henri Leroux, isolated a compound he called salicin from willow bark; a related compound, salicylic acid, was discovered in 1839. Both compounds, though, cause nausea and gastric pain, and chemists continued searching for an effective pain reliever. Another related compound, acetylsalicylic acid, was discovered in 1853, but it wasn't until 1899 that its pharmaceutical value was recognized and the Bayer Company began marketing it as aspirin.

Like many of the 60 or so species of manzanita (*Arctostaphylos*), this one (species unknown) displays eye-catching bark.

Quinine and other antimalarial alkaloids are derived from the bark of several species of *Cinchona,* native to the Andes and related to coffee. There are conflicting accounts of how *Cinchona* trees reached the Old World. In the nineteenth century, both the English and the Dutch tried to smuggle seeds or seedlings out of South America, where the quinine trade was tightly controlled. Eventually the Dutch established large *Cinchona* plantations on Java, and through breeding and selection increased the bark's alkaloid yield from 7% to 17%. Today other drugs are available, but the microscopic protozoan that causes the disease is becoming resistant to many of them, and millions of people are still affected by malaria annually.

To conclude on a happier note, though, where would we be today without the cork oak, whose thick outer bark is used to make flooring, fishing rod handles, woodwind instrument joints, and wine bottle corks by the billion? People have used cork at least since Roman times: Pliny the Elder, writing in the first century A.D., listed fishing floats, women's winter shoes, and stoppers for wine jars among its uses. It takes a cork oak tree 25 to 40 years to build up a layer of cork thick enough to harvest, but the first harvest consists of hard, crumbly material good only for bulletin boards and insulation. If the cork is removed carefully, a new phellogen develops in the phloem 25 to 35 days later. The tree resumes cork production and can be harvested again 9 or 10 years later. Not until the third harvest, however, is the cork of sufficient quality for wine stoppers. The trees typically live 250 to 350 years, so each tree can be harvested many times. The practice of harvesting bark in cork oak forests actually helps preserve this unique ecosystem from land development so many conservation organizations promote the use of natural cork. And even though oenological research suggests that it doesn't really make much difference whether wine is sealed with natural cork, synthetic stoppers, or screw caps, yanking a plastic stopper out of a bottle just doesn't provide the same sort of tactile pleasure that pulling a real cork does. So pull a real cork, pour a glass, and drink a toast to bark.

Further Reading

Bugalho, M. N., M. C. Caldeira, J. S. Pereira, J. Aronson, and J. G. Pausas. 2011. Mediterranean cork oak savannas require human use to sustain biodiversity and ecosystem services. *Frontiers in Ecology and the Environment* 9: 278–286.

Costa, A., H. Pereira, and A. Oliveira. 2003. Variability of radial growth in cork oak adult trees under cork production. *Forest Ecology and Management* 175: 239–246.

Cutter, E. 1978. *Plant Anatomy. Part 1: Cells and Tissues*, 2nd edition. Reading, Massachusetts: Addison-Wesley Publishing Company.

Elphick, C., J. Dunning, and D. Sibley. 2001. *The Sibley Guide to Bird Life and Behavior.* New York: Alfred A. Knopf.

Esau, K. 1965. *Plant Anatomy*. 2nd edition. New York: John Wiley and Sons.

Esau, K. 1977. *Anatomy of Seed Plants*, 2nd edition. New York: John Wiley and Sons.

Heinrich, B. 2003. *Winter World: the Ingenuity of Animal Survival.* New York: Harper Perennial.

Howard, E. T. 1971. Bark structure of the southern pines. *Wood Science* 3(3): 136–138.

Kaufert, F. 1937. Factors influencing the formation of periderm in aspen. *American Journal of Botany* 24(1): 24–30.

Kwiatkowsky, M. J., J. K. Skouroumounis, K. A. Lattey, and E. J. Waters. 2007. The impact of closures, including screw cap with three different headspace volumes, on the composition, colour, and sensory properties of a cabernet sauvignon wine during two years' storage. *Australian Journal of Grape and Wine Research* 13: 81–94.

Lanner, R. M. 1999. *Conifers of California.* Los Olivos, California: Cachuma Press.

Moerman, D. E. 1998. *Native American Ethnobotany.* Portland, Oregon: Timber Press.

Moreira, F., I. Duarte, F. Catry, and V. Acacio. 2007. Cork extraction as a key factor determining post-fire cork oak survival in a mountain region of southern Portugal. *Forest Ecology and Management* 253: 30–37.

Pereira, H. and M. Tome. 2004. Cork oak. In: J. Burley et al., eds. *Encyclopedia of Forest Sciences.* Oxford, UK: Elsevier. pp 613–620.

Pliny the Elder. Translated by J. F. Healy. 1991. *Natural History: a Selection.* London: Penguin Books.

Rupp, R. 1990. *Red Oaks and Black Birches: the Science and Lore of Trees.* Pownal, Vermont: Storey Communications.

Schery, R. W. 1952. *Plants for Man.* Englewood Cliffs, New Jersey: Prentice-Hall,.

Silva, S. P., M. A. Sabino, E. M. Fernandes, V. M. Correlo, L. F. Boesel, and R. L. Reis. 2005. Cork: properties, capabilities, and applications. *International Materials Reviews* 50(6): 345–365.

Stevens, K. J., R. L. Peterson, and R. J. Reader. 2002. The aerenchymatous phellem of *Lythrum salicaria* L.: a pathway for gas transport and its role in flood tolerance. *Annals of Botany* 89: 621–625.

Vander Wall, S. B. 1990. *Food Hoarding in Animals.* Chicago: University of Chicago Press.

Waisel, Y., N. Liphschitz, and T. Arzee. 1967. Phellogen activity in *Robinia pseudoacacia* L. *New Phytologist* 66: 331–335.

Zeiner, D. C. et al. 1990. *California's Wildlife: Volume III—Mammals.* State of California, Department of Fish and Game.

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A Dream Come True

Peter Ashton

The possibility of being appointed director of the Arnold Arboretum in 1978 had come as a considerable surprise, but I jumped at it. Ever since my first professional appointment in 1962 as forest botanist in the Sultan of Brunei's government, I had been sending plant specimens to the Arnold as one of the six leading botanical research institutions both within and outside the Far East that specialize in the flora of East Asia, tropical as well as temperate. I respected the Arnold's scientific reputation in large part because of former Arboretum director Elmer Drew Merrill's astonishing achievements on the flora of the Philippines and southern China. Arboretum notables Ernest Wilson and Alfred Rehder were also well known to me and, as a life-long gardener and amateur horticulturist, the Arboretum's unique design by Frederick Law Olmsted intrigued me.

Mary, my wife, and I will never forget our first glimpse of the Arboretum. During my interview, I sensed unhappiness among staff; morale was low. Mary was asked why she would wish to leave Scotland and her sheep; "Why on earth do you wish to come to this place?" quizzed another. Even the housekeeper in the fine old guesthouse at the faculty club, where we were accommodated on the Harvard campus, expressed the same feelings, and the (somewhat mythical) view that the Boston area had a crime level unimaginable in Aberdeen.

When I arrived, curation and the living collections policies bore the mark of the celebrated horticulturist Donald Wyman who had been at the Arboretum from his appointment by tropical systematic botanist and director Elmer Drew Merrill in 1935 until his retirement in 1970. Wyman's interest had been in ornamental horticulture, reflected in his book *Wyman's Gardening Encyclopedia,* still the most comprehensive text specifically designed for American gardeners. The Arboretum then, as now, continued to sustain the keen interest and support of many members of the Garden Club of America and the Federation of Garden Clubs, as well as the ornamental nursery industry. But I was skeptical that Harvard and its upper administration really understood its fundamental scientific importance, nor the importance of its potential role within the university. Indeed, only one director following Charles Sprague Sargent, Karl Sax, had used the living collections in his research.

But research universities focus on endeavors that advance scientific theory. The Arboretum's global herbarium collection, and with it the systematic botanists, had been removed to Harvard campus in Cambridge in the 1950s on the recommendation of a review chaired by Professor Irving H. Bailey. That decision alone led to nearly a decade of litigation between the University and the Association of the Arnold Arboretum, Inc. Harvard's adjacent Bussey Institute for plant research finally closed near that time, its distinguished faculty, scholars and researchers having been relocated to Cambridge two decades earlier in the 1930s. The Arnold Arboretum had become a backwater for the University, indeed "an orphan institution" within the broad missions of the University to educate and discover. Among faculty, Carroll Wood was alone in running a course based on the collections by our time, though Peter Stevens also used them later.

Around the time I assumed my position, the Jamaica Plain-West Roxbury neighborhoods had been experiencing long decline, and this, too, had impacted the Arboretum. Trash collection had become a major activity for grounds staff, kids periodically drove beat-up automobiles off the summit of Peters Hill, while two corpses were discovered in our first year, one head-first down a road drain. So, there was no shortage of challenges, but that gave the job particular interest!

Once I accepted this challenging position, it became my goal to reinvigorate the research functions of the living collections of the Arbo-

Peter Ashton in the greenhouse, 1983.

Given the pristine appearance of the Arboretum today, it's hard to believe that it was once plagued by litterbugs and vandals. The photo above shows a trash-strewn slope in the Conifer Collection in 1973.

retum. Colleagues in Cambridge had to be convinced that a systematic collection of specimen trees could be a resource for cutting-edge research. But first the living collections themselves had to be reviewed, and a new curatorial policy defined and executed, before a convincing case could be made. Because Sargent, on advice from Asa Gray, one of the world's leading botanists in his time, had established a systematic collection of woody plants, carefully selected and documented, the key was to bring this founding vision back to the fore. As I soon discovered, the Arboretum could then assume a unique role among gardens in Boston that complemented Boston's other two great living botanical and horticultural gardens: Mount Auburn Cemetery, a horticultural landscape focused on trees; and the Garden in the Woods, a native wildflower garden. Together, these three wonderful botanical collections could together offer the public a diversity of plants unequaled anywhere else in the New World, and in very few other places elsewhere. I realized that our collective objective should be to complement, rather than compete.

My first quest, therefore, was to see the original Olmsted road plan and planting scheme. As Sargent had intended, the collections were laid out in such a way that a visitor could observe the families of trees hardy in the climate of Roxbury "without alighting from his carriage." On inquiry, I discovered that the Arboretum library did not have the plans, nor was it clear where they could be found! But the old Olmsted firm buildings and archives still existed at Fairsted in Brookline, thanks to the interest and commitment of the landscape architect Joe Hudack. Arboretum archivist Sheila Connor spent a fortnight searching for the original plans in a garage full of Olmsted's original works; she found them and retrieved them for copying. Only later, Fairsted became a National Historic Site, while the original plans are now in the Library of Congress.

One must recall how revolutionary Olmsted's landscape philosophy was in the late nineteenth century. This was the time when leafy suburbs started to expand on a grand scale, when a new industrial urban rich could express their fantasies in ornate gardens. A vast array of plant introductions from other regions of similar climate had become available during the nineteenth century, to decorate garden space and to ornament domestic architecture. John Claudius Loudon, in England, was the leader, adorning colorful but often fussy gardens with masonry in formal classical mode while, by the end of the century William Robinson was promoting mythical bucolic utopia in elaborate pastiches.

But Olmsted returned to those more serene and unified landscapes, when the whiggish English aristocracy of the eighteenth century could afford to create scenes recalling Claude Lorraine's paintings, and of sufficient scale for architecture to be subordinate to nature. Perhaps significantly, these potentates were against the king and often much in sympathy, politically as well as esthetically, with the American project (did you know that Thomas Hollis, whose name is commemorated in the Harvard library system, Hollis House, and the town of Holliston, was a landowner here in Somerset, England, and a major Harvard benefactor who never visited America?). The foremost proponent of their mythical landscapes, Lancelot "Capability" Brown, used mass plantings of native trees to sculpt his spaces with only the occasional exotic as punctuation. Olmsted was in that spirit and I was empathetic, having been at a high school set in one of Brown's creations.

Arboretum visitors near Bussey Brook in the early 1970s.

That was the time when Sargent, Gifford Pinchot, and their colleagues were instigating the first systematic survey of the American tree flora, gauging the extent of America's forests and revealing the enormous diversity of native trees and their potential for parks and gardens—in comparison to England's rather paltry thirty-five native tree species. Olmsted, although responsible for the plan of Biltmore and other great American private estates in the Brown tradition, was primarily focused on bringing an appreciation of natural landscapes to the general public in city parks, university campuses, and in his involvement with the growing conservation movement. Harking back to Capability Brown, he exploited the majestic spaces of the new continent including the growing cities, and achieved what was unachievable in crowded Europe. This accomplishment can still be admired and cherished in Boston's Emerald Necklace. Olmsted's Arboretum plans revealed how he seamlessly combined his philosophy of landscape design with the requirements of a systematic botanical collection. Bearing in mind that trees within genera and even families share much architecture in common, groves of tree families, rather than species, can achieve a similar effect in the landscape. But cultivars selected for outstanding color or shape must be used with utmost discretion.

Peter Ashton in his office at the Arboretum, 1983.

Thus it became clear that the Olmsted-Sargent design and planting plan not only provided an optimal solution to the design of an arboretum whose purpose was both to provide a representative systematic collection for systematic and comparative research, but it is a historic landscape for designers and planners: a park within which the public can both recreate and learn. I realized that such a project remained unique. The Royal Botanic Gardens, Kew, are a historic landscape, but their land is uncompromisingly flat, denying the curving sweep of Olmsted's contour-hugging roads at the Arnold. Neither did Kew start with a clear accession plan. The aim at the Arnold, to introduce at least three provenances of each taxon, to record location of collection, and to ensure nomenclatural verification with an herbarium voucher, is known to me in only one other great nineteenth century botanical garden, Buitenzorg, which was originally established by the Dutch as an ornamental garden around the palace of their governor-general of the East Indies. Modeled after the king of Prussia's garden Sans Souci ("carefree"), Buitenzorg was set in Bogor, the town that was built as the colonial administrative center on the island of Java. The gardens were reorganized and landscaped under Stamford Raffles, founder of Singapore, who, in his twenties, governed the Dutch East Indies for the British who had expropriated them during the Napoleonic wars. The gardens became a scientific establishment thereafter, while remaining a public park. For me, with a decade in Borneo at the start of my career, the plant explorations of Sargent and Engelmann west of the Mississippi River recalled the great Johannes Teijsmann. Thanks to his intrepid explorations of Borneo and Sumatra in leech-gorged clogs, the Buitenzorg gardens (now the National Botanic Gardens of Indonesia) hold the world's greatest collection of tropical woody plants. From the outset they too had been meticulously documented and curated. And they are beautiful to look at, though nothing compared to the Arboretum! And they have had a research laboratory on their grounds for over a century (though they, too, recently had their herbarium moved to Jakarta by unthinking biological policy-makers).

My prime objective, of returning the Arboretum to the fold of great research institutions within a research university, had therefore to be to review collections policy, and especially to redefine accessions policy. This was admirably accomplished under horticultural taxonomist Stephen Spongberg's leadership. This resurgence also called for enhanced documentation and verification of the living collections. To accomplish this, with National Science Foundation funding, herbarium vouchers were obtained, afresh or for the first time, from all established living collections and sent to taxonomic authorities for verification. That project was led by David Michener, who had little difficulty in attracting a burgeoning team of enthusiastic volunteers. And collections documentation and management was computerized: BG-BASE was introduced by its creator, Kerry Walter, who had come with the fledgling Center for Plant Conservation to whom we had offered the Hunnewell Building attic, at that time unreconstructed. This critical and widely used database system was based on the Arboretum's documentation and workflows, and the Arboretum became the very first user of BG-BASE. Since then, these pioneering efforts in curation and collections management have been enhanced to bear the fruits that represent the Arboretum's current superb program led by Curator of Living Collections Michael Dosmann.

The program of public education, which expanded as membership in the Friends of the Arnold Arboretum had grown, was awarded a major grant to initiate a schools program, including a botany and interpretation program for teachers. In the meantime, we were reaching out to local communities, and to the West Roxbury police who received a Christmas cake from my unstoppable and persuasive Mary. This worked with such effect that officers on horseback soon appeared. And a crash campaign against trash resulted in a dramatic response from the public and less work for grounds staff. Meanwhile the gentrification of Jamaica Plain, Roslindale, and West Roxbury, which was to utterly change community interest in the Arboretum, was starting.

The late 1970s and early 1980s saw an upswing in violence and vandalism in Boston, which led to a subsequent drop-off in visitation to city parks. In response, the Arboretum collaborated with several parks associations and the Boston Parks Department to create the Boston Park Rangers program, with the goal of increasing safety and visitorship. Seen here, mounted Park Rangers interact with Arboretum visitors along Meadow Road in 1983.

Thanks also to Mary's involvement with our volunteers, a support group, the Arboretum Associates, was formed. The group successfully raised funds for a variety of Arboretum projects that had heretofore been on the back burner. The annual plant giveaway and plant sale became a major event thanks to the support gained by the Associates among leading nurseries. For instance, an accompanying auction attracted media attention: Bids came from as far as Paris, and a yellow-flowered *Clivia* went for a princely $2,000!

But returning active fundamental research to the living collections remained an unresolved challenge. Harvard is a "guided democracy." The heart and soul of Harvard is the Faculty of Arts and Sciences (FAS). All academic policy, including

Peter Ashton (center, seated) at a meeting in front of the Hunnewell Building, 1982.

faculty appointments, rests with the faculty themselves. The university's schools have their own faculty and policies. But the allied institutions, such as the Arnold Arboretum, are in a no-man's land in which responsibility for faculty and research appointments has changed from time to time. Those allied institutions that are recognized as essential assets for FAS academic departments were in the best position, for their appointment priorities coincide. But the director of the Arnold Arboretum, clarified by the lawsuit of the fifties, reported directly to the university's president. Derek Bok, president at that time, was

Peter and Mary Ashton in 1988

determined to bring the directors of Harvard's rich panoply of allied institutions, who understandably were perceived as unfettered oligarchs, under appropriate authority within FAS.

This intent was particularly desirable in plant science, which was and still is fragmented under several institutions, each with its own endowment: four herbaria (the Arnold Arboretum, Gray, Ames, and Farlow), the Botanical Museum, Harvard Forest, and the Arnold Arboretum. Only in the case of the Arboretum is there a legal constraint on subsuming the institution within the program of an academic department—and only the Arboretum possessed a sufficient and substantial endowment. President Bok insisted that all research appointments, both curatorial and faculty, receive the support of the faculty of that academic department whose mission was closest to the Arboretum's, in this case, Organismic and Evolutionary Biology (OEB). This at once orphaned the applied research in horticulture and forestry for which the Arboretum had built a distinguished reputation. The Museum of Comparative Zoology (MCZ) had an invaluable research and pedagogic relationship with Harvard's school of applied zoology: the Medical School. But there has been no botanical equivalent at Harvard since the Harvard Forest's program in forestry ceased in 1931. Research appointments at the Arboretum were then exclusively in the field of systematic botany (taxonomy), at that time no longer at the cutting edge of theory as in Sargent's day, although there was about to be a renaissance thanks to advances in molecular genetics. Research was confined to the herbarium, which had been amalgamated with other herbaria in Cambridge.

I saw limitless opportunities for exciting new comparative research that would avail of a systematic collection of living trees, but colleagues in the Arboretum and OEB were unconvinced, skeptical whether candidates of stature could be found. Thanks in large part to the support of Professor Lawrence Bogorad, who chaired the committee of directors of biological institutions at that time, I was able to initiate a search for a junior faculty appointment on the Arboretum staff, in root biology. Bogorad happened to be a distinguished colleague in a different department, Cellular and Developmental Biology. John Einset was appointed, and a modest lab set up for him in the Dana Greenhouses headhouse. His work, on the evolution and systematics of hormonal response to root initiation, was pathbreaking and of both theoretical interest and practical application. Besides, he had the friendly and sympathetic personality that made him a superb instructor and a star among our volunteers and Friends. But Einset did not succeed in gaining tenure, and opinion hardened against my experiment. Most difficult, I was convinced that no research program would flourish at the Arboretum without a good field laboratory, which would allow fresh plant material from the living collections to be brought in at once for study and experiment.

Peter and Mary Ashton at the Arboretum for a reception to honor Peter's receipt of the prestigious Japan Prize in 2007.

Without researchers on the staff who wished to avail of a laboratory, I sought to attract the interest of faculty in the several plant science departments in the universities of the Boston region. Thanks to some beneficent friends of the Arboretum, funds had been promised for construction of a modest lab. But new laboratories are normally approved at Harvard only where there is a potential or existing faculty to attract to them, or where a group of existing faculty campaign for one. Unfortunately, my own research in tropical tree biology could hardly be said to avail of our temperate living collections. Had I depended on the living collections in Jamaica Plain and Roslindale, a case could have been made as a condition of my appointment. Instead, a conclusion was reached at a meeting of the OEB Visiting Committee in 1988 that the Arnold Arboretum should retain a separate existence from the department and therefore FAS, and that no strong case therefore existed for faculty appointments on its staff. Lawrence Bogorad, a past president of the American Association for the Advancement of Science, alone continued to support my viewpoint: It was clearly time for someone more suitably placed to take up the challenge. Eddy Sullivan, educator and at that time vice-mayor in the City of Boston's mayor Kevin White's government, who had become a staunch supporter in my negotiations with the city, quipped, "You don't have to worry, Peter; if it all fails, you can always go home to Ireland"!

Seen in this setting, it was no surprise that my successor as Arboretum director, Bob Cook, was not initially optimistic about the prospects of my case to embed the university's research back into the Arboretum. Bob had come from directing Cornell Plantations, which enjoyed a successful research and pedagogic relationship with academic departments in one of the leading universities in both fundamental and applied agricultural research. In the expected way, he arrived with a new broom. It was not long, though, before he came to realize the importance, even if against all odds, for building a laboratory at the living collections if they were to stand any chance of returning to Harvard's academic fold. Freed of faculty influence as he was by the Arboretum's detachment from FAS, it is to Bob's great credit that with dogged determination he gained the support of the president's representatives in the administration. Those were the times of skyrocketing endowment values, and Bob's ambition came to vastly exceed my wildest dreams. But he—and the endowment—paid a heavy price when the recession of 2008 arrived. But the new laboratory building was nearing completion; it was fortunately too late to go back. Bob Cook should be remembered as the director who successfully brought the Arnold Arboretum back to a position where it could valuably contribute to Harvard's research and pedagogic mission, and in which it could reignite a major program in fundamental tree research—but this is his story to tell. For the first time in almost a century, the magnificent new Weld Hill Research Building might serve as a magnet for a new director, who could be a leader in a field that would avail of both them and what is now again the outstanding research collection of living trees in the temperate world.

And so it has befallen! In spite of severe budgetary constraints, current Arboretum director William (Ned) Friedman has brought the new laboratory building to life with graduate students, with new faculty and classes availing of the living collections, and is attracting researchers from other institutions. Most importantly, thanks to a new generation of faculty in OEB and changing understanding in the Harvard administration, Friedman has been able to gain the university's support for advancing the Arboretum's scholarly mission in spite of current financial constraints. And in the spirit of the original intent, the public programs have been enriched by enhancing public appreciation of science. Regular research seminars have returned to the Arboretum, while the Director's Lecture Series is introducing increasing audiences to a variety of issues in the social as well as biological sciences. My dream has indeed come true, and with a flourish!

Peter Ashton is Harvard University Bullard Professor Emeritus and was Director of the Arnold Arboretum from 1978 to 1987. He and Mary live in Somerset, England.

Lighting the Night: The Use of Pitch Pine and Bayberry in Colonial New England

Sheila Connor

TORCHES OF PINE

In dark, small-windowed Colonial homes, the roaring fireplace brightened the room by day, and it often produced the only light available at night. Had domestic animals been abundant, the typical melted beef-suet or mutton-suet candles that the guildmakers produced in England would have been made. Tallow was scarce, however, and the inventive and resourceful settlers turned to materials ranging from extremely combustible meadow rushes soaked in lard to fish oil burned in shallow, wrought-iron holders, called Betty lamps, to illuminate their homes. These lamps

An illustration of pitch pine (*Pinus rigida*) showing the cones still tightly closed, from *A Description of the Genus Pinus* by Aylmer Bourke Lambert, 1832.

sputtered, smoked, and smelled unpleasant. A new method of lighting discovered by the colonists consisted of burning the resin-rich wood of a conifer that grew on the sandy coastal plains and ridges and in the sand barrens of river valleys. *Pinus rigida* earned the names candlewood and torch pine from the Europeans after they had observed how easily the Indians produced a bright flame by igniting several slivers of wood cut from its "fat" heartwood. The colonists referred to these sputtering torches that dripped pitch as "splint lights."

Whether growing in sterile seaside sands, where they are frequently bathed by salt spray, or rooted on exposed, windswept rocky hill tops, the torch or pitch pine thrives under adverse conditions. Easily blown over when young, a pitch pine eventually develops a root system that is substantial and deep enough to anchor it and to allow the tree to grow on an extremely dry site. Trees not more than four inches in diameter can have roots that penetrate to a depth of more than nine feet. Forest fires in these dry, windy habitats are devastating; however, not only do pitch pines survive, they often come to dominate the landscape after a fire. In New England, only *Pinus rigida* and the rarer *P. banksiana,* the jack pine—a tree of the Boreal Forest—are members of a group of conifers known as fire pines. These trees can withstand fire because they have evolved several specialized characteristics. All fire pines are pioneer trees—trees able to tolerate growing in full sun. Some have a high percentage of cones that remain closed until heat generated by fire melts the resin that glues the tips of their scales together, thereby releasing their seeds. These seeds remain viable inside the cone for many years, and they have the ability to germinate on soil totally lacking a humus component. The term "serotinous," which means late-developing, describes the habit of bearing closed cones that contain viable seeds for many years. Jack pines retain their tightly closed cones for so long that they often become embedded in the wood of the tree's branches and can completely disappear as the branches thicken. Pitch pine's special adaptations include a thick, protective bark, some cones that remain closed, and the ability—unusual among conifers—to sprout

TIM BOLAND

A mature pitch pine cone that has opened and released its seeds. Cones may persist on the tree for years.

from dormant buds on the main stem or at the base of the trunk if the tree is burned or cut.

In New England, wherever the soil is exceptionally sandy, it is likely that pitch pines will be found. One of the few trees that can grow at the ocean's edge, flourish in salt marshes, and inhabit slowly moving sand dunes, *Pinus rigida* abounds on Cape Cod. Stunted oaks (black, red, scarlet, and white), along with the smaller post oak (*Quercus stellata*) and the Cape's ubiquitous scrub oak (*Q. ilicifolia*), are the common deciduous trees, but rising slightly above their crowns are the branches of the pitch pine, the true indicator of this sand-plain community. Usually reaching heights of less than fifty feet under the best of growing conditions, at thirty feet these pitch pines overtop the Cape's stunted forest canopy or form pure stands of low pine woods. Whether described as being New England 's most grotesque or most picturesque pine, a stand of *P. rigida* growing on a sandy hillside evokes an image of an untamed landscape. Pitch pines seldom grow straight; they twist this way and that. Their bark is remarkably rough and scaly, its color a very dark reddish gray-brown. Sparse, irregularly spaced limbs droop downward. Many of them are dead and devoid of any foliage, but they are still covered with old, open, weathered gray or blackened cones. The stiff, twisted needles grow at the ends of stout, short twigs. Each fascicle, or bundle, has three of these three- to five-inch-long yellowish-green needles. These dense clusters of needles festoon the live branches and also form tufts of foliage along the trunks. A multitude of cones with sharp, curved spines at the end of the scales also cling closely to the branches. A few of these cones mature, shed their seeds, and then fall off; most, however, remain firmly attached to the branches long after their seeds have been dispersed.

PITCH—THE JUICE OF THE PINE

It was *Pinus rigida*'s imperfection as a source of illumination that proved to be a clue to its most marketable asset—its abundance of pitchy tar. In the scramble to find and develop commodities for trade, the production of naval stores—pitch, tar, rosin, and turpentine—flourished on the sand plains of the New England colonies, the home of *P. rigida.* As early as 1628, residents of Plymouth, Massachusetts, requested that "men skylfull in making of pitch" be sent from England. Boiling pine tar made pitch, but extracting pine tar could be accomplished only by burning trees. To extract tar, a kiln is constructed that is much the same as that of a charcoal burner—that is, a furnace that greatly restricts the amount of air reaching the fire. The process requires that a pile of pitch pine be burned in the kiln as slowly as possible, often for two weeks or more, while an encircling ditch traps the liquid product as it oozes outward. The simple process of "boxing" or "milking" a tree—chopping away a section of the lower trunk, followed by chipping a channel in the bark—produced rosin, another salable commodity. Apparently, this process appealed to almost everyone who possessed a hatchet. Although the life span of trees treated this way was shortened, a farmer could add to his yearly income by "boxing" a stand of pine for several seasons.

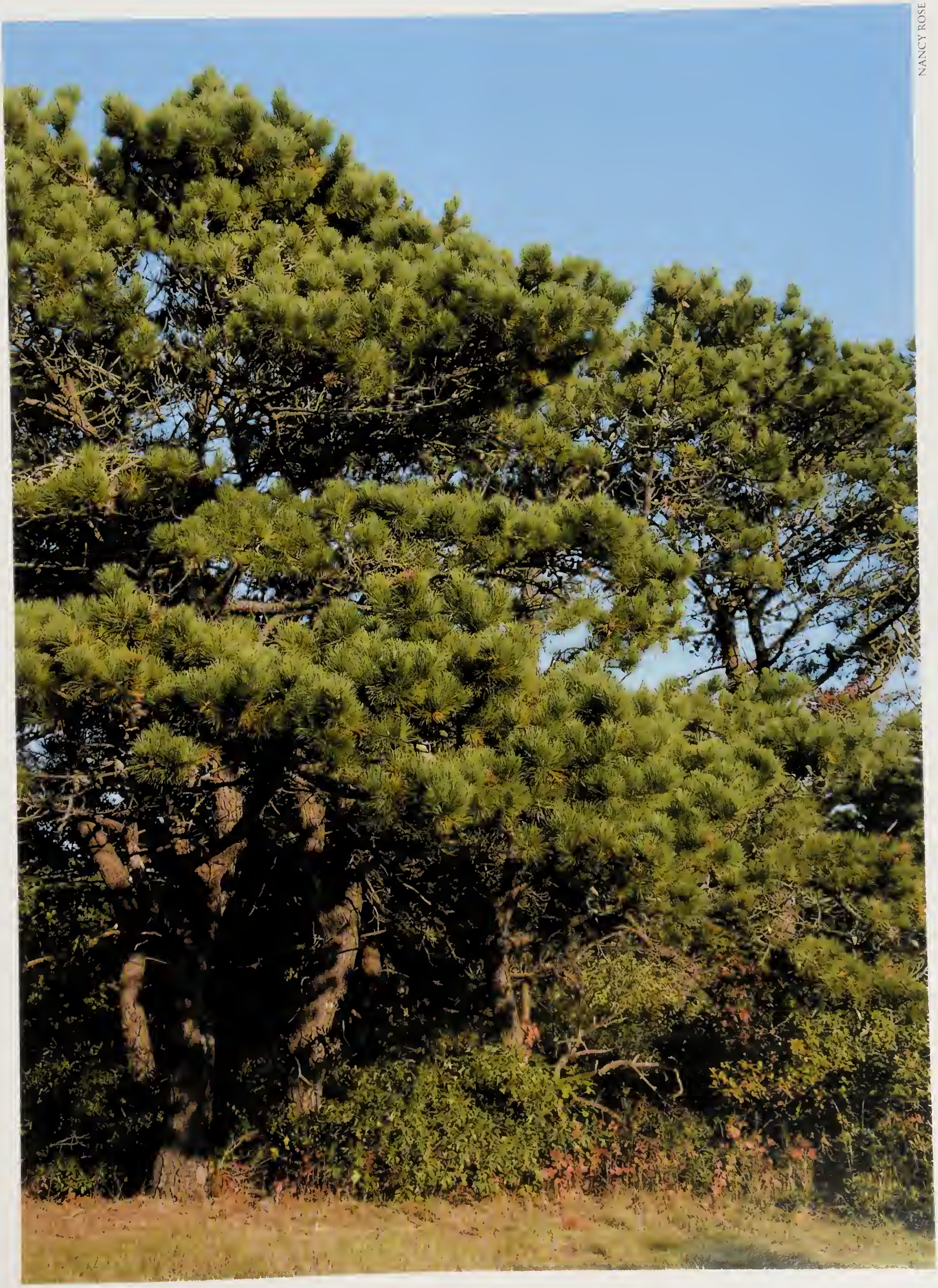
As the production and trade of naval stores increased, whole forests of pitch pines vanished from coastal regions and from the outskirts of river valley towns. When rampant cutting of these trees occurred near the ocean, dunes became unstable, and drifting sand threatened harbors, homes, and pathways. Less than thirty years after the founding of Plymouth, rigid restrictions governing the cutting and the use of pitch pine had been established. By 1702, the town fathers forbade the taking of any pine from Plymouth's beaches. A wealth of pines grew on the sandy plains along rivers, and the rivers themselves provided an easy means for transporting forest products. Although families


TIM BOLAND

Northern bayberry fruits are small nutlets with a thick waxy coating.

Northern bayberry (*Morella pensylvanica* [synonym *Myrica pensylvanica*]) is a shrubby plant that usually grows to a height of three to eight feet, but, in some situations, it can become a leggy shrub of fifteen feet or so. A typical plant usually assumes a dense, rounded, somewhat conical shape, but in places where the plants are exposed to constant winds, such as the seashore, they form a matted ground cover about twelve to fifteen inches high. Northern bayberry is a pioneer species that can colonize sandy, sterile dunes, nutrient-poor abandoned fields, and disturbed waste places. It is a perfect plant for use in dune stabilization.

The waxy coating on bayberry fruits is a vegetable tallow made up of stearin, palmitin, myrsitin, and glycerides. While ordinary white candles are sometimes coated with bayberry wax to give the olive green color and scent of bayberry, most of the "bayberry" candles sold today are made of a chemically scented synthetic wax or are made from the wax of one or more shrub species endemic to Central and South America that are somewhat related to the North American bayberries.



NANCY ROSE

Pitch pines growing on Cape Cod.

TIM BOLAND

Northern bayberry has leathery, dark green leaves.

were allowed to continue gathering wood for lighting and fuel, the taking of pitch pine for making tar was prohibited within six miles of the Connecticut River. Massachusetts enacted conservation measures in 1715 to protect both the pine trees and the land. No one, without a license, could "cut, carry off, bark or box any pine tree...." Violation of the law carried a fine of twenty-five shillings for each tree harmed. Caught between the need to generate revenues and the desire to conserve resources, the fledgling government levied excise taxes, established fixed prices, and imposed controls on the quality and the quantity of naval stores. This New England industry flamed as brightly and burned out as quickly as a knot of pitch pine. By the first quarter of the eighteenth century, the pine belt in the Carolinas and Georgia—a region with an abundance of yellow and loblolly pine—would claim the lead in the production of these commodities. Thus, North Carolina came to be known as the Tar Heel State and its citizens as "tarheelers."

Multiple specimens of northern bayberry and pitch pine can be seen in the Arboretum's collections.

BY EARLY CANDLELIGHT

For lighting the home, New England's sandplain flora yielded an even more aromatic and cleaner-burning plant product. Sharing the ability of the pitch pine to grow in pure sand, the northern bayberry (*Morella pensylvanica* [synonym *Myrica pensylvanica*]) was abundantly distributed along the coast when the colonists arrived. The native Americans made medicinal tea from its aromatic leaves and bark and knew how to obtain wax from its "berries," but it was the new settlers who first turned the fatty coating on its berrylike nutlets into candles. Burning with a steady blue flame and emitting a pleasant, delicate odor, bayberry wax was considered by the colonists to be far superior to splint lights, pine knots, Betty lamps, and candles made from animal tallow.

In autumn, after the bayberries had ripened, the thrifty housewife turned pounds and pounds of berries into a few precious, straight, green candles. (Between five thousand and ten thousand berries were needed to make a single two-ounce candle.)

Forming low, dense mounds on seaside dunes, the many-branched, angular plants were easy to find when laden with small berries, whose color is unlike that of any other northern plant. Its hard, nutlike seeds are embedded in a waxy substance speckled with grayish or bluish granules. These fruits, about a quarter of an inch in diameter, are borne by female plants, and they appear in conspicuous clusters on short spikes along the branches and at the base of the twigs of the preceding year's growth.

Most of the species in the bayberry family (Myricaceae) are evergreen. Unlike the evergreen southern species, *Morella cerifera* (synonym *Myrica cerifera*), the northern bayberry is deciduous. A wise woman waited to gather the berries until several light frosts had brought the growing season to an end and the bayberry's green, shiny leaves had fallen. Stripping the berries earlier than September 10th was outlawed in Connecticut beginning in 1724. Berry gatherers apparently ignored this legislation, however; and illegally collected berries before the authorized date.

As they picked, the women and children noticed that their hands grew smooth as they acquired a thin film of wax from the berries. Inventive housewives saved some of the berries that they collected and filled cloth bags with them in order to grease the bottoms of their heavy flatirons.

For candlemaking, the twigs and other debris that came home in the berry pails were removed, and the cleaned berries were placed in large cauldrons, covered with water, and heated and simmered for hours. A greenish, oily liquid floated to the top and solidified as it cooled. Repeated several times, this part of the process included straining the liquid through cloth to remove any impurities. Finally, a clear, solid cake of olive green wax resulted. The blue green water that remained was put to good use: homemakers used it to dye their homespun cloth.

Patience and a steady hand came next. Dipping a wick twenty-five times or more into the remelted wax made a thin, tapered candle. Allowing each layer of wax to harden before the candle was dipped again meant that this process could take at least half an hour. Dipping several wicks at once saved time; only the size of the pot governed the number of candles that could be produced. Revolving candle stands that enabled the woman to dip several wicks at once decreased the time required, and tinsmiths made metal molds into which the heated wax could be poured, which eliminated the laborious dipping process altogether. It is no wonder that these highly prized and brittle candles, the finest light source available, were carefully stored in long, narrow boxes specifically made for holding candles.

Not only were bayberry candles a useful domestic product that was saved for use on special occasions, they also became articles of trade in the colonies, and they were probably the first objects manufactured by women to be exported from New England. The English held these candles in highest regard, and they even tried to grow bayberries themselves. The French also hoped to establish bayberry plantations. However, neither the French nor the English succeeded in bringing *Morella pensylvanica* into cultivation on a large enough scale to support a candlemaking industry.

Sheila Connor is the former Horticultural Research Archivist at the Arnold Arboretum.

This article is adapted from *New England Natives* by Sheila Connor, Harvard University Press, 1994.

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Erable de Montpellier, the Montpellier Maple

Katherine Urban-Mead

Last year I declared I could never love any other tree as much as a sugar maple. After accepting a several-month ecology internship in Montpellier, France, I bid a teary adieu to the stunning October foliage around my Hudson Valley home. Then I stepped off the airplane into a new world of dusky gray and gnarled Mediterranean greens. Ancient olive trees stand like statues in the roundabouts; streets are dotted with palms, cypresses, and occasional figs; tightly-pruned planetrees line esplanades and bike paths alike. There is no maple syrup here.

On my first day at work, I climbed a rickety external staircase to the third floor, and with some confusion saw samaras waving from an unfamiliar tree growing alongside the stairs. Paired samaras (one-seeded fruits with papery wings) are characteristic of the maples (*Acer*), a group of plants I had worked with as a horticultural intern at the Arboretum last year. During my internship I had puzzled over hawthorn maple (*A. crataegifolium*) and communed with paperbark maple (*A. griseum*), but had never taken time to get to know the species that I now greeted with great glee. It was not a sugar maple, but instead the aptly-named Montpellier maple, *Acer monspessulanum.*

After my joy at finding a local maple subsided, I had to admit that the Montpellier maple is not a particularly elegant tree. It is sometimes referred to as a shrub (*arbuste* in French), with an average height of only 15 to 25 feet (4.6 to 7.6 meters). Its slow growth and small trunk, frequently branched into several stems, give it a craggy feel characteristic of many Mediterranean region trees. Montpellier maple's leathery three-lobed leaves are rounded and smooth-edged, are borne on long petioles, and are only 1.5 to 2.75 inches (4 to 7 centimeters) wide and 1.25 to 2 inches (3 to 5 centimeters) long. By mid-November the morning chill in Montpellier had become crisper; the endearing leaves of the tree I pass each morning turned first yellow then red. Finally brown, they fell and were scattered through the halls by passing boots.

In the spring, Montpellier maple bears small, bright greenish yellow flowers that open earlier than its leaves, followed by the parallel-winged samaras frequently tinted pink or red and maturing to tan. This drought-tolerant species handles occasional cold and persists in USDA hardiness zones 5 to 9 (average annual minimum temperatures -20 to 30°F [-29 to -1°C]; Montpellier has a Zone 9 climate). Montpellier maple is shade intolerant, so should not be sited near faster growing species. It thrives in alkaline and nutrient poor soils; on a recent hike in the Cévennes I found *A. monspessulanum* growing on limestone bluffs near a holly oak (*Quercus ilex*) and the scrub mountain pine (*Pinus mugo*).

Montpellier maple has a wide native range and corresponding variability in form. Taxonomy resource *The Plant List* reports five accepted subspecies—*cinerascens, ibericum, persicum, turcomanicum,* and *microphyllum*; the latter, found in Turkey, Lebanon, and Syria, has very small leaves, just 1.25 inches (3 centimeters) maximum width. Including all subspecies, *Acer monspessulanum* spreads across southern Europe from Portugal to Romania and across Northern Africa and east to the Hyrcanian forests in Iran and Azerbaijan. Here in southern Europe, *A. monspessulanum* is most often confused with the field or hedge maple, *A. campestre.* The field maple, however, has larger, distinctly five-lobed leaves and milky instead of clear sap.

There are three specimens of Montpellier maple at the Arboretum, so you don't need to fly across the pond to find it. Accession 1491-83-B, located just a short way down Oak Path, was wild-collected in the Lautaret botanical garden near Grenoble, France, and is currently 24 feet (7.3 meters) tall. Two other specimens are nestled in the Maple Collection along Willow Path. One young accession (264-2004-B; just under 10 feet [3 meters] tall) originated from a cultivated plant at the Bordeaux Botanical Garden. The second (12507-A), a mature tree accessioned in 1910, is an astonishing 43 feet (13 meters) tall. Bonsai enthusiasts also appreciate *A. monspessulanum* because its small leaves reduce even further under bonsai culture—perhaps we'll see it one day in the Arboretum's Larz Anderson collection.

Although I'll always love sugar maple, there's something to be said for its sturdy Mediterranean cousin. I think I can make some room in my heart for two very-favorite maples.

Katherine Urban-Mead was a 2014 Isabella Welles Hunnewell Intern at the Arnold Arboretum.

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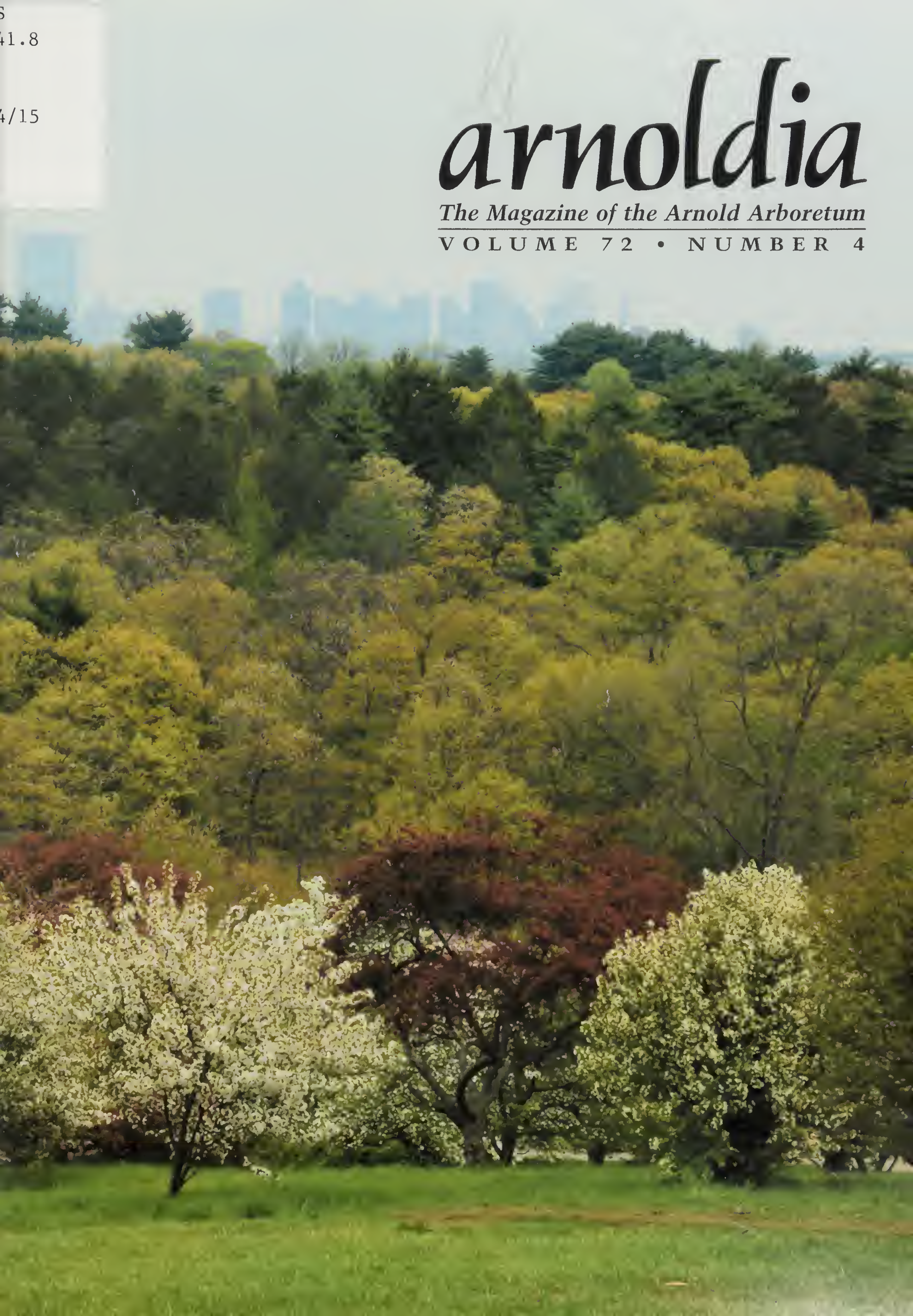

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The ARNOLD ARBORETUM of HARVARD UNIVERSITY

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Front and back covers: After a stunningly cold and snowy winter in Boston, spring's colorful flowers and fresh foliage will be especially welcome. The *Malus* collection on Peters Hill (with Hemlock Hill, the summit of Bussey Hill, and the Boston skyline in the background) is seen in this image from early May, 2008. Photo by Nancy Rose.

Inside front cover: The fragrant flowers of *Magnolia* 'Judy Zuk' (accession 183-2011) were in bloom last year on May 19. This hybrid cultivar has *M. acuminata*, *M. liliiflora*, and *M. stellata* in its parentage. Photo by Kyle Port.

Inside back cover: The pendent panicles of fringed flowers on *Pterostyrax hispidus* lead to its common name, fragrant epaulette tree. Photo by Pamela J. Thompson.

The History of Minimum Temperatures at the Arnold Arboretum: Variation in Time and Space

Michael S. Dosmann

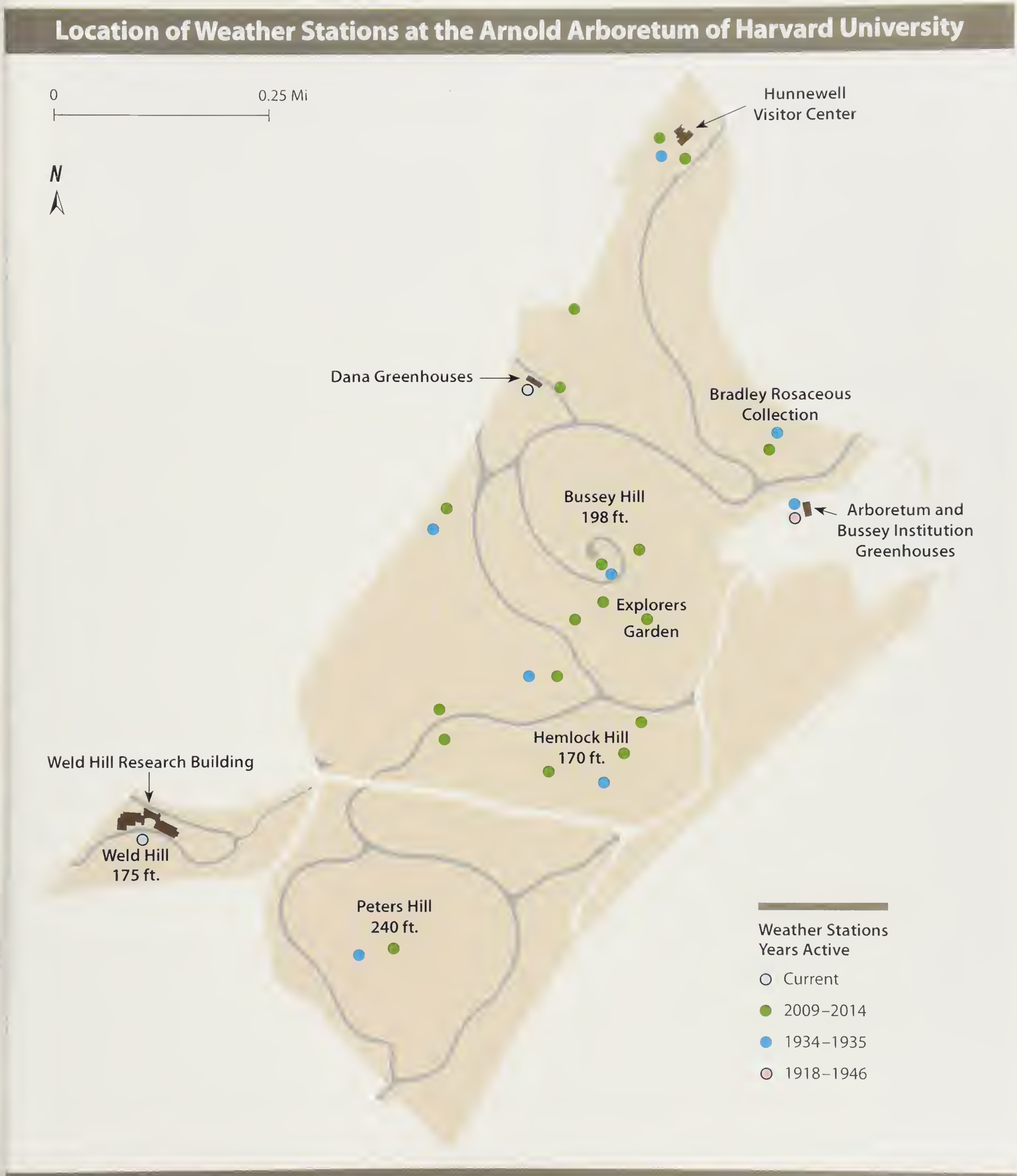
Given the original charge to cultivate "all the trees, shrubs, and herbaceous plants, either indigenous or exotic, which can be raised in the open air," it's not surprising that the Arnold Arboretum has long been interested in documenting local climate and weather, particularly as they relate to plant hardiness. Early publications such as *Garden and Forest* and *Arnoldia*'s predecessor, the *Bulletin of Popular Information,* are replete with notes of what did and did not survive New England's climate. *Arnoldia* continues that theme with annual summaries of the previous year's weather (see page 12 in this issue), often with notes on plant performance.

One of the most innovative projects linking plants and climate was Alfred Rehder's creation of the first Arnold Arboretum Hardiness Zone Map, which was published in the first edition of his *Manual of Cultivated Trees and Shrubs Hardy in North America* (Rehder 1927). On this map, Rehder divided the United States into eight different zones based on the average minimum temperature of the coldest month. Then, using information about what survived the winters in Boston and other regions, he assigned plants in his *Manual* to particular Arnold Arboretum zones of maximum hardiness. This novel application was further updated and improved by the Arnold Arboretum, and later inspired and gave rise to the hardiness zone map (see page 9) created and now perpetuated by the United States Department of Agriculture (USDA). (See Del Tredici 1990 for a broader review, as well as Dosmann and Aiello 2013 for a brief discussion on the 2012 version of the map and its application to plant acquisition and collections planning.) It is important to bear in mind that the zone parameters in the Arnold Arboretum scheme were different from those in the USDA's, thus giving rise to confusion about a species' cold tolerance, particularly when a species was simply said to be "hardy to Zone 6" without further clarification—was it the Arnold's Zone 6 (average annual minimum temperature -5 to 5°F [-20.6 to -15°C]) or the USDA's Zone 6 (-10 to 0°F [-23.3 to -17.8°C])?

The Arnold Arboretum map was last updated in 1971, and the now accepted industry standard, the USDA Plant Hardiness Zone Map, is based on the principle of average annual minimum temperature. Although other climatic factors (e.g., heat, rainfall, wind) certainly affect a plant's ability to survive in a given location, it is the minimum temperature in winter that is a primary driver of plant survival. The Arboretum lies within USDA Hardiness Zone 6. This means that in most winters we can expect a minimum temperature between -10 and 0°F, but it does not mean that temperatures lower than -10°F do not occur.

Just as the Arboretum has been curating plant data for almost 150 years, it has also been gathering and archiving weather data for nearly a century. Starting in 1918, William Judd, Arboretum propagator at the time, began to collect and record weather statistics on a daily basis. He collected these data near the greenhouse, which at the time was located near the former Bussey Institution and what is now the Massachusetts State Laboratory near the Forest Hills train station. Judd diligently recorded the data until his death in 1946, leaving us with a wonderful resource. In 1963, a new weather station was installed at the Dana Greenhouses (which had been constructed the previous year) and the Arboretum began to collect data again in earnest (Fordham 1970). In 2011, a new state-of-the-art weather station was erected at

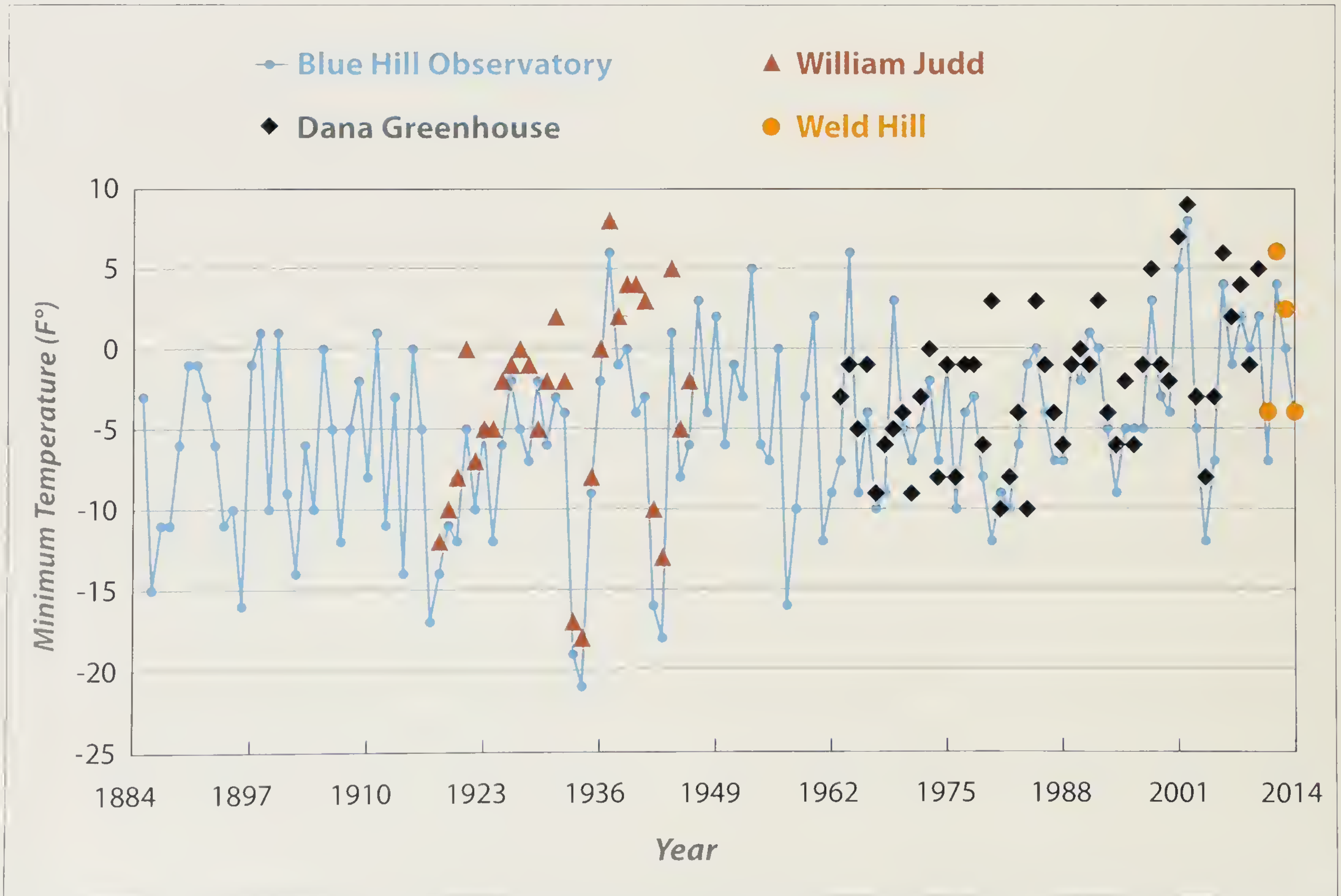
JORDAN WOOD



Over almost a century the Arboretum has acquired temperature data from three permanent stations (William Judd's measurements at the former Arboretum greenhouse [1918–1946]; the Dana Greenhouses; and the Weld Hill Research Building) as well as temporary stations set up by Hugh Raup (1934–1935) and, most recently, data loggers located throughout the grounds (2009–2014).

the Weld Hill Research Building, which, among other attributes, allows digital archiving of data and access via the web.

Although there is a 17-year gap between the end of the Judd period and the beginning of data collection at the Dana Greenhouses, the long-term collection has yielded volumes of information. One notable finding is the dramatic variability over time in the extreme minimum temperature events. The figure below depicts the temperatures from three Arboretum weather stations; I also included the annual minimum temperatures recorded at the Blue Hill Observatory (elevation 635 feet [194 meters]) in Milton, Massachusetts, some 8 miles south of the Arboretum. (Blue Hill Observatory has been collecting weather data since 1885 and is the oldest continuously operating weather observatory in the United States.) At the Arboretum, annual minimum temperatures have, by and large, stayed within the USDA Zone 6 range. However, there have been notable exceptions, including the bitter winters of 1933 and 1934 when Judd noted the thermometer hitting -17 and -18°F (-27.2 and -27.8°C), respectively. These were clearly Zone 5 (-20 to -10°F [-28.9 to -23.3°C]) winters, and the Arboretum documented the death of plants that could not tolerate that extreme. It has been thirty years since the Arboretum experienced a Zone 5 winter, and it was borderline (the Dana Greenhouse thermometer measured -10°F). Since then, annual minimum temperatures have remained in the Zone 6 range, with a number of years experiencing even warmer minimums. Are these due to climate change, or urban heat island effect? Perhaps a combination of both. Do these trends place the Arboretum in a new hardiness zone? I do not believe so. Even if 9 out of 10, or even 19 out of 20 winters never creep below 0°F (i.e., are in the Zone 7 range), all it takes is one Zone 6 winter to elimi-

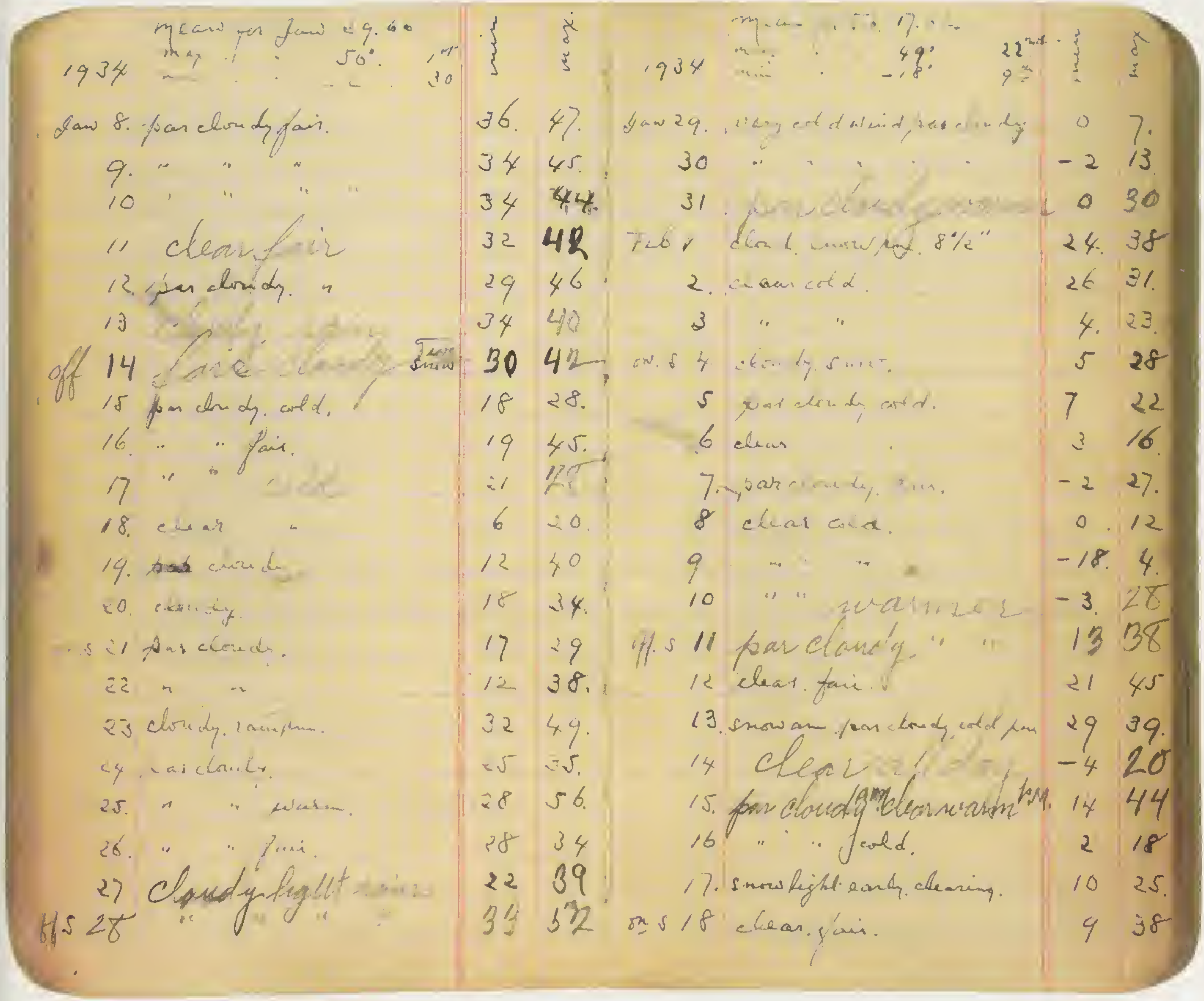


Annual minimum temperatures from the three permanent stations at the Arboretum, plus the annual minimum temperatures recorded since 1885 at the Blue Hill Observatory for comparison.

nate those plants unable to survive at those temperatures. It pays to be conservative when playing the hardiness game.

Location, Location, Location

In examining nearly a century of annual variation in minimum temperature at the Arboretum, one must bear in mind that those data were obtained from three separate and distinct locations, each with its own elevation and proximity to buffering buildings or canopies, as well as differences in aspect. And although we know that the present Weld Hill and Dana Greenhouse stations are sufficiently far away from buildings not to be influenced by them, we are not exactly sure where Judd's station was—it may have been somewhat protected. The Arboretum landscape comprises some 281 acres, with elevations that range from 44 feet (13.4 meters) above sea level in the Meadow by the Hunnewell Building to 240 feet (73.2 meters) on the summit of Peters Hill. Peters, Hemlock, and Bussey Hills each have their own character and microclimates distinct from surrounding areas.



1934			1934		
Jan 8. par cloudy fair.	36	47.	Jan 29. very cold [illegible] par cloudy	0	7.
9. " " "	34	45.	30 "	-2	13
10 " " "	34	44.	31. [illegible]	0	30
11 clear fair	32	42	Feb 1 cloudy snow [illegible] 8½"	24.	38
12. par cloudy. "	29	46	2. clear cold.	26	31.
13 [illegible]	34	40	3 " "	4.	23.
off 14 fair cloudy	30	42	4. cloudy snow.	5	28
15 par cloudy. cold,	18	28.	5 par cloudy cold.	7	22
16. " " fair.	19	45.	6 clear	3	16.
17 " " cold	21	[illegible]	7. par cloudy. [illegible]	-2	27.
18. clear "	6	20.	8 clear cold.	0	12
19. par cloudy	12	40	9 " "	-18.	4.
20. cloudy.	18	34.	10 " " warmer	-3.	28
21 par cloudy.	17	29	11 par cloudy " "	13	38
22 " "	12	38.	12 clear. fair.	21	45
23 cloudy. rain pm.	32	49.	13. snow am. par cloudy, cold pm	29	39.
24. par cloudy.	25	35.	14 clear [illegible]	-4	20
25. " " warm.	28	56.	15. par cloudy am clear warm pm.	14	44
26. " " fair.	28	34	16 " " cold.	2	18
27 cloudy light rain	22	39	17. snow light early clearing.	10	25.
H.S 28 " "	33	52	18 clear. fair.	9	38

William Judd recorded daily weather notes, including maximum and minimum temperatures, from 1918 through 1946. The entry for February 9, 1934, (about half way down on the right) shows an extremely cold reading of -18°F.

ARCHIVES OF THE ARNOLD ARBORETUM

HARVARD FOREST, HARVARD UNIVERSITY

(Above) William Judd, longtime plant propagator at the Arboretum, working on cuttings in the former greenhouse (undated photo, probably from the 1930s).

(Left) Plant ecologist Hugh Raup had a long career at Harvard University, including serving as a research associate at the Arboretum and later as director of Harvard Forest.

These microclimates have been studied in the past, and also more recently. During the winter of 1934–1935, plant ecologist Hugh Raup conducted a study to document variation in minimum temperature, no doubt inspired by the bitter winters in the previous two years. As summarized by Al Fordham (1970), Raup set up eight stations across the Arboretum, with each station comprising a minimum-maximum thermometer. He then visited each station twice a day to record the maximum and minimum temperature that occurred for each site (one station on Peters Hill was stolen a month into the study, leaving us with data from just seven stations).

Even though this experiment lasted for only one winter and did not examine all of the undulations in topography, it confirmed the presence of a range of microclimates. According to Raup's measurements, the coldest temperatures for the winter occurred on January 28, 1935, a calm evening with no cloud cover that led to radiational cooling. During radiational cooling, warm air is lost to the atmosphere and cools. This forms a temperature inversion, where the denser, colder air then settles into the exposed areas at the lower elevations, creating what are often referred to as frost pockets. On this evening, the average minimum temperature of Raup's seven stations was -18.6°F (-28.1°C), yet the range extended from a high of -7.5°F (-21.9°C) near the former greenhouse located at the Bussey Institution (now the site of the Massachusetts State Lab) to a low of -26°F (-32.2°C) in the shrub collection (now the home of the Bradley Rosaceous Collection). The flat area south of the Bussey Hill summit (now called the Explorers Garden) experienced a minimum temperature of -16.9°F (-27.2°C).

Finding Frost Pockets

Not long after I rejoined the Arboretum staff as Curator of Living Collections in 2007, I decided to repeat Raup's experiment using more modern technology and a greater number of stations. The goal was to again identify and confirm frost pockets as well as protected spots that the Arboretum might not be aware of. For instance, the Explorers Garden has long been exploited as a protected site, particularly the area along Chinese Path on the southwestern side where most of the plants in that collection have been grown. During radiational cooling, the dense cold air settles into the valley between Bussey and Hemlock Hills, leaving this area warmer. I was curious to know to what extent other areas of Bussey Hill—perhaps the eastern side—have the same moderating characteristics. This was particularly important to document because the Arboretum is running out of planting space in the crowded Explorers Garden. It would be wonderful to exploit other regions of Bussey Hill as well as other areas of the Arboretum for their moderating characteristics.

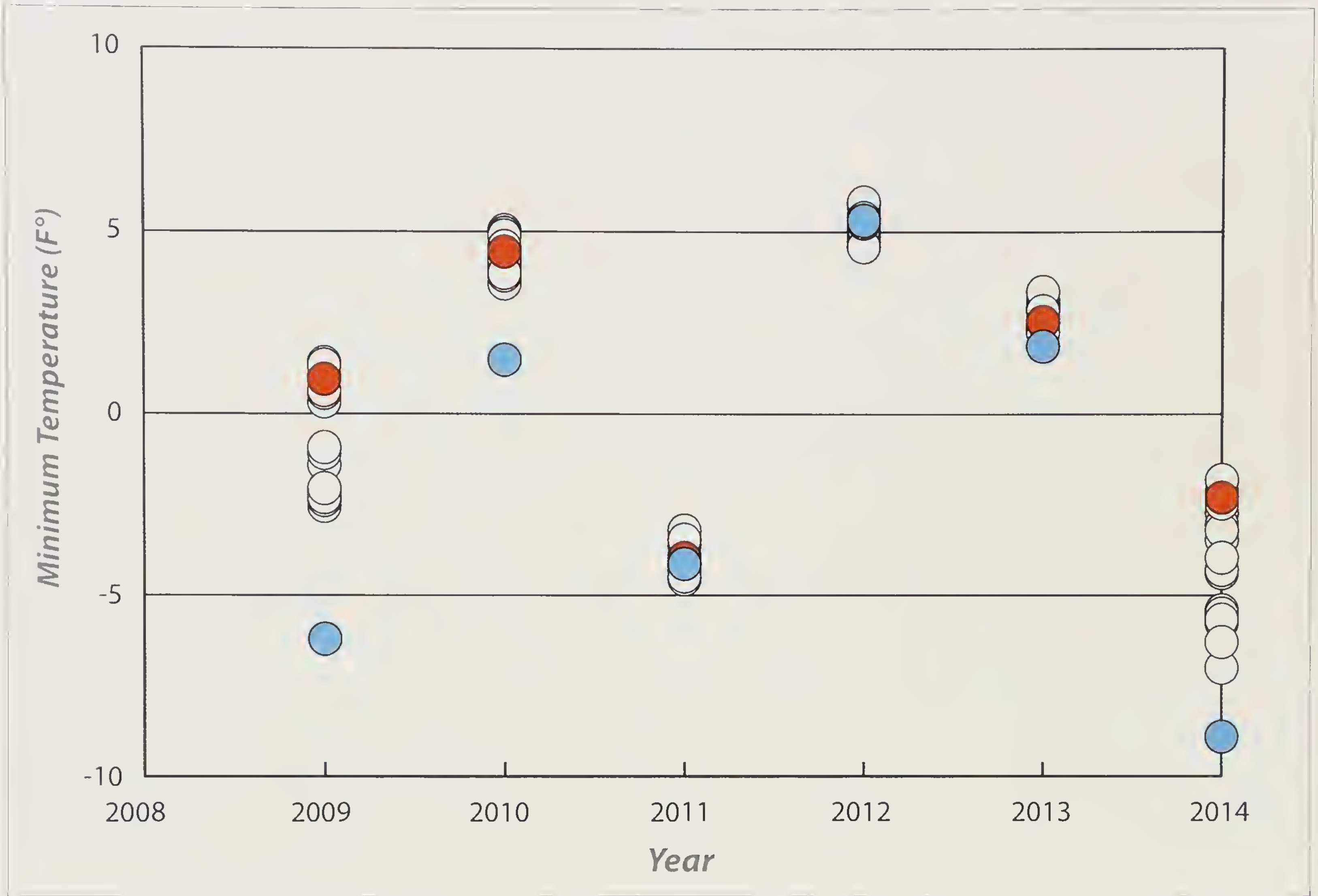
To achieve this task, I purchased some data loggers (Hobo U23 - Pro V2), small micro-meteorological stations that were programmed to record the temperature at 15-minute intervals. Each logger was enclosed in a plastic solar radiation shield, which ensured that the loggers would accurately record the air temperature and not heat up artificially on bright sunny days. The shields also kept out precipitation. The

MICHAEL S. DOSMANN

Curatorial assistant Jonathan Damery checks one of the data loggers that collect weather information throughout the Arboretum.

entire apparatus would normally be mounted to a post or a building just a few feet off the ground. However, I was a bit concerned that the loggers might suffer vandalism, like Raup's Peters Hill thermometer, particularly after many years. Thus we hung the loggers from tree branches about 10 feet (3 meters) from the ground using herbarium press straps and pieces of PVC pipe, effectively keeping the units out of the reach of curious passersby.

The loggers were deployed at 18 separate stations across the landscape (see map on page 3). Most of Raup's station descriptions were sufficient to identify the general area where they were located. New loggers were placed in the general vicinity for seven of Raup's sites; the one at the former Bussey Institution was not used because it is no longer part of the Harvard University enterprise. The remaining 11 stations were chosen for comparative purposes. For example, the station to the south of

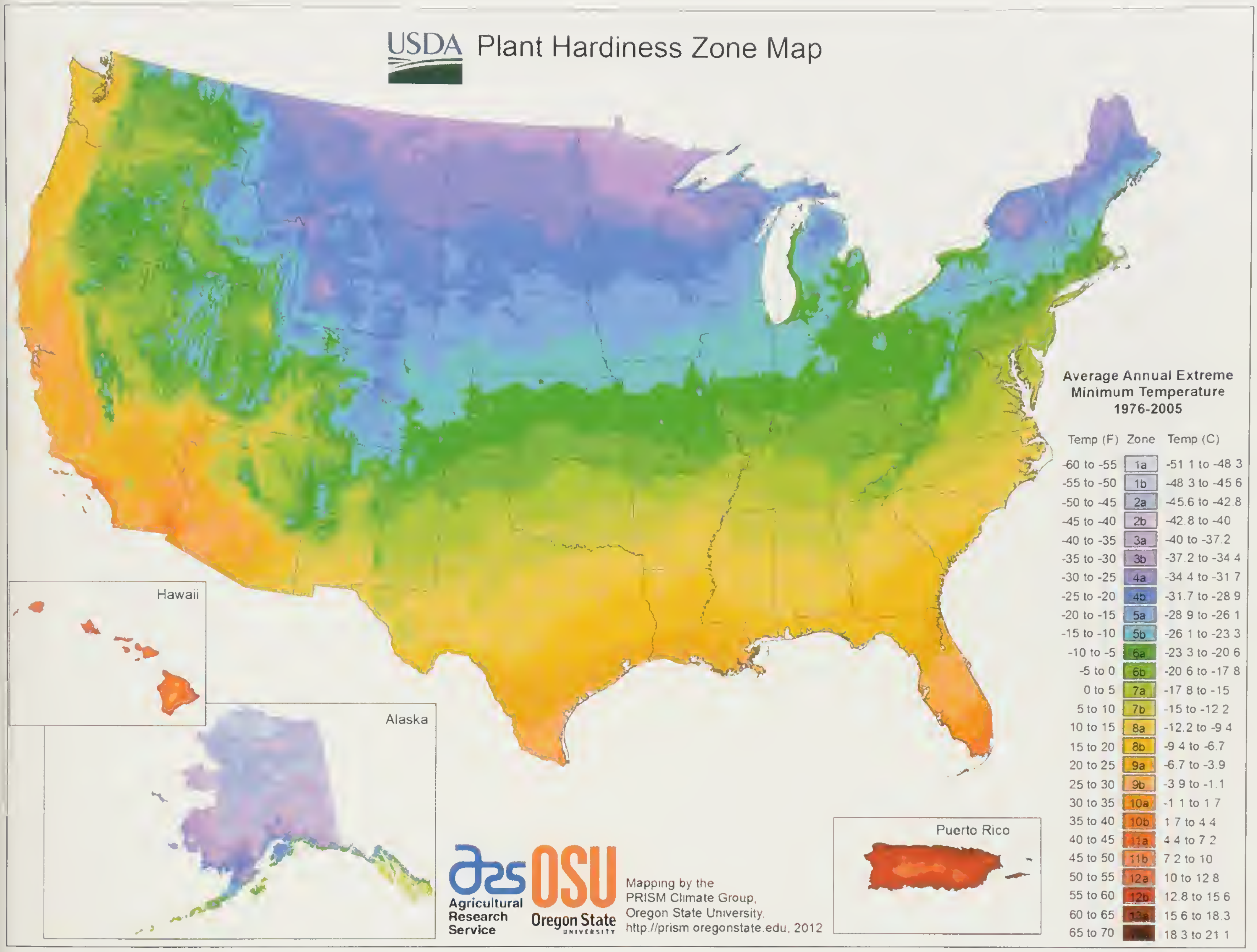


Annual minimum temperatures recorded for the winters of 2008–2009 through 2013–2014 at 18 monitoring stations across the Arboretum landscape. For readability, the individual stations are unlabeled; however, based on the 6-year average, the coldest (Bradley Rosaceous Collection) is shown in blue, and warmest (middle of Hemlock Hill) is shown in red. Cold-weather events of 2009, 2010, and 2014 are indicative of radiational cooling and the development of frost pockets, which led to great variation among stations.

the Hunnewell Visitor Center was paired with one behind the building, to assess the degree to which this site was protected. Raup had only one station on Hemlock Hill, at mid-elevation; we added stations at the summit and the bottom of the hill, in an east-west transect, as well as one in Rhododendron Dell, which lies in the valley between Hemlock and Bussey Hills. And to capture the possible variations in different exposures on Bussey Hill, loggers were placed on its summit and the edges of the Explorers Garden.

Curatorial staff visited each logger in spring to download the data from the previous winter and to provide some routine maintenance. The loggers performed quite well, with just a few anomalies. We are missing data for three separate loggers (one for one year, and two for another) when they stopped recording midway through winter. And on occasion there would be an aberrant spike or drop in temperature, much different from the readings 15 minutes before and after, so each logger's data were reviewed for consistency and the outliers tossed out. What I report upon here is just the minimum temperature recorded for each logger each year.

Although these data only refer to the previous six years and should be interpreted with caution, a few notable and fascinating trends cropped up (see figure above). To begin with, not just is there year-to-year variation in minimum temperature (which is obvious to anyone who has lived in New England!), but notice the variation among stations within a given year. In years 2009 and 2014, the absolute differences between the warmest and coldest stations were respectively 7.6 and 7.1°F (4.2 and 3.9°C)—a considerable spread, one that even spans multiple hardiness zones in 2009. In these events, the Arboretum experienced radiational cooling; the stations at higher elevations and in protected sites were warmer while those in the bottoms



of bowls—the frost pockets—had cold, dense air. Yet in other years, such as 2011–2013, the station minimum temperatures were all clustered together with only minor variation. Those years' coldest events occurred at times with ample cloud cover that prevented heat from escaping to the atmosphere, and perhaps windy conditions that ensured mixing of the air.

And, just where are these microclimates? Consistently, as it was in Raup's time, the Bradley Rosaceous Collection is the dependable frost pocket (note blue dots on page 8 figure). Cold air sinks down from the surrounding hills into this flat, low area. Across all years, the average warmest station was again the one sited on the middle of Hemlock Hill (note red dots on page 8 figure). However, numerous other stations in the Arboretum experienced rather similar temperatures year-in and year-out, and there was always another station warmer than the Hemlock Hill spot, so it is difficult to identify the most buffered microclimate. Other sites with moderated minimum temperatures are those clustered around the Bussey Hill summit and Explorers Garden (demonstrating that there is plenty of space to grow tender material), the area behind the Hunnewell Visitor Center (where we have already started to site a few tender plants), the summit of Peters Hill, the Centre Street beds, and the remaining two Hemlock Hill stations. It is worth noting that even if these stations have average minimum temperatures that place them within Zone 7, *all* stations in the Arboretum experienced Zone 6 minimum temperatures in 2011, as well as in 2014. Besides the Bradley Rosaceous Collection, what other frost pockets exist? The Juniper Collection, Rhododendron Dell, and the open area southwest of the Hunnewell Visitor Center all have average annual minimum temperatures that place them in Zone 6.

Continuing Weather Data Collection

While it is tempting to draw major conclusions on six years of data, I'm not ready to create a new hardiness zone map of the Arboretum landscape just yet! The current USDA Hardiness Zone map relies on 30 years of thorough documentation; its 1990 predecessor used only 13 years of data and was deemed unreliable. So, perhaps after another 20 years of recording temperatures in the landscape, I'll feel more confident in creating such a map. Speaking of the future, we are looking into better technology

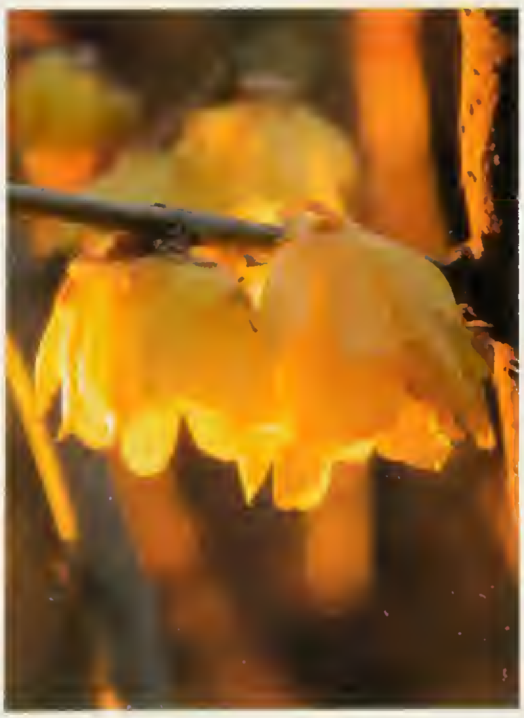
Right Plant, Right Place

The interplay between plant hardiness and microclimates has been well documented at the Arboretum. For example, many of the young cedars-of-Lebanon (*Cedrus libani*) grown from seeds collected in Turkey at the turn of the previous century were sited in a grove on Bussey Hill. Because the plants' hardiness was unknown, planting in this protected site provided some insurance in case the trees failed to survive elsewhere on the grounds. They grew with vigor, and this provenance proved to be fully hardy throughout the Arboretum and even in colder regions of North America. Other successes, like that of *Franklinia alatamaha*, were attributable to both site selection and keen horticultural practice (Del Tredici 2005). Not only was Bussey Hill the sweet spot for cultivation of this rarity, but the Franklin trees were also covered in mulch during the initial winters to ensure survival. Among recent accomplishments, the Arboretum has been able to successfully cultivate wintersweet (*Chimonanthus praecox*), generally known as a solid Zone 7 plant. In 2007, accession 236-98-A was finally planted in the Explorers Garden, and in March of 2010 it produced over a dozen cheerful yellow flowers. In 2012, a milder year, the fragrant flowers started to bloom in the middle of January and lasted for well over a month (for more see Yih 2014).

One thing to note is the difference between a plant's survival and actual performance. The ideal at the Arboretum is not just to grow plants that survive but that are healthy enough to reach mature size, or at least sexual maturity to produce flowers and fruits for study and enjoyment. A great example of this is *Stachyurus praecox*, which requires a favorable microclimate to perform best in New England. Although the species is able to survive—with occasional dieback—throughout the Arboretum, the flowers, which appear in very early spring, are particularly susceptible to low temperature damage. Thus, the plants growing in the Explorers Garden not only survive but consistently produce their unique pendent racemes of flowers.

LEFT TO RIGHT: KYLE PORT, MICHAEL S. DOSMANN, NANCY ROSE

Stachyurus praecox



Chimonanthus praecox

Franklinia alatamaha

ARCHIVES OF THE ARNOLD ARBORETUM

KYLE PORT

The weather station at the Dana Greenhouses, photographed by Arboretum plant propagator Al Fordham in the summer of 1969 (left), and the current state-of-the-art weather station located at the Weld Hill Research Building (right).

for data collection. This season we are experimenting with a new set of loggers. The originals, while excellent in some respects, were nearing the end of their lifespan and required too much additional care; we have retired them. As part of her research, Arboretum Putnam Fellow Ailene Ettinger deployed a new set of loggers across an even wider swath of the landscape. These pendent loggers (Hobo 8K-UA-002-08) are less intrusive in the landscape, easier to access and maintain, and are collecting temperature data at similar intervals.

As I hope this article has demonstrated, a single landscape like the Arboretum's is marvelously variable. The year-to-year variation in elements such as temperature can be quite significant, particularly when compared across the Arboretum's unique nooks and crannies. I not only find this fascinating as a scientist, but as a dedicated horticulturist I am excited that ongoing data collection and analysis will allow us to best match the plants curated in the Arboretum with their optimum locations.

Acknowledgements

The deployment and maintenance of the data loggers and subsequent data wrangling have been no small task, and I wish to call attention to the many who have assisted in the venture over the years. Erik Youngerman, Sue Pfeiffer, Abby Hird, Jonathan Damery, Sam Schmerler, Stephanie Stuber, Joyce Chery, and Kyle Port did a lot of the heavy lifting out in the landscape with the loggers and data. Jordan Wood created the wonderful map integrating the old and new stations. Will Buchanan spent countless hours in the library putting the Raup and Judd data into spreadsheet form. Lastly, Mike Iacono not only provided data from the Blue Hill Observatory but also gave valuable comments on an earlier draft of this article.

References

Aiello, A. S. and M. S. Dosmann. 2007. The Quest for the Hardy Cedar-of-Lebanon. *Arnoldia* 65(1): 26–35.

Del Tredici, P. 1990. The New USDA Plant Hardiness Zone Map. *Arnoldia* 50(3): 16–20.

Del Tredici, P. 2005. Against All Odds: Growing *Franklinia* in Boston. *Arnoldia* 63(4): 2–7.

Dosmann, M. S. and A. S. Aiello. 2013. The Quest for the Hardy Live Oak. *Arnoldia* 70(3): 12–24.

Fordham, A. J. 1970. Climate at the Arnold Arboretum. *Arnoldia* 30(5): 186–193.

Rehder, A. 1927. *Manual of Cultivated Trees and Shrubs hardy in North America*. New York: Macmillan.

Yih, D. 2014. *Chimonanthus praecox*: A Redolence of China. *Arnoldia* 71(3): 36.

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2014 Weather Summary

Sue A. Pfeiffer

KYLE PORT

Horticultural Technologist Dennis Harris worked on clearing Meadow Road while intrepid visitors enjoyed the snowfall on February 5th.

JANUARY started out cold and quite snowy. The first winter storm on the 2nd and 3rd delivered 15 inches of fluffy snow while the temperature dipped to -4°F, which turned out to be the coldest reading for the entire year. Temperatures rose thereafter, melting the snow within days. A front moved in on the 11th, bringing downpours and unseasonably warm temperatures in the 50s that lasted for three days—a welcome surprise. Temperatures remained above freezing over the following week; three additional storms passed through over this period but because of the warm temperatures all precipitation fell as rain. A small storm on the 21st and 22nd left 5 inches of snow on the ground which, despite the mostly cold temperatures, had melted away by the end of the month. Wind speeds reached 16 mph with gusts as high as 38 mph on the 25th; fortunately there was no significant damage to Arboretum plants. Overall, January was cooler than normal and total precipitation was slightly above average.

FEBRUARY began with sunny and warm conditions. A storm passed through on the 4th and 5th dropping a foot of snow, which remained on the ground until mid-March. A cold front arrived following the storm, bringing a week of cold temperatures with highs in the 20s and lows in the teens and single digits. Seasonal temperatures returned on the 13th, and in the following week an additional foot of snow fell. Frigid temperatures returned and we finished out the month with lows in the single digits once again. The cold trend continued and the average high for the month fell four degrees below the historical average.

MARCH brought a continuation of the cold pattern with lows in the single digits during the first week. The first signs of spring were evident on the 8th as temperatures warmed to the mid 50s, greatly melting the snow cover and reducing the icy, hard-crusted remnants of plowed snow. As the snow cover retreated, rabbit damage was visible on many shrubs. Precipitation during the month was scarce; we received two rainfall events on the 12th and 13th and on the 20th, amounting to less than an inch cumulatively. As temperatures warmed, the snow and ice continued to melt; by the 23rd, three days after the spring equinox, bare ground was visible as the snow cover had completely melted. A couple of cold and windy fronts moved in on the 22nd and 26th, both with average wind speeds of 16 mph and gusts reaching 36 mph, making it feel even colder. A storm arrived on the 29th bringing two days of consistent rain followed by a combination of rain, sleet, and hail as the storm lingered into the 31st. Over three inches of rain fell, making up for the lack of precipitation earlier in the month. It felt as if spring was right around the corner as spring ephemerals popped up from the warming soil. Despite rising temperatures, the month as a whole turned out to be colder than the historical average; both the average high and average low temperatures were 5°F colder.

GROWING DEGREE DAYS (GDD) measure heat accumulation and are calculated by subtracting a base temperature (50°F is the standard we use) from the day's average temperature (maximum temperature + minimum temperature, divided by 2). For example, if the day's high temperature was 70°F and the low was 50°F, the average temperature was 60°F, and subtracting the base (50°F) from the average results in 10 GDD. Growing degree days are cumulative (if a day's average temperature is 50°F or below, no GDD accrue). Keeping track of GDD is an important tool for determining the expected emergence of insect pests (for example, gypsy moth eggs hatch when 90 to 100 GDD have accumulated), which allows for well-timed control efforts when needed.

APRIL saw seasonal temperatures with lower than average precipitation. We started the month with temperatures in the high 40s and 50s. A storm arrived and dropped half an inch of rain during the 4th and 5th. Temperatures continued to warm slowly to the high 50s and mid 60s as a second storm passed through on the 8th and 9th, delivering over an inch of rain. Rising temperatures associated with the storm lead to our first accumulation of growing degree days on the 8th. Temperatures continued to rise into the 70s as the third storm of the month arrived. As the storm passed over on the 14th and 15th, strong wind gusts were recorded; a 43.6 mph gust on the 15th proved to be the highest of the year. Rain was followed by sleet and a dusting of snow on the 16th, accumulating over an inch of precipitation. Despite the high winds, there was only minor storm damage to the collection. The latter half of the month saw typical temperature fluctuations and an additional six small storms, accumulating over 3/4 of an inch. The last frost

KYLE PORT

Ninety-six days later: the Lilac Collection on February 7th and May 14th.

date was recorded on April 21st, marking the beginning of the growing season. The month ended with five days of below seasonal temperatures, with highs mostly in the 40s, resulting in frost damage to some early flowering magnolias.

MAY was an average month for both precipitation and temperature. The first storm on May 1st dropped over an inch of rain and was followed by a week of temperatures in the 60s; spring had finally arrived. These temperatures were welcome and necessary for plant development; the effects of the harsh winter were becoming more evident as we waited for buds to break and leaves to emerge. We experienced summer-like conditions over Mother's Day weekend when temperatures soared into the high 80s. Despite these warm conditions, only the early lilacs had started to bloom by Lilac Sunday (May 11th), while the common lilacs were still in bud. Half way through the month, some plants had yet to break bud despite the recent favorable conditions. A second storm passed through on the 16th and 17th, providing nearly an inch of rain. The remainder of the month saw cooler temperatures and typical spring weather fluctuations along with regular precipitation—rain fell on 10 out of the 15 days. A storm on the 27th brought torrential downpours in the evening, depositing 0.41 inches of rain within half an hour. We finished the month with cooler temperatures—May 28th and 29th were so cold that we did not accumulate any growing degree days.

JUNE was somewhat cooler and drier than average. The month started with temperatures in the 80s before a couple of storms passed through on the 4th and 5th, delivering close to an inch of rain combined as temperatures dropped into the 60s. Temperatures warmed again into the 80s until the next storm passed through on the evening of the 10th, again dropping temperatures into the 60s for three days. Warm weather returned through the end of the month with only an additional 2/3 inch of rain. Warm, sunny conditions prevailed through much of the month. The extent of fire blight infection became evident as damage became visible throughout the collection.

Ups and Downs

Significant temperature fluctuations can affect many natural processes, and we saw several examples in May 2014. This was an explosive year for fire blight (*Erwinia amylovora*), a bacterial disease that affects apples (*Malus*), pears (*Pyrus*), and a number of other rose family genera including mountain ash (*Sorbus*), hawthorn (*Crataegus*), firethorn (*Pyracantha*), and flowering quince (*Chaenomeles*). The warmer temperatures experienced early in the month followed by cooler conditions with regular rain provided ideal conditions for fire blight bacteria to spread throughout the collection. We also witnessed a substantial fish kill in Dawson Pond (the largest of our three ponds) over the Memorial Day weekend. This common natural event, observed across the region, was attributed to low oxygen levels in the water caused by temperature fluctuations.

JULY was characterized by heat, humidity, and torrential downpours. We experienced several consecutive days of hot and humid weather, with the hottest day of the year (94°F) on the 3rd. Summer had arrived! This heat was quelled by a downpour on the 3rd that resulted in a few downed tree limbs. Hurricane Arthur arrived on the 4th, delivering a day filled with blowing rain (a total of 2.6 inches fell) and consistent wind. Fortunately there was minimal damage to the collection. A windy system passed through overnight on the 7th, leaving behind some fallen limbs. Temperatures remained seasonal for the remainder of the month. A couple of storms arrived on the 14th and 16th bringing soaking rains; rainfall rates of approximately half an inch of rain over 30-minute periods were recorded during each storm. Thunderstorms returned on the 27th and 28th, the latter pummeling

KYLE PORT

Goldsmith Brook overflowed its banks and flooded the north end of Willow Path during heavy downpours on July 28th.

the earth with over an inch of rain in a 20-minute period and leaving gravel and dirt roads completely washed out and mulch rivers emanating from planting beds. By the end of the month, despite four torrential downpours, two windstorms, and Hurricane Arthur, the Arboretum collection was relatively unscathed, a testament to the resilience of the well-maintained collection.

AUGUST was dry and 2 degrees cooler than average. The first 12 days of the month were quite comfortable with temperatures mostly in the 80s. A system moved through on the 13th, bringing an all-day rain that soaked the ground with 1.35 inches of rain. Temperatures cooled and remained comfortably in the 70s until the 25th. Heat returned for several days as we reached highs in the 90s on the 26th and 27th. Rain continued to be sparse throughout the month and the soil was only moderately moist. A second rainfall was recorded on the 31st, dropping 1/3 inch of rain and adding much-needed moisture to the landscape where plants had begun showing signs of water stress.

SEPTEMBER continued as August ended, the feeling of fall was in the air and rain was nowhere to be found. The month started out very warm as temperatures hit the 90s on three occasions over the first five days before returning to seasonal levels. We received small amounts of precipitation on four occasions throughout the month, none totaling more than 0.15 inches. The weather was perfect for vacations but the plants were suffering from lack of moisture. Additional irrigation was provided throughout the entire month; we had received only 0.39 inches

SUE A. PFEIFFER

High-volume irrigators were used in the collections during what turned out to be the driest September on record.

A garter snake (*Thamnophis sirtalis*), the state reptile of Massachusetts, navigated through fallen leaves in mid-October.

of rain, officially making it the driest September since climate records began. These drought conditions, combined with the low rainfall amounts during late August, translated to accumulations of only 0.83 inches over a six-week period. The effects of this drought were apparent throughout the landscape; soils were extremely dry and the air was very dusty. Two of the Arboretum ponds almost dried up completely. Most plants showed some signs of drought stress and severe stress was obvious on many plants. Leaves were flagging, some turning brown; many plants had already formed their winter buds and appeared to go dormant early. Because of these continued dry conditions, fall planting was postponed until the following spring. Despite all this, fall leaf color on maples (*Acer*), cork trees (*Phellodendron*), and birches (*Betula*) was exceptional throughout the landscape.

OCTOBER was a warm and wet month. We started out with some much-needed precipitation from a storm that passed through on the 1st and 2nd, delivering well over an inch of rain. Sunny skies were prevalent as temperatures remained above average. A warm front moved through mid-month and we hit a high in the 80s on the 15th before temperatures returned to seasonal averages. The first nor'easter of the season arrived on the morning of the 22nd, bringing with it a welcome rain. As the storm intensified overnight, torrential downpours and high winds prevailed; recorded gusts peaked at 41 mph. A microburst (a small but intense downdraft of air) in the Centre Street Gate vicinity resulted in the complete loss of two accessions—a black hickory (*Carya texana*, accession 12892-A) along with a centenarian pin oak (*Quercus palustris*, accession 22896-E) were completely uprooted and broken below the base. Rain continued to fall until the 24th, delivering over three inches of precipitation. Other than the loss of the two large trees and damage to several nearby plants, the impact on the collection was minor with just some smaller branches down. Rain accumulation for the month was more than double that of the months of August and September combined!

NOVEMBER began with a nor'easter on the 1st and 2nd; wind gusts reached 35 mph and we recorded an additional 3/4 of an inch of precipitation equivalence which included a few hours of snow flurries on the 2nd. The snow created a beautiful juxtaposition in the landscape, but this did not last long as temperatures quickly warmed into the 60s. The growing season came to an end on November 10th when the first frost was recorded, ending the growing season at 202 days, the

Arnold Arboretum Weather Station Data • 2014

	Avg. Max. (°F)	Avg. Min. (°F)	Avg. Temp. (°F)	Max. Temp. (°F)	Min. Temp. (°F)	Precipitation (inches)	Snowfall (inches)
JAN	34.5	17.8	26.1	58.8	-4.0	3.98	20.0
FEB	35.5	19.1	27.3	54.4	5.1	3.35	24.0
MAR	41.6	23.3	32.5	58.5	6.9	4.19	
APR	57.0	38.3	47.7	75.2	28.9	3.26	
MAY	68.0	49.0	58.5	85.7	37.8	3.14	
JUN	78.1	56.5	67.3	88.8	44.6	2.51	
JUL	82.6	64.0	73.3	93.5	56.9	6.00	
AUG	79.6	59.1	69.4	90.2	51.0	1.83	
SEP	75.1	54.1	64.6	92.9	37.3	0.39	
OCT	64.0	46.5	55.3	81.4	33.4	5.51	
NOV	49.5	32.2	40.9	66.9	17.6	5.26	1.5
DEC	43.1	30.7	36.9	63.3	12.7	6.97	

Average Maximum Temperature . . . . 59.1°F

Average Minimum Temperature . . . . 40.9°F

Average Temperature . . . . 50.0°F

Total Precipitation . . . . 46.39 inches

Total Snowfall in 2014 . . . . 45.5 inches

Snowfall During Winter 2013–2014 . . . . 57.0 inches

Warmest Temperature . . . . 93.5°F on July 3

Coldest Temperature . . . . -4.0°F on January 4

Strongest Wind Gust . . . . 43.6 mph on April 15

Last Frost Date . . . . 32.0°F on April 21

First Frost Date . . . . 32.0°F on November 10

Growing Season . . . . 202 days

Growing Degree Days . . . . 2815.0 days

SUE A. PFEIFFER

Heavy rain in early December resulted in mulch washouts, especially on slopes like this one in the Lilac Collection.

longest we have seen in over 7 years. Mid-November saw overnight temperatures dip well below freezing; this combined with rain and wind resulted in many trees dropping the remainder of their leaves, bringing an end to fall color. Another significant rainfall was recorded on the 17th, bringing over an inch and a half of rain. The last week of the month was very moist; we received 3 rain/snow events accounting for almost 2 inches of precipitation equivalence. Overall, November was a wet and cool month; average temperatures were 2 degrees below normal and accumulated precipitation exceeded five inches.

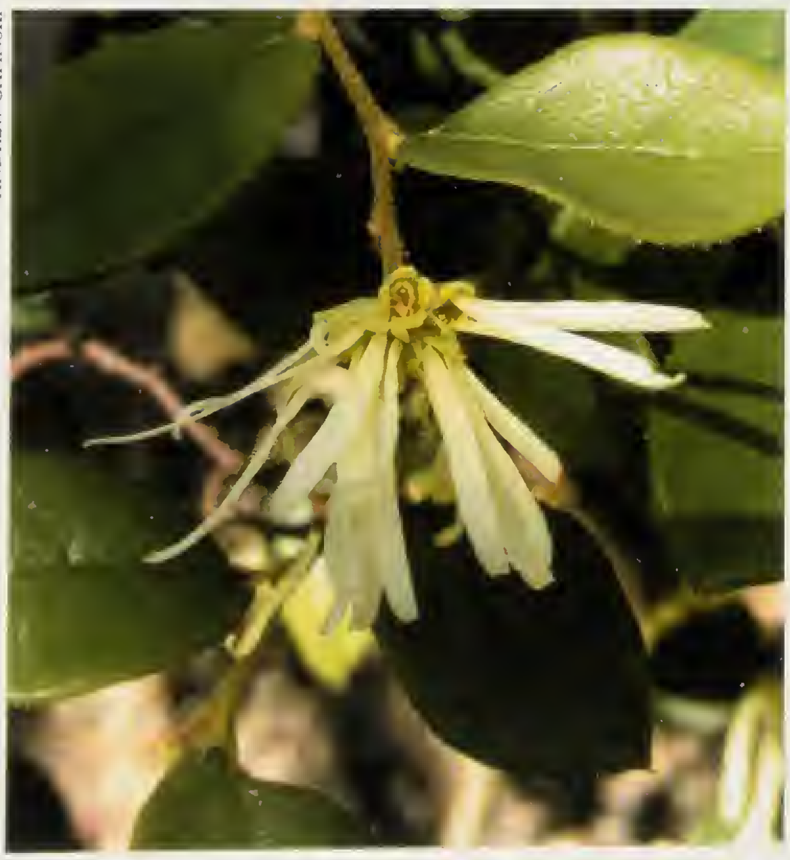
DECEMBER was a very wet and warm month; temperatures were 4 degrees above average and rainfall was abundant for the third month in a row. High temperatures during the first week fluctuated between the mid 30s and lower 60s with three storms depositing a total of almost two inches of rain. The next storm hit on the 9th, bringing wind gusts of over 40 mph and sustained winds at 18 mph—the highest recorded for the year. An additional three inches of rain fell, bringing the 10-day total to more than 5 inches. All of this rain left eroded gullies in gravel pathways and mulch washouts from planting beds, especially those in the lilacs. The rain subsided temporarily and temperatures remained above seasonal averages, allowing the grounds crew to accomplish much pruning and mulching. We recorded four additional rain events before we hit a high in the 60s on the 25th. These temperatures would not last as we ended the year with highs just below freezing. Little did we know what lay in store for the rest of the winter as we moved into 2015.

Sue A. Pfeiffer is an Arboretum Horticulturist at the Arnold Arboretum.

Hamamelidaceae, Part 2: Exploring the Witch-hazel Relatives of the Arnold Arboretum

Andrew Gapinski

In "Hamamelidaceae, Part 1" we looked at just one genus, *Hamamelis,* in the witch-hazel family. In Part 2, we'll study the other representatives of the family that are present in the Arnold Arboretum. It's helpful to start by looking at the evolutionary relationships among the genera in Hamamelidaceae. As mentioned in Part 1, witch-hazel (*Hamamelis*) displays showy flowers, each with four straplike petals. Several other genera within the family also have four-petaled flowers but they are found in warmer regions of the world and are not represented in the Arboretum, except for a lone specimen of *Loropetalum* (see page 26). In the past, these four-petaled genera were thought to be closely related on the family tree but recent DNA work is proving otherwise (Li and Bogle 2001). For example, when looking at the very similar appearing flowers of *Hamamelis* and *Loropetalum* it's easy to think they must be closely related (at one time both were included in the same genus), but in fact they are distant relatives found on separate branches of the family tree. The closest relatives of *Hamamelis* actually include genera such as *Fothergilla, Parrotiopsis,* and *Parrotia* (Li and Bogle 2001). Furthermore, the more advanced genera on each branch of the tree are those that have lost their showy, insect-attracting petals altogether, which is seen as an evolutionary shift from insect to wind pollination (Figure 1) (Li and Del Tredici 2008; Li et al. 1999). Among these aforementioned genera, *Hamamelis* is the oldest in evolutionary terms and is insect pollinated; *Fothergilla* and *Parrotiopsis* appear to represent an intermediate state in the transitional period and likely have both insect and wind pollination; and *Parrotia,* the most advanced, relies mainly on wind for pollination. Similar transitions take place on the other branches of the tree as well. We pick up here with the historical, taxonomic, and horticultural stories of the rest of the witch-hazel family starting with the closest relatives of *Hamamelis.*



ANDREW GAPINSKI

The flowers of *Loropetalum* look very similar to those of *Hamamelis,* but the two genera are not closely related within the witch-hazel family. This is a flower of *L. chinense* on the Arboretum's sole specimen (see page 26).

Fothergilla

> Fothergilla Gardeni[i] was introduced into English gardens one hundred and thirty years ago [1765], and judging by the number of figures that were published of it in Europe toward the end of the last and at the beginning of the present century, it must at that time have been a well-known and favorite inhabitant of gardens from which it has now almost entirely disappeared, in spite of the fact that few shrubs present a more curious and beautiful effect than Fothergilla when it is covered with flowers. Its habit is excellent, too, and its foliage is abundant and rich in color.
>
> C. S. Sargent, *Garden and Forest,* 1895

Beyond the witch-hazels (*Hamamelis*), the genus *Fothergilla* is perhaps the second most recognizable and utilized member of the witch-hazel family among gardeners. It is also the genus most closely related to *Hamamelis*. An exclusively North American genus, *Fothergilla* consists of two species, *F. gardenii* and *F. major*, both of which grow natively in the southeastern United States. Despite the favorable assessment of its ornamental traits by Sargent and others through the years, *Fothergilla* still remains underutilized, though new cultivar introductions as well as recent mentions in trade and popular publications are helping the cause (Darke 2008; Dirr 2009). Like its Ozarks relative, vernal witch-hazel (*Hamamelis vernalis*), the fothergillas carry with them winter hardiness well beyond their native range. They grow successfully at the Arnold Arboretum (USDA Hardiness Zone 6, -10 to 0°F [-23.3 to -17.8°C]) and even colder areas.

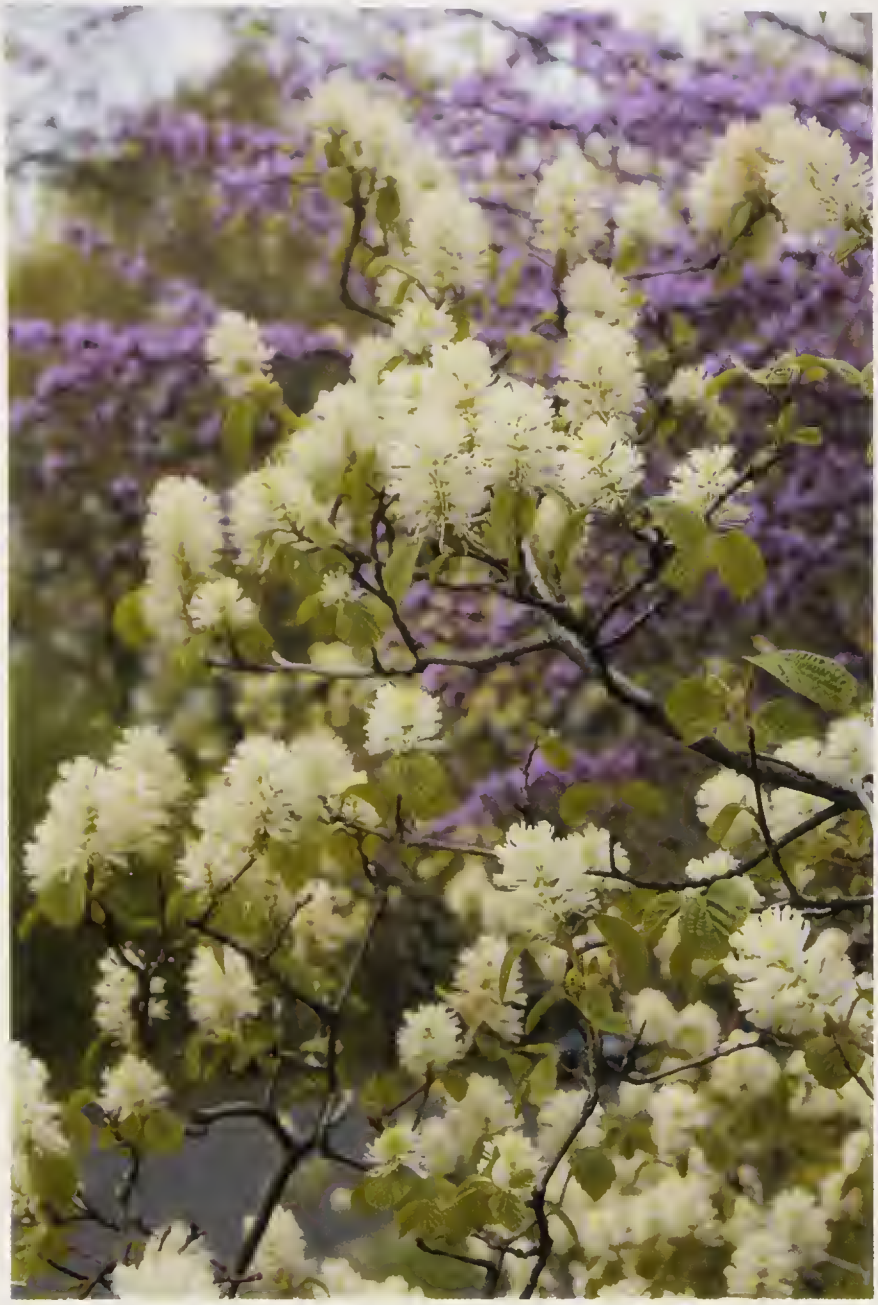
The flowers of *Fothergilla* are apetalous (lack petals) but are far from inconspicuous. The sweetly scented, bottle-brush-like inflorescences—composed of many individual flowers clustered together—appear in May in New England, with full bloom occurring just as the leaves begin to emerge, *F. gardenii* typically slightly ahead of *F. major*. Lacking petals, the species' insect pollinators are attracted to the creamy white coloration of the flowers' enlarged stamens, tipped with yellow, pollen-bearing anthers. The fall foliage color of the genus is second to none. Typically the plant transitions from its clean, dark green to bluish green summer foliage to an array of yellow, orange, and red shades in autumn. Given these attributes, it's surprising that fothergilla isn't more widely planted, though the lack of a catchy and recognizable common name may have limited the marketability of the plant in the nursery industry. Anderson and Judd (1933) note, "Fortunate, indeed, are those plants whose common names are attractive and imaginative ... Lacking such a name, the Fothergillas have made their way slowly into public favor."

Fothergilla gardenii, commonly called dwarf fothergilla, is native to the moist coastal plain from North Carolina to Georgia and also the Florida panhandle along the Gulf Coast. The plant typically grows only 2 to 3 feet (.6 to .9 meters) tall and spreads slowly by underground stems, making it an ideal size for smaller landscapes. Although its native range falls within

(Figure 1) An example of the evolutionary transition from insect pollination (*Hamamelis*) to more advanced wind pollination (*Parrotia*) within the witch-hazel family. The sweetly-scented flowers of Chinese witch-hazel (*Hamamelis mollis*) have showy petals and freely exposed nectaries and stigmas to support insect pollination, while the flowers of Persian parrotia (*Parrotia persica*) are apetalous and have large, elongated anthers common to wind-pollinated species (Endress 1993).

Hamamelis →	*Fothergilla* →	*Parrotiopsis* →	*Parrotia* →
Insect pollination	**Secondary-insect pollination**	**Secondary-insect pollination**	**Mainly wind pollination**
Showy petals	**Lacks petals, but other showy flower parts present**	**Lacks petals, but other showy flower parts present (petal-like bracts appear below the inflorescence)**	**Apetalous, with large anthers and stigmas and powdery pollen**

NANCY ROSE



The bottle-brush-like blooms of large fothergilla (*Fothergilla major*) are sweetly fragrant.

USDA Plant Hardiness Zones 8a to 9a, it can be grown successfully through Zone 5. The Arboretum's most interesting individual of the species, accession 681-88-A, was originally wild collected near Jesup, Georgia, by Harold Epstein, renowned New York plantsman. The specimen was much smaller than typical *F. gardenii*—only 12 to 15 inches tall and with proportionately smaller leaves and flowers. A rooted layer of the plant was sent to the Arboretum for evaluation in 1988, and in 2001, as part of our Plant Introduction, Promotion, and Distribution Program, it was released under the cultivar name *Fothergilla gardenii* 'Harold Epstein' (Bennett 2000). The original diminutive plant we received can still be seen in the Arboretum's Leventritt Shrub and Vine Garden.

Its cousin, *F. major,* commonly called large fothergilla or mountain witch-alder, grows upland from *F. gardenii* in the southern Appalachian Mountains from North Carolina and Tennessee to South Carolina, Georgia, and Alabama. A disjunct population is also found in Arkansas. Growing at higher elevations (and therefore in cooler conditions) and in leaner, drier soils, large fothergilla is hardier (to USDA Zone 4) and less finicky than dwarf fothergilla. Large fothergilla can reach upwards of 10 feet (3 meters) in height, forming a large mass over time. The Arboretum's finest specimen (694-34-A), accessioned in 1934, was found as a seedling growing at the base of the parent plant in the Arboretum. It was ultimately transplanted to a spot near the main gate along the Arborway, where it thrives today for all to enjoy. The 10- by 10-foot plant is consistently engulfed with blooms in the spring and displays magnificent fall color. Wild-collected representatives of the species can be found in the Leventritt Shrub and Vine Garden and on the summit of Bussey Hill and in the Explorers Garden.

Increasing interest in finding reliable native plants for home landscapes has boosted the popularity of fothergilla in recent years (Darke 2008). Another factor in raising fothergilla's profile is the recent introduction of new cultivars, particularly those that we now know are the result of hybridization between *F. major* and *F. gardenii.* In the Arboretum's propagation records, the earliest determination of a hybrid between the species is from 1980, made by Richard Weaver, the Arboretum's horticultural taxonomist and assistant curator at the time. As a graduate student at Duke University, Weaver had helped to settle the long-standing debate over the number of *Fothergilla* taxa (some authors had cited as many as four) by counting chromosome numbers and comparing morphological features of the species (Weaver 1969). Some of the samples he used for comparisons were from the Arboretum, and in his subsequent years working here Weaver continued his interest in *Fothergilla* and the rest of Hamamelidaceae (Weaver 1976; Weaver 1981).

The plants noted in 1980 as "*Fothergilla* hybrid—*F. major* × *F. gardenii*" were seedlings from a 1967 accession (709-67) received as open-

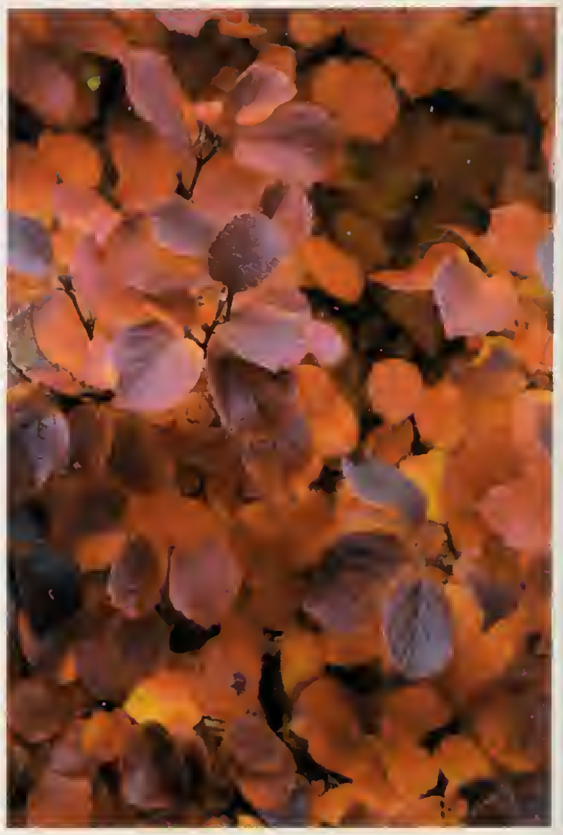
This splendid specimen of *Fothergilla major* (694-34-A) grows near the Arboretum's main gate.

pollinated *Fothergilla gardenii* seed from the Botanical Gardens of Villa Taranto in northern Italy. Several individuals appeared distinct from the others, leading to the hybrid notation. Later entries (1983) noted that in fact "Dr. Weaver counted chromosomes" to determine that the plants were hybrids between *gardenii* and *major.* Although no formal publication of the hybrid was made, Michael Dirr, following a year-long fellowship at the Arnold, notes in the 1983 revision of his *Manual of Woody Landscape Plants* that "The Arnold Arboretum has identified a hybrid between the two species which offers intermediate size and other characteristics. This could be a most valuable shrub for modern landscapes." Dirr's manual, well known for its cultivar descriptions, listed no cultivars for *Fothergilla* at the time—a testament to the lack of horticultural attention the genus had received (Dirr 1983).

Around the same time, selections of fothergilla noted for improved ornamental traits and adaptability began to enter the nursery trade, most identified as *F. gardenii* cultivars (Darke 2008). 'Mt. Airy', a 1988 Michael Dirr selection from a plant growing in Cincinnati's Mt. Airy Arboretum, was one of the first named fothergilla cultivars and is still perhaps the best known and most widely planted. The true identity of 'Mt. Airy' and other cultivars as either *gardenii* or *major* was certainly confusing, and in many cases the species names were used interchangeably in the horticulture industry. Research by Ranney and others (2007) finally determined, through cytometry, that the majority of cultivars available today, including 'Mt. Airy', are in fact hybrids between *gardenii* and *major.*

The hybrid was officially described and named *Fothergilla* × *intermedia* (Ranney et al. 2007).

JON HETMAN



The hybrid fothergilla cultivar 'Mt. Airy' has notable displays of spring flowers and bright fall color.

The increasing success of fothergilla in cultivation can be attributed to the hybrid's adaptability and hardiness—gained from *F. major*—and the landscape-friendly intermediate size, typically 4 to 5 feet (1.2 to 1.5 meters) tall. Within the Arboretum collections, fine specimens of *Fothergilla × intermedia* 'Mt. Airy' grow in the Leventritt Shrub and Vine Garden (429-2002- B and -D), along with several accessions near the summit of Bussey Hill.

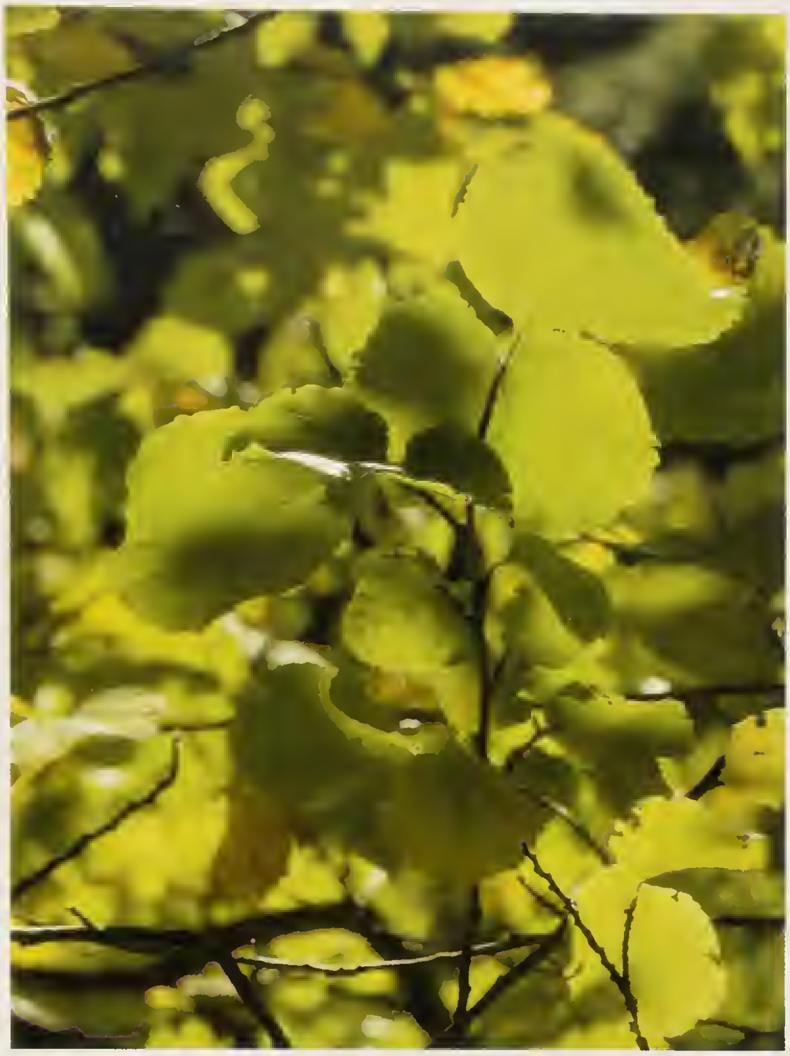
Ancestors from the Persian Empire

> Parrotia Jacquemontiana. – This is now flowering for the first time in the arboretum at Kew. It differs from Parrotia Persica in having smaller flowers arranged in a conical head and surrounded by ovate petaloid whitish bracts nearly an inch long. The flowers are developed before the young leaves. When mature, the leaves are orbicular or obovate, distinctly toothed all around the edges, dull green, and they do not assume the bright colors in autumn so characteristic of Persian species. The former is a native of Kashmir at an elevation of from 5,000 to 9,000 feet, where it forms a Hazel-like bush, six to twelve feet high. Dr. Aitchison [Scottish surgeon and botanist known for his plant collecting in India and Afghanistan in the late 1800s] found it in abundance in Afghanistan in the interior of the hills, forming much of the shrub jungle there. He says the long slender stems and pliant branches are used in wicker-work and for the handles of farm implements. As a garden plant it is not as valuable as P. Persica, which at Kew forms a beautiful shrub or small tree, bearing large glossy leaves all summer, which in autumn change to the richest hues of orange, red, brown and yellow.
>
> C. S. Sargent, *Garden and Forest: Foreign Correspondence. London Letter.* 1896

The monotypic genus *Parrotiopsis,* containing only *P. jacquemontiana,* as it is known today, is the topic of Sargent's writing above. Originally named *Fothergilla involucrata* without being formally described, the species would later be reclassified as *Parrotia jacquemontiana.* In 1905, the plant was placed in its very own genus as *Parrotiopsis involucrata* because its floral characteristics were found to be distinct from both *Fothergilla* and *Parrotia.* Alfred Rehder, Arboretum taxonomist, revised the specific epithet to *jacquemontiana* in 1920. Splitting hairs, he justified the name change because *F. involucrata,* as it was originally called, was never published with a description and thus the specific epithet *involucrata* was invalid and "cannot stand" (Rehder 1920).

An illustration of *Parrotiopsis jacquemontiana* (known then as *Parrotia jacquemontiana*) from an issue of *Curtis's Botanical Magazine* published in 1896.

KYLE PORT



Foliage of a *Parrotiopsis jacquemontiana* specimen (656-75-A) growing at the Arboretum.

The taxonomists of the day were certainly not far off in their placement of *Parrotiopsis* with *Fothergilla* and then *Parrotia.* They are closely related on the family tree, with *Parrotiopsis* serving as the transitional link between the two other genera (Li and Bogle 2001). The most conspicuous difference in *Parrotiopsis* is the white floral bracts (modified leaves) that surround the conical cluster of flowers, which are apetalous but feature enlarged yellowish stamens, as is the case with both *Fothergilla* and *Parrotia.* These bracts are similar in function and appearance to those of flowering dogwood (*Cornus florida*), serving as a device to attract insect pollinators. The species is abundant in the northwestern Himalayan Mountains of India, Pakistan, and Afghanistan at elevations up to 9,000 feet (2,743 meters).

The Arboretum's best specimen of *Parrotiopsis jacquemontiana* (656-75-A) is located under the shade of the hickory (*Carya*) collection just off of Valley Road. Although a fascinating plant with modest horticultural merit as a large multi-stemmed shrub or small tree, it is rare in cultivation but certainly deserving of a place in any plant collector's garden.

Its cousin, *Parrotia persica,* known as Persian parrotia or Persian ironwood, occurs on the mountain slopes of Iran at the southern end of the Caspian Sea. Unlike *Parrotiopsis, Parrotia persica* offers undoubtable ornamental value and environmental adaptability. An upright, often multi-trunked small tree, it is notable for its attractive foliage that develops excellent fall color and its multi-colored, jigsaw-puzzle-like bark (see Nicholson 1989 for more on the species). The oldest and largest specimen of *Parrotia persica* (2230-A) at the Arnold Arboretum

A Lone *Loropetalum*

Chinese fringe-flower (*Loropetalum chinense*) is a shrub in the witch-hazel family that is commonly featured in southern landscapes (USDA Zones 7 to 9) but is not hardy outdoors at the Arboretum (USDA Zone 6). However, we do have a handsome penjing (the Chinese predecessor of Japanese bonsai) specimen of this species (accession 200-90) that is kept in a cool greenhouse over winter before moving to the dwarf potted plant pavilion for the warmer months.

ANDREW GAPINSKI

Views of the multi-trunked form and bark detail of *Parrotia persica* (2230-A), which was received in 1881 as a cutting from the Harvard Botanical Garden in Cambridge, Massachusetts.

MICHAEL DOSMANN

This handsome specimen of Persian parrotia was received as cultivar 'Pendula' (accession 629-87-A), though it has a spreading rather than weeping habit.

ANDREW GAPINSKI

This specimen of *Parrotia subaequalis* (accession 304-2004-A) developed outstanding fall color in 2014.

(and possibly all of North America) grows in the Centre Street Beds adjacent to the hickories.

A second species of *Parrotia, P. subaequalis,* has recently been uncovered. The plant was originally described in 1960 as *Hamamelis subaequalis,* then in 1992 was placed within a newly proposed genus as *Shaniodendron subaequale.* After DNA analysis showed that *S. subaequale* was actually a sibling species of *Parrotia persica,* the plant was once again renamed in 1998 as *Parrotia subaequalis.* Critically endangered in the wild, only a handful of populations are known to exist in eastern China. The Arboretum has several specimens growing in the collections, the finest of which (304-2004-A) grows in the shade of mature white pines in the Explorers Garden. Although it has yet to show the exfoliating bark for which *Parrotia* are known, last fall the specimen developed outstanding orange, red, and purple foliage coloration, certainly among the most spectacular plants at the Arboretum that season.

Chinese Wilson

> The genus *Sinowilsonia* is named in compliment to Mr. E. H. Wilson, whose excellent collections have thrown light on many doubtful points connected with Chinese plants.
>
> W. Botting Hemsley, *Hooker's Icones Plantarum,* 1906

The genus *Sinowilsonia* consists of a single species, *S. henryi,* named after the plant explorers Augustine Henry and E. H. Wilson who collected the herbarium specimens from which the species was described; Wilson also first introduced the species into cultivation in 1908 as part of his first expedition for the Arnold Arboretum. *Sinowilsonia* specifically refers to Wilson—the term *sino* refers to China, and he was nicknamed "Chinese" Wilson among his peers in the botanical world.

While of botanical and historical interest, *Sinowilsonia* offers little in the way of ornamental value. Apetalous male and female flowers are borne on separate catkin-like structures (similar to birch) and rely on wind for polli-

JAN DE LAET, WWW.PLANTSYSTEMATICS.ORG

Flowers of *Sinowilsonia henryi.*

This *Sinowilsonia henryi* growing at Planting Fields Arboretum is linked to the original introduction of the species into cultivation. A sapling propagated from the original tree—intended to take the place of its parent one day—can be seen growing nearby.

Foliage of a *Sinowilsonia henryi* specimen (156-99-A) that was propagated from the large tree at Planting Fields Arboretum on Long Island, New York.

nation. Similar in form to witch-hazel, the species is a large shrub or multi-stemmed small tree. From his collection notes, Wilson observed that the species was, "Common in the sheltered valleys and ravines of north-western Hupeh, very rare elsewhere in the province and unreported from western Szech'uan [Sichuan]. It is very partial to the sides of mountain-streams where it forms a large bush or bushy tree, and in general appearance resembles a witch-hazel" (Wilson and Sargent 1913). Today we know the species' range to be throughout central China, but it is threatened, like many species, by habitat degradation.

The Wilson collections of *Sinowilsonia* in 1908 grew in various locations throughout the Arboretum until the devastatingly cold winter of 1933–1934, in which dozens of taxa, including all the *Sinowilsonia*, were outright killed and many more plants died back to the ground (Faull et al. 1934). Fortunately, material from the Wilson collection had been distributed to other gardens, though it is unclear how many plants from this original collection remain in cultivation today. A truly grand specimen of *Sinowilsonia*—possibly the finest in North America—grows at Planting Fields Arboretum State Historic Park, Long Island, New York. It originated from material shared by the Arnold Arboretum and undoubtedly represents the lineage of the original Wilson introduction. Propagules from this now 40- by 50-foot multi-stemmed tree have been obtained on several occasions to reestablish the Wilson pedigree here; one such specimen (156-99-A) currently grows on the edges of the hickory collection. Our best representative of the species (1970-80-A) grew from the only seed to germinate from a seed lot acquired during the 1980 Sino-American Botanical Expedition (Spongberg 1991). Today, it thrives in its permanent location on the edge of a gentle slope adjacent to the east nursery at the Dana Greenhouses.

At the same time of Wilson's expedition to introduce *Sinowilsonia* to the cultivated world, he discovered a plant that Augustine Henry overlooked in his travels in Hubei 20 years prior:

> Ichang [Yichang]
>
> June 28, 1907
>
> Dear Professor Sargent,
>
> ... I am enclosing a fragment of what is to me perhaps the most interesting plant, together with a similar fragment of *Sinowilsonia* for comparison. The new plant may be any one of these things ... a new genus; a new species of the *Sinowilsonia*; the male form of *S. henryi*, allowing that the latter plant is sexually dioecious ... If I can only secure fruits of both, the point can be easily settled. Unfortunately, the new plant is very rare, occurring only in oak woods ...
>
> Believe me, Dear Professor Sargent
>
> Faithfully and obediently yours,
>
> E. H. Wilson

Returning to the location that autumn to prospect for seeds, Wilson again wrote to Sargent:

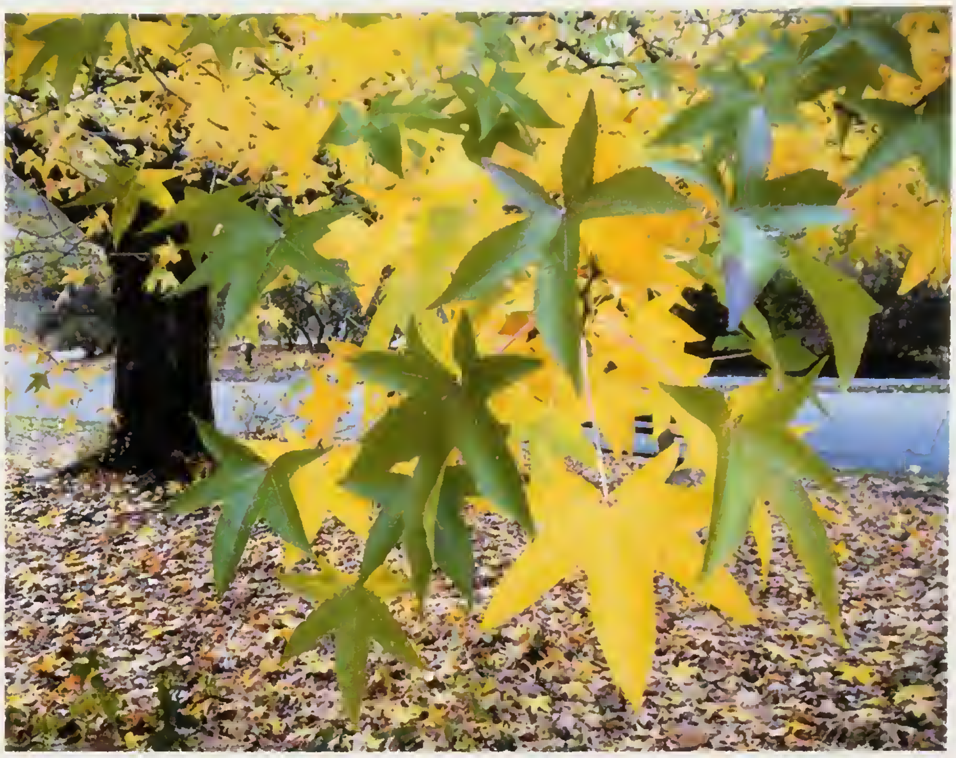
> Ichang [Yichang]
>
> November 30, 1907
>
> Dear Professor Sargent,
>
> ... Some time ago I wrote you about (and forwarded a fragment of) what I thought was either the male form of *Sinowilsonia henryi* or a new species. I have now secured ripe fruits and seeds of both plants and these conclusively prove the latter view to be correct. The species are very distinct in every way, so much so in fact that some doubtless will be inclined to regard them as constituting distinct genera. I am particularly delighted over this find and only hope you succeed in raising plants ...
>
> I am, dear Professor,
>
> Faithfully and obediently yours,
>
> E. H. Wilson

At the conclusion of his first expedition to China for the Arboretum in 1907–1908, Wilson returned to Boston, accepting an offer from Sargent to supervise the investigation in the Arboretum's herbarium of the plant vouchers he had collected. Working alongside Alfred Rehder, the pair described several new species from Wilson's collections. The vouchers Wilson mentioned in his correspondence with Sargent were cited when Wilson and Rehder introduced a new genus, *Fortunearia*, to the botanical world:

> This new Chinese genus is named for the late Robert Fortune whose travels in China and Japan, from 1843–1861 resulted in important additions to our knowledge of the far eastern, and particularly the Chinese flora and enriched our garden with a large number of highly ornamental plants ... *Fortunearia* closely resembles in foliage and habit *Sinowilsonia*, which differs chiefly in its tubular calyx-tube several times longer than the ovary and enclosing it, by the absence of petals, the larger spatulate sepals, sessile flowers and the flat cotyledons ...
>
> *Plantae Wilsonianae* Volume 1, 1913

As Wilson noted, *Fortunearia* differs from *Sinowilsonia* in its reproductive structures. The two species are close cousins on the family tree and again the evolutionary transition from

What About Sweetgum?



ANDREW GAPINSKI

The sweetgums (*Liquidambar* spp.) have traditionally been included in Hamamelidaceae, forming the subfamily Altingioideae along with two other genera, *Altingia* and *Semiliquidambar*. However, the members of Altingioideae have enough morphological differences from the rest of Hamamelidaceae that some taxonomists through the years have suggested that the group be elevated to their own separate family, Altingiaceae. Recent research at the molecular level supports this separate family, and some (though not all) taxonomic references now list sweetgums under Altingiaceae rather than Hamamelidaceae. The Arboretum has accessions of three *Liquidambar* species in the collection: *L. styraciflua* from North America, and *L. acalycina* and *L. formosana*, both from China. This large specimen of *L. styraciflua* (135-38-B) grows near the juncture of Bussey Hill Road and Valley Road.

petals to no petals is apparent. A few accessions of *Fortunearia sinensis* do exist in the Arboretum, most notably a pair growing in the Explorers Garden under the shade of a large Canadian hemlock (*Tsuga canadensis*) just up the slope from Oak Path. These specimens were received as wild collected seed in 1980 from the Chinese Academy of Forestry. No plants collected directly through Arboretum expeditions currently exist on the grounds; seedlings from Wilson's original collection survived only a few years in cultivation. Seeds were also collected on the 1994 NACPEC expedition, but no plants resulted. This is another example of an extremely rare plant in cultivation, given its modest ornamental interest.

KYLE PORT

Foliage and warty developing seed capsules of an Arboretum specimen of *Fortunearia sinensis* (580-79-B) grown from seeds received from the Nanjing Botanical Garden.

Herbarium voucher in flower collected May 25, 1907, in Fang Hsien, Hubei, China, by E. H. Wilson, who considered it a possible new species at the time of collection. It would later be named *Fortunearia sinensis* by Wilson and Rehder.

KYLE PORT

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NANCY ROSE

(Clockwise from top left) The bonsai specimen of *Corylopsis spicata* was in bloom in mid-April last year.

A raceme of pale yellow flowers dangles from a branch of *Corylopsis sinensis* var. *calvescens* in the Explorers Garden.

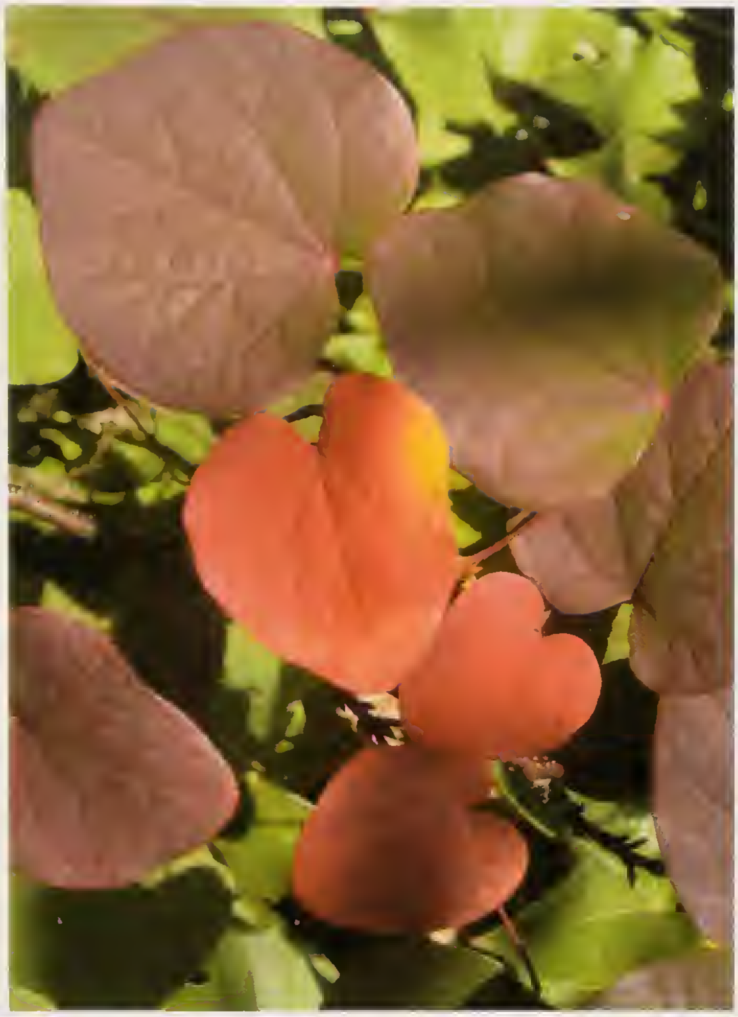
A specimen of *Corylopsis glabrescens* 'Longwood Chimes' (159-99) in full bloom in the Leventritt Shrub and Vine Garden.

Winter-hazel

Corylopsis. All the species of this genus of shrubs of the Witch Hazel Family cultivated in the Arboretum have survived the winter with little or no loss of wood, but the flower-buds of the Chinese C. Veitchiana and C. Willmottae, and of the Japanese C. pauciflora and C. spicata have been killed by the cold, and the only species which has flowered is C. Gotoana of the elevated region of central Japan. This is evidently the hardiest of the plants of this genus, and as it has now flowered in the Arboretum every spring for several years there is good reason to hope that we have here an important shrub for the decoration of northern gardens. The flowers are produced in drooping spikes and open before the leaves appear, as in the other species, and are of a delicate canary-yellow color and pleasantly fragrant.

Arnold Arboretum, *Bulletin of Popular Information*, May 4, 1918

In the early to mid-1900s, the status of the winter-hazels (*Corylopsis*) was a topic of interest in Arboretum publications each spring. As noted above, the most reliably flower hardy species has been *C. gotoana*, which some taxonomic references now group with another Japanese montane species, *C. glabrescens*, under the latter name. There is still much debate about the most appropriate treatment of the *Corylopsis*


MICHAEL DOSMANN

A Missing Gem

Disanthus cercidifolius **is a witch-hazel family member that is, unfortunately, missing from the Arboretum collection. This large shrub from China and Japan is noted for its attractive heart-shaped leaves; the specific name *cercidifolius* alludes to their resemblance to the leaves of *Cercis*, the redbuds. Like several of its relatives in Hamamelidaceae, *Disanthus* has excellent fall foliage color featuring rich shades of red and purple.**

The Arboretum has accessioned this species a number of times but we currently have no living specimens. Some seed accessions had poor or no germination, and unfavorable climate or site conditions may be responsible for other failures. Arboretum Curator of Living Collections Michael Dosmann reports that *Disanthus cercidifolius* is high on his "wanted" list, and future accessions will be carefully sited to provide the fertile, moist, well-drained soil, partial shade, and wind protection that this plant prefers.

taxa. Some references have listed upwards of 30 taxa, though most research today groups many of these together into around ten species. E. H. Wilson even proclaimed his confusion with the genus in field correspondence with Sargent from China dated August 17, 1907: "Corylopsis are exceedingly common shrubs and extremely variable in foliage and degree of hairiness. At present I am undecided as to whether one, two or three species occur ..."

All of the species are similar in appearance, growing as multi-stemmed, broad-spreading shrubs of varying size. Of particular ornamental value are the early spring flowers—fragrant, bell-shaped, pale yellow to greenish yellow, and borne in pendulous racemes. Fall foliage color is a rather muted greenish yellow, unimpressive compared with many other family members. There are reports of better fall color farther south; possibly the leaves fall prematurely in colder northern regions.

Corylopsis glabrescens (*C. gotoana*), reportedly the hardiest species and the most well suited for New England gardens, was first introduced into cultivation by Arboretum dendrologist John George Jack. He sent seeds back to the Arboretum from Japan in 1905, the year he spent touring Northern China, Korea, and Japan as only the second Arboretum staff member (after Sargent) to visit Asia. Another Arboretum connection to the genus came when Wilson and Rehder named several new *Corylopsis* taxa from the herbarium vouchers Wilson brought back from his early expeditions for the Arboretum. Although some of these *Corylopsis* have now been lumped together with other taxa, I think Wilson would be pleased to hear that the topic continues to confuse taxonomists even today!

The greatest concentrations of winter-hazel in the Arboretum can be found adjacent to the hickories in the area known as the Centre

Street Beds and in the Explorers Garden near the summit of Bussey Hill—a visit to these areas in early spring is certainly worth the trip. A bonsai specimen of *Corylopsis spicata* can also be seen in the dwarf potted plant pavilion adjacent to the Leventritt Shrub and Vine Garden.

A Family Worth Knowing

The witch-hazel family contains a relatively small number of species (around 100), yet the group is tremendously diverse. Its members are botanically fascinating and carry with them a remarkable history of exploration and discovery. From witch-hazel to winter-hazel, *Fothergilla* to *Parrotia*, they are among the most charming of garden plants. Although much work has been done to increase the utility of the family members in our landscapes, their presence remains understated. In New England and many other regions, the plants of Hamamelidaceae fill our gardens with beauty, even in the depths of winter. As has been stated before, there is a tree or shrub in bloom every month of the year in the Arnold Arboretum—a phenomenon only possible because of the witch-hazel family.

References

Anderson, E. and W. H. Judd. 1933. Fothergilla major. *Bulletin of Popular Information.* ser. 4. vol. 1, no. 12.

Arnold Arboretum. 1918. Effects of the severe winter. *Bulletin of Popular Information.* vol. 4 no. 1.

Bennett, E. S. (ed.). 2000. 2001 PIPD releases, in Arnold Arboretum News. *Arnoldia* 60(4).

Darke, R. 2008. Fothergilla in cultivation. *The Plantsman.* 7(1): 10–17.

Dirr, M. A. 2009. *Manual of woody landscape plants.* Champaign, IL: Stipes Publishing.

Dirr, M. A. 1983. *Manual of woody landscape plants.* Champaign, IL: Stipes Publishing.

Endress, P. K. 1993. Hamamelidaceae. In: K. Kubitzki, J. G. Rohwer, and V. Bittrich (eds.), *The families and genera of vascular plants,* vol. 2, page 324. Berlin-Heidelberg-New York: Springer-Verlag.

Faull, J. H., J. G. Jack, W. H. Judd, L. V. Schmitt. 1934. Winter hardiness of trees and shrubs growing in the Arnold Arboretum. *Bulletin of Popular Information.* ser. 4. vol. 2, no. 7: 29–36.

Hemsley, W. B. 1906. *Sinowilsonia henryi,* Hemsl. *Hooker's Icones Plantarum* 29: t. 2817.

Li, J. and A. L. Bogle. 2001. A new suprageneric classification system of the Hamamelidoideae based on morphology and sequences of nuclear and chloroplast DNA. *Harvard Papers in Botany* 5: 499–515.

Li, J., A. L. Bogle, and A. S. Klein. 1999. Phylogenetic relationships of the Hamamelidaceae inferred from sequences of internal transcribed spacers (ITS) of nuclear ribosomal DNA. *American Journal of Botany* 86: 1027–1037.

Li, J. and P. Del Tredici. 2008. The Chinese *Parrotia*: A sibling species of the Persian *Parrotia. Arnoldia* 66(1): 2–9.

Nicholson, R. G. 1989. *Parrotia persica*: An ancient tree for the modern landscape. *Arnoldia* 49(4): 34–39.

Ranney, T. G., N. P. Lynch, P. R Fantz, and P. Cappiello. 2007. Clarifying taxonomy and nomenclature of *Fothergilla* (Hamamelidaceae) cultivars and hybrids. *HortScience* 42: 470–473.

Rehder, A. 1920. New species, varieties and combinations from the herbarium and the collections of the Arnold Arboretum. *Journal of the Arnold Arboretum* 1: 256–263.

Sargent, C. S. 1895. New or little-known plants. Fothergilla Gardeni. *Garden and Forest.* 8: 446.

Spongberg, S. A. 1991. A Sino-American Sampler. *Arnoldia* 51(1): 2–14.

Watson, W. 1896. Foreign correspondence: London letter. Parrotia Jacquemontiana. *Garden and Forest.* 9: 173–174.

Weaver, R. E. 1969. Studies in the North American genus *Fothergilla* (Hamamelidaceae). *Journal of the Arnold Arboretum.* 50: 599–619.

Weaver, R. E. 1981. *Hamamelis* 'Arnold Promise'. *Arnoldia* 41(1): 30–31.

Weaver, R. E. 1976. The witch hazel family (Hamamelidaceae). *Arnoldia* 36(3): 69–109.

Wilson, E. H. and C. S. Sargent (ed.). 1913. Sinowilsonia. Plantae Wilsonianae. Vol. 1. Cambridge, Massachusetts: Harvard University Press.

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Pterostyrax hispidus, the Fragrant Epaulette Tree

Pamela J. Thompson

I began my relationship with fragrant epaulette tree (*Pterostyrax hispidus*) when longtime Arboretum supporter and volunteer Elise Sigel brought me a lanky, homely specimen, wondering if I could give it a home. Elise couldn't recall its full botanical name (some sort of styrax?), and I failed to record even this. I planted it in my Milton garden, not knowing what I had, or how it might grow. Though I don't widely recommend this blind-faith landscape design strategy, in this case I've been delighted with the results.

Pterostyrax hispidus is a deciduous tree native to Japan, specifically in the forested mountains of Honshu, Shikoku, and Kyushu. A member of the storax family (Styracaceae), it is closely related to the silverbells (*Halesia*). Though it can grow almost as broad as tall, reaching up to 50 feet (15.2 meters) in height and 40 feet (12.2 meters) in width as a tree, it is more often noted as a large multi-stemmed shrub reaching about 25 feet tall. In fact, it was the shrub form that Arboretum Director C. S. Sargent first saw in 1892 growing "... wild in Japan on the banks of a stream among the mountains above Fukushima."

The leaves of fragrant epaulette tree are oblong with a tapered point and have finely-toothed margins. They range from 3 to 7 inches (7.6 to 17.8 centimeters) long and 2 to 4 inches (5.1 to 10.2 centimeters) wide. Handsomely bright green above and gray-green below in spring and summer, the leaves turn yellow-green to yellow in autumn before dropping. A truly remarkable feature of this plant is its profusion of 7- to 9-inch-long panicles of fringed, downward facing, white flowers that appear in mid to late June (in the Boston area). Hanging below the leaves, the flower clusters sway in the breeze, attracting multitudes of pollinators and giving off a delicate sweet scent. The inflorescences, reminiscent of the fringed epaulettes that once adorned the shoulders of military uniforms as a show of rank, give fragrant epaulette tree its common name. Through the summer, long clusters of indehiscent, bristly dry drupes develop, adorning the tree like bronze-chartreuse ornaments. These are most evident once the leaves have dropped, looking somewhat reminiscent of dangling sections of a DNA helix.

The Arboretum's accession records for *Pterostyrax hispidus* reveal a history of human interest and persistence in growing this plant. The Arboretum acquired its first accession in 1880 from J. Veitch and Son in England. Over the next 130 years, the Arboretum acquired plants and seeds, including the 1892 accession collected by Sargent in Japan. Many of these acquisitions, though, were of garden origin or uncertain provenance. The Arboretum currently has 3 accessions (9 total plants) of *Pterostyrax hispidus*. Accession 218-60 came to the Arboretum as seed from the University of British Columbia, Canada, but with uncertain provenance. Accession 241-2008, received from Chiba University in Japan as seed, was wild collected in 2006 in Gunma Prefecture, Kanto District, about 20 miles northwest of Tokyo. The third accession, 843-76, came from the Academy of Sciences, Vacratot, Hungary, in 1976 and is also of uncertain provenance.

Though it received the Royal Horticultural Society's Award of Garden Merit in 1993, *Pterostyrax hispidus* remains uncommon in the nursery trade. It is often listed as hardy to USDA Zone 4 (average annual minimum temperature -20 to -30°F), but Arboretum observations over the years indicate that this species may be only marginally cold hardy and is also intolerant of drought. Notes about leader dieback and vigorous basal sprouting imply that this species is more likely to grow as a multi-stemmed shrub in the Boston area.

As the snow has melted from around my now 15-foot-tall tree, I can see that several lower lateral branches have snapped off at the trunk union from the weight of this winter's snow. Even so, it is a plant worth trying in southern New England, even if only on blind faith.

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