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Front cover: The buttery yellow of the autumn leaves and flowers of *Hamamelis virginiana.* One of its great admirers was Henry David Thoreau. In his journal of October 9, 1851, he recorded that "The witch-hazel tree is in full blossom on this magical hillside, while its broad yellow leaves are falling. . . . It is an extremely interesting plant, October and November's child, and yet reminds me of the very earliest spring. . . . I lie on my back with joy under its bounds. While its leaves fall its blossoms spring."

Inside front cover: A stone wall surrounded by forest bears witness to abandoned farmland. Photograph by Peter Del Tredici.

Inside back cover: The cork-like bark of *Phellodendron amurense,* AA #143–A, photographed in 1988 by Rácz & Debreczy

Back cover: The tree-of-heaven, *Ailanthus altissima,* demonstrates its propensity for root suckering at the interface of a concrete block wall and an asphalt surface in Brighton, Massachusetts. Photograph by Peter Del Tredici.

Reading the Landscape: Primary vs. Secondary Forests

P. L. Marks

In much of the eastern United States, the forests within a region vary enormously. Some forests are young thickets while others consist of old, majestic trees. There are oak forests and there are maple forests; some are wet, others dry. Distinguishing between primary and secondary forests can help to explain some of the variation.

"Secondary forests" are those growing on land that was once cleared for farming, and "primary forests" are on land that has never been cleared for agriculture. Both primary and secondary forests are common in the eastern United States, and their distribution is largely a function of land history. How land has been used, in turn, has been strongly influenced by intrinsic features such as soils and topography. In prime agricultural regions secondary forest is generally uncommon because little farmland has been abandoned. In mountainous regions secondary forest is also uncommon, in this case because very little land is suitable for farming. In other areas where agriculture was widely practiced and then substantially abandoned, secondary forests are common today. This essay focuses on why and how these two kinds of forest differ and, using the example of beech trees, discusses the process of succession that occurs when land is reverting from agricultural use to forest.

The term "primary" forest should not be confused with "old-growth" forest—forest free from significant human disturbance or influence. The few old-growth stands that exist today in the eastern United States are all primary forests, but the reverse is not true. The vast majority of primary forests are not old growth because they have been substantially disturbed by the activities of people, most commonly by logging and grazing. Despite having been disturbed in various ways, often repeatedly, primary forests have had continuity of forest habitat for thousands of years.

Looking for Clues

Trying to decipher the history of forests when walking in the woods is fun and informative. Sometimes it is easy. Younger secondary forests (say twenty to forty years since farming) are readily recognizable from their scrubby or thicket-like structure, the absence of large trees or stumps, and the presence of some trees with open, spreading growth forms resembling specimen trees in lawns. As secondary forests age, however, they gradually take on some of the appearance of primary forests. After sixty or ninety years or more, they can be more difficult to distinguish and closer scrutiny is required.

One useful clue is the degree of undulation in the ground surface. Conspicuous irregularities are normally present in the ground surface of primary forests, the result of centuries of tree-uprooting by wind. The mounds and pits, as these small-scale topographical features are called, tend to be on the order of one to two yards across. In contrast, the ground under secondary forests is relatively level because over the years agricultural plowing smoothed the surface of the ground.

Other features useful in distinguishing primary from secondary forests can be seen at the

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The initial stage of pit-and-mound formation. In this photo of red pine trees (Pinus resinosa) *uprooted by wind, the mounds are the root balls and the pits are the original locations of the root balls*

PETER DEL TREDICI

When soil is displaced by an uprooted tree, a mound and a closely associated pit are formed The pits and mounds in this photo, of Hemlock Hill in the Arnold Arboretum, were created nearly sixty years ago, in the hurricane of 1938

P L MARKS

A well-defined edge (above the arrow) between an older primary forest to the right and a younger secondary forest to the left. Note the profusion of spreading branches on the left side of the edge.

P L MARKS

Secondary forest grows on both sides of this older hedgerow of trees, which runs from the left foreground of the picture to the center rear. Note the spreading branches growing out on both sides of the hedgerow.

edges of stands. One hundred (or more) years ago, when the sites that today support older secondary forests were still being farmed, the edges of farm fields were commonly either hedgerows or primary forest. Many of the trees that once grew on the edge of these fields retain evidence of their former edge environment. Specifically, trees on the edge of a primary forest adjacent to secondary forest will show a pronounced asymmetry in their branching, with more large, nearly horizontal, low-to-the-ground branches on the formerly sunny side. Older hedgerows with older secondary forest on both sides will likewise show evidence of a remnant branching pattern, but in this case large, spreading branches grow out on both sides of the trees. Sometimes, the large, spreading branches have died but their former existence can be deciphered from the large, bulging branch bases along the trunk.

Rocks can also tell a story. Rock piles or walls are common occurrences along the edges of secondary forest, generally indicating that the rocks were moved to the edge of the field to facilitate plowing. Sometimes it is unclear at first from which side of an edge the rocks came, but a bit of sleuthing usually reveals the answer. For example, two common situations are (1) an edge between primary and older secondary forest and (2) two older secondary forests separated by a hedgerow that was present when the forests were fields. Suppose that the edges in both situations contain rock piles. Which site did the rocks come from, and how can you be sure?

In the first situation, the secondary forest would have relatively smooth ground, the result of previous plowing, and thus the rocks must have been removed from that site; the adjacent primary site, in contrast, would show mounds and pits. Confirmation should come from the branching pattern of the edge trees: many more large, spreading branches should be growing out into what is now the secondary forest. In the second situation, mounds and pits would most likely be absent from both sites, suggesting that the rocks came from fields that were on both sides of the hedgerow. If the branches of the larger hedgerow trees are growing outward on both sides, this would confirm secondary forest on both sides of the hedgerow.

How Do They Differ In Species?

Secondary forests contain more sun-loving, open habitat plants than do primary forests. Examples are *Cornus racemosa* (gray dogwood), *Lonicera* spp. (honeysuckle), *Rhamnus cathartica* (buckthorn), and *Solidago rugosa* (goldenrod). These open habitat species typically invade early in old field succession; they are present in secondary forests because they can persist, at least for a while, in a shady forest understory. A number of the open habitat shrub and herbaceous plants are exotic species, and thus another difference between primary and secondary forests is that the latter have more exotic (nonnative) plant species.

There are other noteworthy differences in species, if we consider just the common plants of primary forests. Secondary forests contain a subset of the forest plants and animals found in primary forests; a few examples of plants that are common in each kind of forest in the northeastern United States are listed in Table 1. Even within a group of closely related species, we sometimes find that one species is common only in primary forests, while another is common in both secondary and primary forests, as shown in Table 2. For example, in central New York (and elsewhere) *Acer rubrum* (red maple) is common both in primary and secondary forests whereas *A. saccharum* (sugar maple) is abundant in primary forests but is seldom abundant in secondary forests. Where forest plants are present in secondary as well as primary forests, we can assume that they colonized the secondary forest sites from the primary forests and hedgerows that surround most fields. Why have some forest plants been so successful in colonizing secondary forests from source populations in primary forests and hedgerows?

To answer this question, consider the different land-use histories of primary and secondary forests. Clearing of the original forests, combined with the sustained use of a site for agriculture for the better part of a century, would eliminate the forest plants and animals present at the time of clearing. Thus, when a farm field is abandoned, primary forest plants and animals can colonize it only if they can get there from nearby forests and hedgerows. The distances over which forest species must travel in order to

Table 1. A list of selected plants that are characteristic of primary or secondary forests in the northeastern United States

Primary	Secondary
Fagus grandifolia (American beech)	*Acer rubrum* (red maple)
Acer saccharum (sugar maple)	*Fraxinus americana* (white ash)
Tilia americana (basswood)	*Pinus strobus* (white pine)
Tsuga canadensis (hemlock)	*Cornus racemosa* (gray dogwood)
Polystichum acrostichoides (Christmas fern)	*Viburnum dentatum* (arrowwood viburnum)
Trillium grandiflorum	*Botrychium virginianum* (grape fern)
Dentaria diphyllum (toothwort)	*Lycopodium flabelliforme* (ground pine)
Caulophyllum thalictroides (blue cohosh)	

Table 2. Examples of plant differences between primary and secondary forests in the northeastern United States

	Primary	Secondary
Trees	*Acer rubrum* (red maple)	*Acer rubrum*
	Acer saccharum (sugar maple)	
Shrubs	*Viburnum dentatum* (arrowwood viburnum)	*Viburnum dentatum*
	Viburnum acerifolium (mapleleaf viburnum)	
Herbs	*Dryopteris austriaca* var. *spinulosa* (spinulose wood fern)	*Dryopteris austriaca* var. *spinulosa*
	Polystichum acrostichoides (Christmas fern)	

colonize abandoned farmlands are often not great—perhaps fifty to several hundred yards—but they are nonetheless significant because plant species differ so much in seed dispersal ability. Some forest species are much better than others at dispersing seeds to abandoned fields. Thus one reason secondary forests differ in species from primary forests is that they contain species with better dispersal capabilities. I suspect this explains why secondary forests contain herbaceous plants with tiny spores that drift long distances on the wind, such as spinulose wood fern.

But not all forest species capable of dispersing to abandoned farmlands are well represented in secondary forests. Some shade-tolerant forest species are uncommon in secondary forests, perhaps because they cannot tolerate the sunny, open conditions of rundown, abandoned fields. And finally, plants may be uncommon in secondary forests because of seed size. Small seeds give rise to small seedlings, which compete poorly with the dense meadow vegetation of abandoned farm fields. The scarcity in secondary forests of the primary forest species listed in Table 1 can presumably be explained by one or more of the three factors just described.

The Case of Beech Tree Colonization

Beech *(Fagus grandifolia)* behaves quite differently in secondary forests than it does in primary forests, and the pattern of its invasion

Investigating Two Centuries of Change

In studying how much of Tompkins County's forest was once cleared for agriculture, we made extensive use of aerial photographs. This one shows primary forest as well as abandoned agricultural fields in the process of becoming secondary forest.

In the eastern United States, the mixture of forest and open nonforest land has changed dramatically over the last two hundred to three hundred years. A recent study estimated how much forest was present in rural Tompkins County, central New York, in 1790, 1900, 1938, and 1980. Our estimates were drawn from a variety of sources. We used contemporary information for 1790, 1938, and 1980. Records from the original land surveyors indicated that in 1790, 99.7% of the county was covered in forest. By carefully examining aerial photographs taken in 1938 and 1980 we determined the amount of forest present at those times: 28.5% in 1938; 50.7% in 1980. Old agricultural census records revealed that the maximum acreage in farmlands occurred between 1890 and 1900. This was a key date because the amount of forest in Tompkins County would have been at its lowest when the amount of agricultural land was at its maximum. Before 1890, forest was still being converted to agricultural land; after 1900, agricultural lands were being abandoned. Fortunately, the short time interval between 1900 and 1938, when the earliest aerial photographs were taken, meant that we could distinguish on the 1938 photos young forest growing on abandoned agricultural fields from older forest that had been present in 1900. By this means we estimated that only 19.4% of the county was forested in 1900. Thus, in only two hundred years, the landscape of Tompkins County changed from being all forested, to mostly agricultural, to an equal mixture of agricultural and forest lands today.

The major kinds of vegetation present in 1790 are here today: oak forests, swamp forests, and various forests with sugar maple, basswood, beech, hemlock, and other trees. Cattail marshes, other marshes, beaver meadows, and alder thickets are some other landscape components present today and in 1790. There are also present today landscape components that were rare or absent in 1790. Examples are active and abandoned cow pastures and abandoned crop fields (old field succession). Thus, we see that landscape components have changed both quantitatively and qualitatively over the last two hundred years. Many of the original components are still with us, but we have less of each one. At the same time we have some distinctly new components.

How general are the results from Tompkins County? The results probably apply to many parts of the eastern United States, provided that allowance is made for differences in both the dates and the amount of forest cleared. For example, the chronology would be shifted earlier in southern New England.

This information is based on two collaborative studies, which are cited at the end of the article B E Smith, P L Marks, and S. Gardescu, 1993, and P L Marks and S Gardescu, 1992 illustrates one of the general principles underlying plant succession. I first noticed that beech was showing an interesting pattern about ten years ago when I was studying forests around Ithaca, New York, to determine whether each stand was primary or secondary. After a while I realized that if I saw a stand with large beech trees—trunks greater than about fifteen inches in diameter—invariably the forest had not been cleared for agriculture. (Incidentally, the reverse was not true. Not all forests that lacked large beech trees had been farmed. Some were primary forests, but the soil was too wet or too dry for beech.)

Subsequently I began to notice the widespread occurrence of beech seedlings and saplings in secondary forests, the same forests that lacked large beech trees. Apparently, secondary forests were being invaded by beech, since there were small, vigorously growing beech in the understory but no large beech trees in the overstory. On my own land, there is a well-defined edge between secondary and primary forest. The primary forest contains lots of beech, ranging from large trees to small stems. The adjacent secondary forest grew up in a field where agriculture had been abandoned around 1920, an estimate derived from examining old aerial photographs and deed records. Maples, pines, and ashes, but not beech, are among the dominant, tall tree species in the secondary forest today. These trees are sixty or seventy years old, having invaded the field within a decade or two after the last time crops were grown. In the understory, seedlings and saplings of beech are common. Many of the large beech in the adjacent primary forest are close to the edge of the secondary stand, and there is every reason to think that these trees have produced large numbers of beech seeds for a hundred years or more. Nevertheless, beech has been able to invade the former agricultural site only in the last couple of decades. Why? Why has it apparently taken so long for beech seedlings to get started after the field was abandoned?

Students in the plant ecology course at Cornell University have studied beech invasion in secondary forests, and it is instructive to examine some of their results. In several older secondary forests—on land that was last farmed

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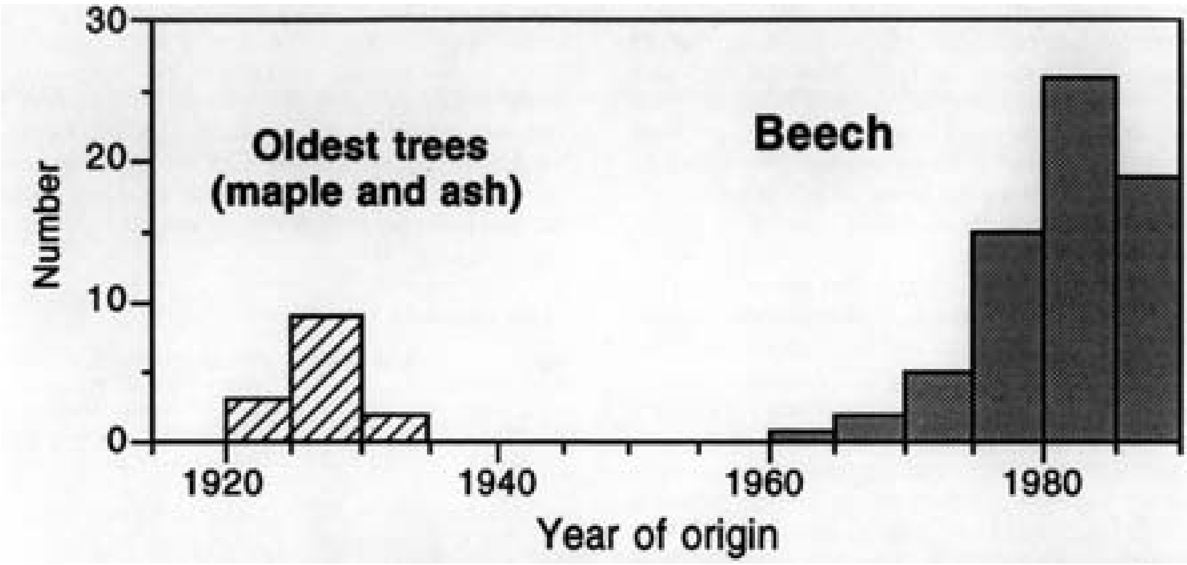
Beech leaves remain on saplings and lower tree branches throughout winter, making it easy to spot beech in a forest when other deciduous trees are leafless.

about seventy years ago—the density of beech seedlings and saplings is about one stem per hundred square feet, dense enough to produce a beech forest in the future if most of these stems survive. The ages of the beech invaders are revealing, as can be seen in the graph on the next page. In the secondary stand on my own land, beech began to invade about forty years after abandonment—thirty to forty years after the other tree species got started. The beech invasion continues, and most of the beech seedlings and saplings became established in the last twenty years. However, we can't tell whether the low density of beech dating from the 1960s and early 1970s is due to mortality or to a gradual beginning of the invasion.

More specifically, how might we explain the failure of beech seedling establishment in the first forty years following agricultural abandonment and the clearly successful establishment over the ensuing twenty-five years? As with vir-



Abundances of different ages of beech seedlings and saplings (in gray), and of the oldest trees of other species (diagonal lines), showing the years in which they originated, in a secondary forest that developed on farmland abandoned about 1920. (Younger maple and ash are not shown.)

tually all such questions in the science of ecology, there is more than one plausible answer. First, although as I have suggested above beech seeds have no doubt been available throughout the past seventy-five years, perhaps seeds began dispersing into the site only after it had become a forest, rather than in its earlier stages of meadow or thicket. In this part of the world, around forty years are necessary for an abandoned agricultural field to develop into young forest through natural succession. A second possible answer is that beech seeds have been dispersing into the site for the entire seventy-five years but were unable to become established as seedlings until something changed about thirty years ago.

How do beech seeds disperse from one place to another? What sorts of changes might have occurred thirty years ago that could have favored the establishment of beech seedlings? The answer to the first question hinges on the behavior of the animals that disperse beech seeds. Beechnuts are contained in prickly burs, which hold two shiny brown triangular nuts, each the size of a small acorn or a large lima bean. The burs open in early fall, at which time the seeds are eaten by birds such as blue jays, grouse, and turkeys, and by mammals ranging from chipmunks and squirrels to fox and deer. Of these animals, blue jays, squirrels, and chipmunks do carry beechnuts away from the trees, burying them to eat later. Blue jays, for example, can carry up to fourteen nuts at a time and may fly several miles from the beech trees back to their feeding territories, where they bury the nuts individually beneath the leaf litter covering the soil. When food is abundant in the fall of the year, these animals store beechnuts, acorns, and other tree seeds in their feeding territories, returning over the winter to eat the nuts. Even though the number of nuts left behind may be a small fraction of the number stored in the feeding territory, these seeds have been "planted" by the animal and thus stand a good chance of germinating and becoming established as seedlings.

The explanation for the delay in beech invasion could involve the behavior of the dispersal agent. It may be that blue jays, squirrels, and chipmunks bury beechnuts mainly in forests. In other words, forty years or so are required to produce the kind of habitat where these animals bury nuts. There is an alternative explanation, however. Blue jays, and for shorter distances, chipmunks and squirrels, could be burying beechnuts during most or all of the forty years from farm abandonment to young forest, but the uneaten nuts may seldom become vigorous seedlings during this early period because beech seedlings require shade to keep their roots from drying out. Several decades would therefore be needed to produce the forest conditions that permit beech seedlings to thrive.

Whatever the reasons for the delay in beech invasion into post agricultural forest, the phenomenon illustrates one of the earliest theories about how succession works—namely, that the first invading plants alter the characteristics of a site in ways that favor invasion by other plants. These first invaders might cast shade that favors plants that do better away from direct sunlight. Or they might be legumes that fix nitrogen and thus favor plants that do better in richer soil.

But this process of "facilitation"—of early invaders facilitating later invaders—is not the only determinant of succession. When—or even whether—a species invades involves an element of chance. For example, a tree species might invade an abandoned field if it happens to be common around the edges of the field, or if it has a good seed year during a critical decade of succession, or if the weather is favorable during a critical stage in the life cycle (for example, during seed germination). In the case of delayed invasion of beech in secondary forests, both of the likely explanations appear to involve facilitation: Before beech trees can become established, an abandoned farm field apparently must become young forest either to encourage burial of beechnuts by animals, or to provide the environmental conditions that allow beech seedling establishment, or both.

The history of the landscape cannot be read with certainty, but that hasn't stopped historically minded ecologists from thinking about it. There is much to learn about today's landscapes by developing a picture of how they were in the past. Because landscapes are constantly changing, especially under the influence of humans, there are striking contrasts between contemporary and historical landscapes. Such contrasts help our present understanding by revealing how recently certain kinds of habitats, which we may take for granted, have become part of the landscape. At the same time, other elements of the landscape are relatively old; they are present today and were also present hundreds of years ago. Deciphering the landscape's history enriches our understanding by allowing us to see it as dynamic, as something that has changed from an earlier condition, and that is still changing today.

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Shoots From Roots: A Horticultural Review

Peter Del Tredici

Many successful plant propagation techniques were inspired by observations of plants in nature. What plant propagator has not seen suckers arising at some distance from the main stem of a tree or shrub and concluded that this is a plant that could be propagated from root cuttings.

Such observations can be traced back at least to the days of the ancient Greek philosopher Theophrastus (371–287 BC). As he was in most botanical matters, Theophrastus was the first to describe the process of root-sucker formation and to attempt to elucidate the causes:

> Now most trees produce these suckers next to the trunk, the roots being here most shallow; and the olive produces them from the base of the trunk as well. But the pear, pomegranate and all trees that produce suckers not only close to the trunk but at a distance from it, have long roots, and send up the shoot wherever the long root comes near the surface, for it is here that the conflux is formed with the resulting concoction as it is warmed. This is why there is nothing fixed about the place of the sucker, for there is nothing fixed about the approach of the root to the surface and the site of the conflux (Book 1: 3.5).

A stand of root sprouts from a single forty-year-old sweetgum tree, Liquidambar styraciflua. *The sprouts range in age from one to fifteen years, and some are over five inches in diameter at breast height. The grids are one meter on each side. Photograph by P. P. Kormanik, U.S. Forest Service, Athens, Georgia, from Kormanik and Brown, 1967.*

The earliest description that I could find of actual propagation of trees from roots is by John Evelyn, who in 1706 (and perhaps as early as 1664) noted that species of *Ulmus*, *Prunus*, and *Populus* produced root suckers that could be dug up and planted. Evelyn went so far as to include detailed instructions for how to propagate trees from roots: "To produce succers, lay the roots bare and slit some of them here and there discretely, and then cover them."

The most famous case of plant propagation from root cuttings is, of course, that of the breadfruit, *Artocarpus altilis.* This was the plant that the notorious Captain Bligh of the HMS *Bounty* was charged with transporting from the South Pacific to the West Indies. It was during the breadfruit's five-month propagation period in Tahiti that the Bounty's crew developed the taste for liberty that ultimately led to their infamous mutiny in 1789.

The Ecology of Root Suckering

In addition to its importance to propagation, root suckering in trees and shrubs also has significant ecological implications, as documented in the new edition of *Silvics of North America,* edited by Russell Burns and Barbara Honkala and published in 1990. Of the 108 nontropical, native trees listed in *Silvics,* 22 of them (21%) are reported to reproduce from root sprouts. Whether this ratio of root-sprouting to nonroot-sprouting species would hold true for a wider sample of trees remains to be determined.

The most well-known root-suckering tree is the quaking aspen, *Populus tremuloides.* This species plays a particularly important ecological role in the Rocky Mountain region, where "clones" of a single tree have been found covering more than 107 acres and totalling an estimated 47,000 distinct stems. In the East, *Sassafras albidum* spreads primarily from root suckers, as does the ubiquitous black locust, *Robinia pseudoacacia,* and the understory-dwelling pawpaw, *Asimina triloba.* Another root-suckering species that has been extensively studied is the American beech, *Fagus grandifolia,* which grows over much of eastern North America. In the northern and eastern parts of its range, the species grows at moderate elevations on cool, rocky slopes and root suckers profusely following logging or disease-induced injury. In the southern and western parts of its range, however, beech is a bottomland species and shows little or no tendency to root sucker. Because this trait is difficult to put onto a herbarium sheet, however, few taxonomists have recognized it as a legitimate character for distinguishing the southern and northern ecotypes as distinct subspecies.

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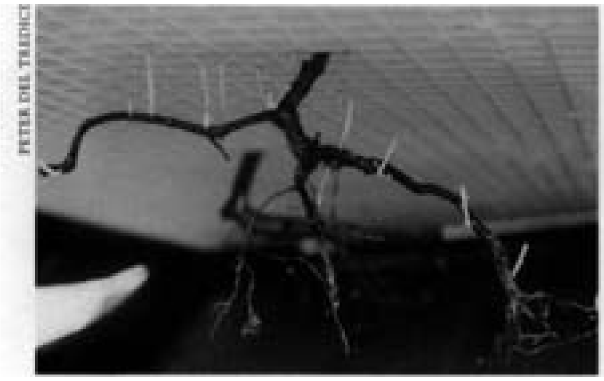
An old specimen of the American beech growing at the Arnold Arboretum. It has produced abundant root suckers.

Propagation From Root Cuttings

Since the mid-1800's, an extensive literature on the propagation of plants from root cuttings has appeared. Especially noteworthy is an article by the German author, Wobst (1868), that provides an extensive list of species—including many not referred to by other authors—that can be propagated from root cuttings. Other early articles on root-cutting propagation are by an American (Saul 1847), a German (Katzer 1868), and an Englishman (Lindsay 1877, 1882). Interestingly, references to root-cutting propagation are more numerous in the older literature than in the modern. This is probably because modern advances in softwood stem-cutting technology—



This specimen of sweet fern (Comptonia peregrina) *was dug up from the wild and placed in a closed "mist box." Buds developed along the roots within a month.*

including the use of polyethylene film, rooting hormones, and intermittent mist—have rendered the slower and more cumbersome process of propagating by root cutting obsolete. Nevertheless, a number of difficult-to-root woody plants—primarily in the families Anacardiaceae, Araliaceae, Leguminoseae, Myricaceae, and Rosaceae—are still most effectively propagated from root cuttings. In particular, there are many native shrubs that, because of their root-suckering habit, are ideal candidates for stabilizing roadside banks and other difficult habitats. Species in the genera *Rhus, Comptonia, Myrica, Robinia, Aralia,* and *Clethra* do well under such conditions and can all be propagated from root cuttings.

Unfortunately, much of the literature on root-cutting propagation is difficult to interpret because of imprecise use of terminology. In particular, many horticulturists consider any woody structure that occurs underground to be a root, regardless of its anatomical origin. This means that plants that produce shoots from underground stems—including rhizomes, stolons, or lignotubers—are often incorrectly classified as "root sprouters." Another problem is that many horticulturists have uncritically copied plant lists from earlier writers without either evaluating the validity of the prior observation or citing a proper source (*e.g.*, Donovan 1976).

The primary purpose of this article is to cut through the confusion that has plagued the literature on root cuttings by identifying those species that have been reported by more than one author to reproduce from root cuttings (see Tables 1 and 2). I have made an exception to this requirement of independent confirmation if an author provides documentary evidence of successful root-cutting propagation with a given species. Of necessity, this article is limited to hardy woody plants. To critically evaluate the extensive literature on tropical plants or herbaceous perennials propagated from root cuttings would be a massive task that is well beyond this author's experience or expertise.

It is worth noting that all of the species listed in this article as being propagated from root cuttings are angiosperms. The only two gymnosperms ever documented as producing root suckers in nature are tropical conifers, *Araucaria cunninghamii* (Burrows 1990) and *Dacrydium xanthandrum* (Wong 1994). Interestingly, *A. cunninghamii* was also listed by Wobst in 1868 as propagated from root cuttings. Despite reports that *Ginkgo biloba* and *Sequoia*

Root suckers produced by Crataegus punctata *(AA#5608) growing at the Arnold Arboretum.*

sempervirens produce root sprouts (Donovan 1976), recent research (Del Tredici 1992) has shown that these gymnosperms produce shoots from underground stems (lignotubers) not from roots.

The anatomy and physiology of root sprouts is a very complex subject, and well beyond the scope of this paper. For information on this topic, one should consult the excellent review by Peterson (1975). For a detailed ecological study of root sprouting by a tree in its native habitat, consult Kormanik and Brown (1967) on *Liquidambar styraciflua.*

What follows is a summary of the information available on the techniques for propagating woody plants from root cuttings, as described in the English-language horticultural literature. After the section on techniques are lists of species that have been successfully propagated from root cuttings.

Types of Root Cuttings

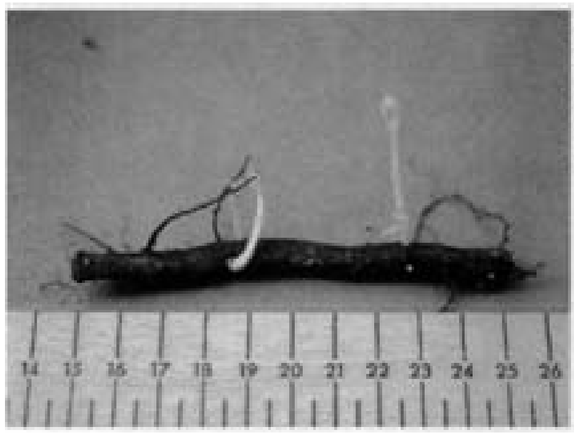
When discussing the propagation of plants from root cuttings, precise terminology is needed to describe the so-called polarity of the root. *Proximal* describes the end of the root nearest to the stem from which the root grew; *distal* describes the end furthest from the parent stem. This is important to remember because when a root cutting develops a bud, it typically forms at the proximal end. Following the classification system established by Hudson (1956), five distinct types of root propagation can be distinguished among woody plants, based on the relationship between parent plant and root sprouts, or suckers, as they are also known:

1) *Natural suckering without division.* This category includes species that produce root suckers naturally near the parent trunk, forming a densely packed cluster of stems.

2) *Natural suckering with division.* This category includes plants—mainly shrubs—that sucker from uninjured roots at some distance from the base of the parent plant. Under undisturbed conditions these plants form large, spreading colonies. The connecting roots have a tendency to wither away, thereby creating natural fragments of the parent plant that can be readily transplanted.

3) *Induced suckering.* This category includes plants that form root suckers in response to superficial injury to the root, such as that caused by lawn mowers. Induced suckering also occurs following traumatic injury to the trunk of a tree or shrub, provided its root system is left intact. Many of the tree species listed in *Silvics of North America* (Burns and Honkala 1990) fall into this category insofar as they only produce root sprouts following logging.

4) In situ *whole root cuttings.* This category includes plants that form suckers from a root that has been completely severed from the parent plant but left *in situ* until a sucker has grown from the proximal end. This phenomenon is often observed in nurseries after a tree or shrub has been dug, leaving numerous severed roots behind. Provided they are not disturbed, these roots will give rise to new shoots.



Successfully propagated root cuttings of the English hawthorn, Crataegus laevigata.

5) Ex situ *detached root cuttings.* This category includes plants that form suckers from root cuttings dug up in the fall or winter, cut into short segments, and planted in the field or in containers. From the propagator's point of view, this is the most important category of root-cutting propagation because it allows for rapid increase in the number of plants produced.

Source of Root Cuttings

When propagating plants from root cuttings, the source of the propagules is critical. The following generalizations apply:

1) There is a clear distinction between roots spouting in nature and induced sprouting from root cuttings. Some species that do not appear to sucker in nature can be induced to produce sprouts from root cuttings propagated under nursery conditions.

2) Unfortunately, many horticultural selections in which the desired mutation consists of a periclinal chimera, including many desirable variegated plants, will not come true from root cuttings. This is because root buds typically arise endogenously from the interior of the root, while buds that are produced on shoots arise exogenously from more superficial tissue layers. This difference in the point of origin produces different types of meristems in root versus shoot buds, a difference that is most strikingly seen in blackberries (*Rubus* spp.), in which plants propagated from stem cuttings are covered with thorns while those from root cuttings are thornless (Creech 1954; Peterson 1975).

3) While it may seem obvious, it is important to remember that horticultural selections grafted onto seedling understock cannot be propagated from root cuttings.

4) Younger plants reproduce more reliably from root cuttings than older plants.

5) Thick pieces of the root proximal to the parent trunk seem to produce shoots more readily than thin root pieces distal to the parent trunk (Creech 1954).

6) Some species can readily be propagated from *ex situ* detached root cuttings, while others will only produce shoots from *in situ* whole root cuttings. Experience is the only way to determine the most effective type of propagation method for any given species.

Timing for Root-Cutting Collection

Most authors agree that late fall or early winter—from October through December, when roots possess their maximum carbohy-

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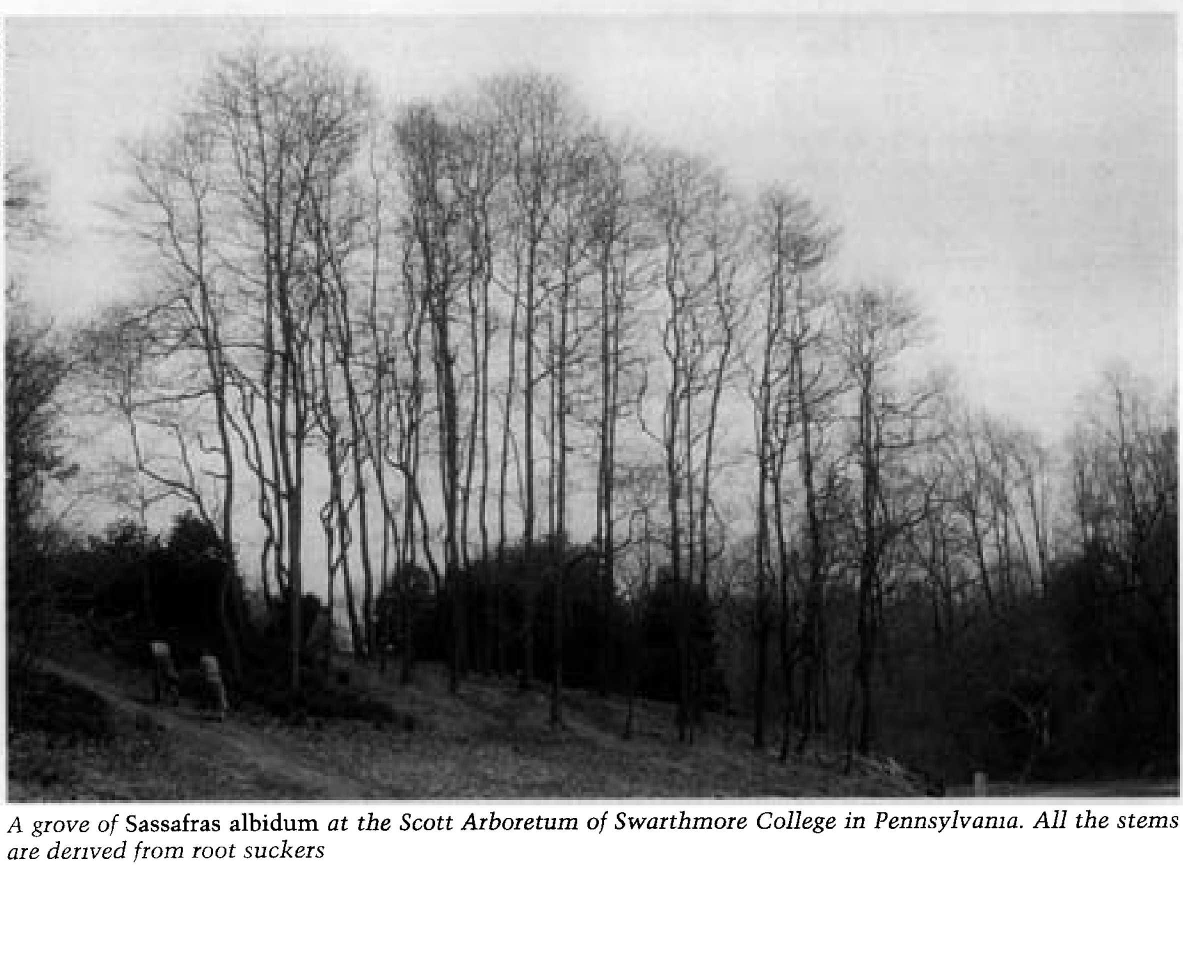

A grove of Sassafras albidum *at the Scott Arboretum of Swarthmore College in Pennsylvania. All the stems are derived from root suckers* drate concentrations—is the best time to collect root cuttings (Browse 1980b; Macdonald 1987; Hartman et al. 1990). In areas with cold climates, root cuttings are also collected in late winter to early spring (Saul 1847; Flemmer 1961). Because root buds must develop *de novo* from the inner tissues of the root, they can sometimes be quite slow to develop. In contrast, dormant buds on the trunk are preformed and sprout out rapidly following injury. In general, the later in the season the root cuttings are collected, the warmer the environment they require for successful propagation (Hudson 1956; Browse 1980b).

Size of Root Cuttings

The optimal size of the cuttings is determined by the environment in which the cuttings will be placed. In general, cuttings stuck in a greenhouse can be three to six centimeters long, while those planted directly out-of-doors should be ten to fifteen centimeters long (Flemmer 1961; Dirr and Heuser 1983). As Browse (1980b) points out, however, such generalizations can sometimes oversimplify the situation: "Only experience can dictate the length of the root cutting of any particular plant and only then in relation to the environment to which it will be subjected—usually a prepared outdoor bed, a cold frame, or a glasshouse bench—the size of the cutting needed decreasing with the warmth of the environment. Size is, of course, a function of two parameters, length and thickness, and although it has been shown that thicker cuttings produce shoots more effectively, those produced from thinner roots establish better."

Polarity of Root Cuttings

All authors agree that the so-called polarity of the cuttings must always be respected. Buds tend to form most readily at the proximal end of the cutting (that closest to the trunk). Most authors recommend that this end of the cutting be given a straight horizontal cut, while the distal end of the cuttings receives a sloping, diagonal cut (Flemmer 1961; Macdonald 1987). This makes it easier to establish proper orientation when sticking the cuttings into the propagation bed. Cuttings can be stuck either vertically or diagonally, with the proximal end of the cuttings just at or slightly above the soil surface. Cuttings can also be placed horizontally in flats and covered with a centimeter or two of soil (Creech 1954; Macdonald 1987).

Treatment of Root Cuttings

The use of fungicide greatly improves the success rates of root cuttings (Browse 1980b; Macdonald 1987). Once cuttings have been made, they can either be put in a plastic bag with a powdered fungicide and shaken so that the entire root piece is covered or dipped briefly in a liquid formulation. Treating root cuttings with superficially applied cytokinin does not appear to significantly enhance shoot production above that of untreated controls (Brown and McAlpine 1964; Macdonald 1987).

Winter Storage of Root Cuttings

Root cuttings collected in the fall can be stored in boxes or flats, covered with a moist, well-aerated medium, and put in a minimally heated storage structure until early spring. During this storage period, the cuttings will callus over and begin the bud formation process. (Browse 1980b; Macdonald 1987).

Propagation Environment

1) *Out-of-doors.* In areas with mild winters, root cuttings can be planted directly in the field in late fall or early winter. In areas with severe winters, root cuttings can be collected in the fall and put in cold storage until spring, when they can be planted directly in the nursery. Direct field planting works best with shrubs that naturally form root buds (Flemmer 1961).

2) *Cold frames.* These have reportedly been used successfully in areas with relatively mild winters, such as Great Britain or the Pacific Northwest. They afford more protection to the cuttings than does field planting and therefore offer a greater chance of success.

3) *Cool greenhouse.* Fall-collected root cuttings that have been kept in cold storage can be propagated very well in a cool greenhouse when "direct stuck" in individual containers in late winter. Root cuttings collected in late winter or early spring should be immediately planted in a cool greenhouse with bottom heat (Dirr and Heuser 1987).

Additional information on the relationship between the propagation environment and root cutting performance, as well as the optimum environment for propagating selected species, can be found in Browse (1980b) and Macdonald (1987).

Propagation Medium

The rooting medium should be very well drained to provide maximum aeration. Good drainage inhibits the growth of pathogenic fungi and enhances root development (Flemmer 1961; Browse 1980b; Macdonald 1987). Successful mixes consist of various percentages of peat, bark, sharp sand or grit, and perlite.

Root Cuttings as a Source of Shoots for Stem-Cutting Propagation

Interestingly, many root cuttings will produce shoots relatively quickly, but soon collapse after failing to generate new roots (Creech 1954; Macdonald 1987). Typically, new roots do not form on a cutting until after the shoot is formed, and often they develop from the base of the new shoot rather than from the original root piece. Because of this phenomenon, a modified technique has been developed that involves removing shoots propagated from root cuttings in the greenhouse and using them as softwood cuttings. Because these shoots are physiologically juvenile, they tend to root more readily than cuttings taken from other parts of the tree (Creech 1954; Flemmer 1961; Fordham 1969).

In Situ Root Cutting Techniques

It is important to keep in mind that there are many species that sucker naturally in nature, such as the pawpaw, *Asimina triloba,* that have not been successfully propagated from *ex situ* root cuttings. These species must be pro-

Table 1. Hardy trees that have been successfully propagated from root cuttings, followed by their appropriate literature citations

Ailanthus altissima: 2, 4, 6, 14, 17, 23, 26, 28	*Laurus nobilis:* 2, 12
Albizia julibrissin: 2, 4, 8, 10, 14, 15, 17, 23, 26	*Liquidambar styraciflua:* 3
Amelanchier spp.: 4, 10, 14, 23, 28	*Maackia amurensis:* 4, 8, 10
Asimina triloba: 1, 2	*Maclura pomifera:* 4, 5, 22, 26
Broussonettia papyrifera: 2, 10, 17, 23, 26	*Malus* spp.: 4, 10, 14, 17, 24
Carya spp.: 2	*Morus* spp.: 2, 14, 28
Catalpa spp.: 2, 4, 23, 26, 28	*Paulownia tomentosa:* 6, 23, 26, 28
Cedrela sinensis: 1, 2, 4, 23	*Phellodendron amurense:* 2, 4,10, 23
Cladrastis spp.: 2, 4, 10, 23	*Picrasma quassioides:* 15, 23
Crataegus spp.: 1, 28	*Populus* spp.: 1, 10, 14, 17, 23, 25, 26
Cydonia oblonga: 2, 12, 26, 28	*Prunus* spp.: 1, 2, 4, 8, 14, 17, 24, 28
Elliottia racemosa: 15	*Pterocarya* spp.: 1, 10
Euonymus spp.: 1, 12, 24	*Pyrus calleryana:* 10, 17, 24
Evodia spp.: 2, 4	*Robinia pseudoacacia·* 2, 14, 17, 23, 25, 28
Ficus carica: 17, 28	*Sassafras albidum:* 2, 4, 14, 17, 23, 26
Gleditsia triacanthos: 10, 24	*Sophora japonica:* 17, 28
Gymnocladus dioicus: 4, 10, 22, 23, 26	*Staphylea* spp.: 2, 10, 28
Halesia spp.: 2, 26	*Ulmus* spp.: 10, 14, 17, 28
Kalopanax pictus: 10, 23	*Xanthoceras sorbifolium:* 1, 2, 4, 8, 10, 21, 23
Koelreuteria paniculata: 1, 2, 4, 8, 10, 17, 23, 26	*Zizyphus jujuba:* 2, 17, 28

pagated using *in situ* techniques applied to plants in the late fall. The method involves cutting around the stem(s) of a plant with a sharp spade, then moving out fifteen to twenty-five centimeters and cutting a second, concentric, circle around the first. All roots are left in the ground, and shoot buds will form at their distal ends come spring. Such "pre-cut" plants can easily be dug and potted up in the fall or the following spring. This technique is particularly effective for propagating shrubs that sucker naturally.

Table 2. Hardy shrubs and vines that have been successfully propagated from root cuttings, followed by their appropriate literature citations

Acanthopanax spp.: 2, 17
Actinidia deliciosa: 10, 17
Aesculus parviflora: 4, 10, 14, 17, 23
Amorpha spp.: 4, 28
Aralia spp.: 1, 2, 4, 10, 14, 17, 23, 28
Aristolochia spp.: 1, 22
Aronia spp.: 4, 24, 28
Berberis spp.: 12, 28
Bignonia capreolata: 4, 23, 26, 28
Camellia spp.: 8, 19
Campsis radicans: 4, 14, 17, 23
Caragana spp.: 2, 28
Celastrus spp.: 1, 2, 4, 14, 17, 28
Chaenomeles spp.: 2, 4, 8, 10, 14, 17, 23, 24, 26, 28
Clematis: 21, 28
Clerodendrum spp.: 1, 4, 10, 14, 17, 23, 22
Clethra alnifolia: 1, 8, 10
Comptonia peregrina: 1, 4, 10, 14, 17, 23, 28
Corylus maxima: 12, 17
Cotinus spp.: 11, 24
Cyrilla racemiflora: 8, 10, 17
Daphne spp.: 4, 8, 10, 17, 23, 28
Decaisnea fargesii: 23
Elaeagnus spp.: 2, 26
Fatsia spp.: 2, 4
Forsythia spp.: 12, 17, 24, 28
Fothergilla spp.: 10, 28
Gardenia spp.: 19, 28
Hippophae rhamnoides. 2, 26, 28
Hydrangea quercifolia: 10, 14
Hypericum calycinum: 17, 12
Ilex spp.: 8, 11, 24
Illicium floridanum: 10, 11
Indigofera spp.: 4, 10, 23
Lagerstroemia indica: 4, 8, 10, 23
Leitneria floridana: 1, 4
Lonicera spp.: 12, 28
Meliosma spp.: 4, 23
Myrica spp.:10, 14, 17
Nandina: 26, 28
Orixa japonica: 4, 23
Paliurus spp.: 2, 26
Pyracantha coccinea · 10, 24
Rhododendron spp. (azaleas): 8, 16, 28
Rhodotypos scandens: 10, 24
Rhus spp.: 4, 10, 14, 17, 23, 26, 28
Ribes spp.: 10, 28
Robinia hispida: 4,10, 14, 17, 23
Rosa spp.: 2, 10, 14, 17, 21, 23, 28
Rubus spp.: 1, 2, 4, 10, 14, 17, 18, 23, 28
Sambucus spp.: 2, 23
Sorbaria sorbifolia · 2, 10
Spirea spp.: 11, 24
Symphoricarpos spp.: 17, 24
Syringa vulgaris: 2, 8, 10, 14, 17, 23, 24, 28
Vaccinium spp.: 1, 2
Viburnum spp.: 24, 28
Wisteria spp.: 4, 8, 14, 28
Xanthorhiza simplicissima: 14, 28
Zanthoxylum spp.: 2, 4, 10, 23, 28

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Mystical, Medicinal Witch Hazel

Sheila Connor

Fall is our native witch hazel's best time. In this season it will reward the passerby with a faint, clean scent reminiscent of spring and the sight of ribbons of gold among equally golden leaves. But because it has long been used as a natural astringent, *Hamamelis virginiana* may be more familiar to most people as a bottle of liquid on a shelf in the medicine cabinet than as an understory species of the New England woodland.

As an all-purpose home remedy, witch hazel extract has outlived many of the patent medicines of our great-grandparents' day. Commercial manufacture of witch hazel extract began in 1866, when Thomas Newton Dickinson, a minister and entrepreneur, built a witch hazel distillery in Essex, Connecticut. Originally, witch hazel brush was cut locally and then transported either by boat or by horse and wagon to the distillery. The company has always obtained the witch hazel it needs from the forests of southern New England, and most of the harvest now comes from the northwestern corner of Connecticut. And today, as in the past, the brushcutters—farmers and woodcutters working their own land or land they have contracted to clear—sell directly to the distiller. Work begins in October and often continues until late spring. Sometimes only the branches are cut; otherwise, the plant is cut to the ground. But because witch hazel quickly sprouts from stumps, only a few years will pass before a plant may be harvested again. The invention of the portable chipper allowed the refining process to begin right on site, and now the brush arrives at the factory ready to be distilled in stainless-steel vats, where steam is applied for more than thirty-six hours to the chopped brush. The vaporized essence, which comes from the cambium layer just under the outer bark, is "scrubbed" in washing chambers, reheated to vapor, condensed, and filtered. Today's modern equipment and techniques still deal with three basic elements—witch hazel brush, water, and heat—and T. N. Dickinson's "formula." The clear liquid you see in a bottle of hamamelis extract is 86 percent "double distilled" witch hazel and 14 percent alcohol.

Witch hazel's applications seem to have changed as little as its manufacturing process. The explorer-botanist Peter Kalm reported the use of *Hamamelis virginiana* by Native Americans in treating eye diseases as early as 1751. They called the plant "magic water," boiled the stems and used the liquid not only for their eyes but also to treat cuts, bruises, and scratches. The many modern-day applications of aqueous witch hazel approved by the Food and Drug Administration include treating sores, minor lacerations, sprains, and tired and puffy eyes.

There is also a mystical side to *Hamamelis virginiana:* its use in the occult arts. The common name witch hazel was given to *H. virginiana* by early English settlers because they believed it possessed the ability to "divine." Our native tree was not the first plant to be called witch hazel; the colonists brought the name with them across the Atlantic. Its application is an example of how often a common name reflects an association people make with a plant, rather than an accurate description of it.

In Great Britain, dowsers used their native elm, *Ulmus glabra,* which they called the "witch hazel tree," to find hidden veins of precious metal or underground springs. In

The enduring commercial success of witch hazel may lie in imaginative marketing Early advertising of the E. E. Dickinson Witch Hazel Company took advantage of romantic legends, as in this label for a bottle of Witchal, a stronger mix of witch hazel and alcohol: "In the early days it was believed that when the good witches boiled the witch hazel twigs in their caldrons it was a sign that the potion was ready for use when the phantomlike shape of a beautiful young woman could be seen riding through the steam." Apparently the batch in this illustration isn't quite ready.

Old English, *wice* meant "lively" or "to bend," and as a dowser approached the site of, say, a potentially productive spring, the branch would become "lively" and begin to point to the source.

The pliant branches of the elm were also used by archers to make their bows. When it was reported that the "aborigines" made the same use of *Hamamelis virginiana* for their weapons, it seems that the colonists transferred all the elm's associated powers to the New World plant. Although many plants were used for dowsing, witch hazel became the preferred one for use as a divining rod.

Sheila Connor is Horticultural Research Archivist at the Arnold Arboretum. This article is adapted from her book, *New England Natives A Celebration of Trees and People,* published by Harvard University Press, 1994

Requiem for a Cork Tree

Peter Del Tredici

Around two o'clock on the afternoon of Thursday, 28 September 1995, one of the best loved trees at the Arnold Arboretum died—the old Amur cork tree, *Phellodendron amurense,* which grew along Meadow Road.

It died as it lived, giving of itself freely to an adoring public: a group of twenty-two schoolchildren from the Winsor School in Boston were perched in the tree, posing for a photograph, when the weight of the group caused the tree to crack audibly and collapse. The children hastily climbed down, with no one suffering injury.

Phellodendron amurense, AA #143–A, age 121 On 29 September 1995, the day after the "accident," the massive climbing limb is on the ground

Without a doubt it was the most photographed tree in the Arboretum, and the most loved. In fact, it was loved to death. The tree had been in a slow state of decline, particularly over the last ten years, as a steady parade of trampling feet compacted the soil around its base, smothering its roots, and as children and adults of all ages climbed among its low, spreading limbs. Those pressures simply compounded the health problems that are normal for a tree that is over one-hundred-and-twenty years old. Over the years, the Arboretum staff had tried various techniques to keep the public out of the tree but found none that could overcome its sheer magnetism—the irresistible urge it inspired to go up and touch the soft bark that had been rubbed to a smooth polish by countless generations of Boston children. So the decision was made to let the cork tree die as gracefully as possible. It became the only tree in the Arboretum that people were "allowed" to climb.

When the end finally came, the tree was clearly on its last legs. Every year for the last ten years, Arboretum pruners had had to remove dead branches from the tree, making it ever thinner and weaker. The low, spreading limb, where all the children perched, had descended from four feet above the ground in 1983 to only two feet in 1995. This past summer's drought, bringing forty straight days without rain, was just one more problem for the tree to cope with.

The cork tree had an altogether remarkable history. It arrived in Boston as a seed from the Imperial Botanic Garden in Saint Petersburg, Russia, on September 14, 1874, just two years after the Arboretum was founded. It was assigned the accession number 143–A, indicating it was the one-hundred-and-forty-third tree to be acquired by the Arboretum and very likely one of the first trees planted on the grounds.

E. H. WILSON

In the prime of life in April 1924, at age fifty, the cork tree's broad, spreading crown is fully formed. Obviously, children have not yet started to climb among the branches.

WORCESTER TELEGRAPH

In July 1946, at age seventy-two, a tradition of photographing the tree with children is beginning to emerge and the cork tree's lower limb is adding girth.

When death finally came, at the hands of its friends, it had passed its one-hundred-and-twenty-first birthday only two weeks before.

One of the interesting things about cork trees is that they are dioecious, meaning there are separate male and female individuals. Our beloved specimen was a male. Despite its common name and the corky feel of its bark, *Phellodendron amurense* is not the source of commercial cork used for wine bottles and bulletin boards. (That product comes from a species of oak that grows in the Mediterranean region, *Quercus suber.*) The specific name, *amurense,* refers to the tree's origin in the Amur River Valley of Manchuria, a region with very severe winters. Many other plants from this region are growing well at the Arboretum and seem particularly well adapted to the rigorous climate of New England.

By 1988, one of the cork tree's lower limbs has been removed and children are clearly comfortable climbing along its spreading limbs.

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The Arnold Arboretum

FALL • NEWS • 1995

Cathaya Comes to the Arnold Arboretum

Stephen A. Spongberg, Horticultural Taxonomist

Likuo Fu (left) and Nan Li (center) from the Institute of Botany, Academia Sinica, Beijing, with Peter Del Tredici and Kim Tripp of the Arnold Arboretum and conifer specialist John Silba. It was wonderfully serendipitous that Professor Fu was visiting the Arboretum when the *Cathaya* seeds arrived in Jamaica Plain from Edinburgh.

The Arnold Arboretum of Harvard University has recently received fifty seeds of *Cathaya argyrophylla* Chun & Kuang, a rare and endangered conifer endemic to China, which has not been grown or cultivated previously outside of the People's Republic. Like the dawn redwood, *Metasequoia glyptostroboides*, which was known as a fossil before living trees were discovered in China in the early 1940s and subsequently introduced into cultivation by the Arnold Arboretum in 1948, *Cathaya* is known as a fossil from Tertiary sediments in Eurasia and was only discovered as a living plant by Chinese botanists in the early 1950s.

Small native populations of this unusual cone-bearing tree are now known to exist in six counties in Guangxi, Hunan, Sichuan, and Guizhou provinces in China, yet the tree ranks as a rare and endangered species and is listed in the *China Plant Red Data Book.*

Cathaya is intriguing from an evolutionary perspective inasmuch as its embryo and pollen are similar to those of the true pines (species of *Pinus*), while its wood resembles that of the Douglas firs (species of *Pseudotsuga*), and its overall habit and seed-producing cones are much like those of the spruces (species of *Picea*).

The consignment of seeds received at the Arnold Arboretum was forwarded from the offices of the Conifer Conservation Programme at the Royal Botanic Garden, Edinburgh, where a quantity of seed collected from one of the native populations was provided by Professor Likuo Fu, Director of the Herbarium and Laboratory of Taxonomy and Plant Geography, Institute of Botany, Academia Sinica, in Beijing. Professor Fu had requested that the seeds be shared with other botanical institutions in Europe and North America.

While these seeds provide the first opportunity to attempt germination of *Cathaya* at the Arboretum, the propagation staff is optimistic that plants will result. Diverse treatments will be applied to induce germination, but it may be six to eight months before it is known if plants will result. If plants are successfully grown, asexual propagation will be under-taken to increase their numbers. The young trees will ultimately be included in the living collections of the Arboretum to evaluate cold hardiness and performance under New England climatic conditions. Material of *Cathaya* will also be available for further botanical and horticultural investigations by scientists utilizing the Arboretum's collections. It is hoped that the success rate with the Cathaya seeds will be similar to the high germination levels obtained with the *Metasequoia* seeds received in 1948 and that this unique conifer will be preserved in cultivation as well as in nature in China.

Plant Sale Ends Drought

This summer's forty-day drought came to a spectacular end on the day of the 1995 Fall Plant Sale. Despite the downpour, the event was a great success. Over six hundred members and friends participated in the sale, Rare Plant Auction, and Plant Society Row.

John Furlong

A Visit From Mike Dirr

Dorothy Littel Greco

This fall Mike Dirr (center), author of *Manual of Woody Landscape Plants* and former Arboretum Fellow, gave a lecture and led two walks through the living collections for over two hundred students. Here, Gary Koller (left) enters into an animated exchange on the virtues of various cultivars.

How to Create a Logo

Bob Cook, Director

There comes a time in the life of every institution when it confronts the logo issue, that desire to project a modern, with-it image. Such times typically follow the arrival of a new administration. The usual procedure is to put a blank check in the hands of highly paid consultants who will bring a progressive understanding of marketing to the design of an emblem that—once created—will be ridiculed by your entire staff and vilified by at least half your constituency.

Instead, about a year ago we decided to tackle this issue ourselves with the help of *Arnoldia* designer, Andy Winther. Our first decision was recognition of reality: If one's institution is an arboretum, one can hardly avoid a tree in the logo. Next we asked whether there was something lying around that we already liked. Our attention immediately turned to an old, much-loved bookplate used by our first director, Charles Sprague Sargent. Could it be modified to enhance its symbolic content and simplify its design while retaining the quality of antiquity appropriate for the oldest public arboretum in the country?

With a reduction in ornamentation, we decided to keep the Victorian frame and banners but to seek a different, more emblematic tree. We quickly chose *Metasequoia glyptostroboides,* more popularly known as the dawn redwood, to replace the nondescript pine in the bookplate.

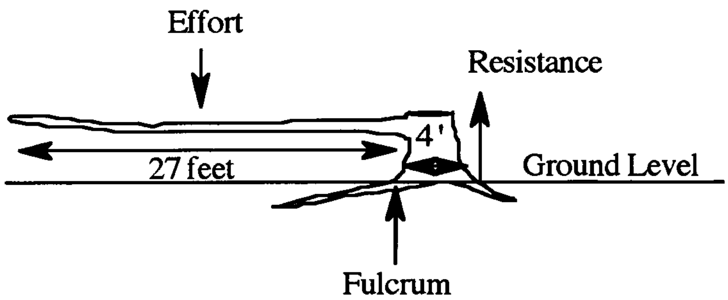
This species was once abundant in the forests of North America millions of year ago, known to Western science only as an extinct species preserved in fossilized stone. During World War II the dawn redwood was discovered growing in a remote river valley of central China, and an Arboretum-sponsored expedition was sent late in 1947 to retrieve seed. Following the arrival of the first shipment in early 1948, the Arboretum distributed the newly discovered species to over six hundred botanical institutions around the world. The first dawn redwood repatriated to North America after an absence of several million years is growing in the Arnold Arboretum today.

By choosing this species for our new logo, we hope to symbolize our traditional mission to support research and education through the collection of trees from distant lands. At the same time, by setting the dawn redwood against a rising sun, we hope to signal a new dawn for the future programs of the institution.

Cork Tree's Last Hurrah Provides a Science Lesson on Leverage

Christopher Randall

Can there be a silver lining to the passing of an old friend? As someone who has spent more than ten years teaching in the science classroom, my first reaction after an initial sadness was to consider the toppling of the cork tree in terms of a science lesson. Soon after hearing the news, I was bursting with questions: How many girls were on the branch? How much does a sixth grader weigh? How long was the branch they were sitting on? This tragedy was shaping up into a great lesson on levers and leverage.



Cork tree and branch depicted as a lever.

The cork tree was a classic example of a lever. The tree was similar to a seesaw, albeit a very unequally proportioned one. This seesaw had one incredibly long side, the branch, and a phenomenally short side, roughly the diameter of the tree. The roots at the base of the trunk directly under the branch were the fulcrum at the "center" of this lopsided seesaw.

Intuitively, we know that on a seesaw, the farther out we sit or the more weight we add to our side, the easier it is to lift our partner. Furthermore, if we place a great deal of weight at the extreme position of our seesaw, we can lift even an enormous partner. To determine the effect of a particular force (the weight of the girls in this case) at a certain position, one can use the following equation, known in physical-science parlance as the Law of the Lever:

Effort Force	×	Effort Distance	=	Resistance Force	×	Resistance Distance
(Girl's Weight)		*(Girl's Position)*		*(Force on Roots)*		*(Root's Distance from Fulcrum)*

That fateful day, 22 sixth-grade girls seated themselves along the branch, as had been the custom each year at the end of their class visit to the Arboretum. Let's assume that the average sixth grader weighs 100 pounds and that the branch is 27 feet long—quite close to the actual situation. To calculate the cumulative force the group developed, the force each girl contributed must be calculated. Since each girl sat at a different distance from the fulcrum, the force each girl contributed must be calculated individually, and then each of these forces must be added together to find the total force on the effort side of the above equation. Assuming the girls were equally spaced along the branch, this force amounts to 31,050 foot-pounds!

Let's now assume that the tree was four feet in diameter, again not far off the actual dimension. According to the Law of the Lever, the relationship between the two sides of the fulcrum can be stated as:

31,050 foot-pounds = 4 feet × ? Resistance Force

Dividing this through yields:

Resistance Force = 15,600 pounds (or 7.8 tons)

By using leverage, 2,200 pounds worth of sixth graders translated themselves into 7,763 pounds of force. Add to this the considerable weight of the branch itself, and it is no wonder the tree roots gave way. Interestingly, the fact that the tree's central leader and a large lateral branch had been removed a few years ago meant that the appreciable counterbalancing effect of the original trunk was absent. Additionally, the rot affecting the roots on the opposite side of the limb may have weakened the roots' ability to support the girls that day. I am not sure anyone approves of extending this lesson to other trees in the Arboretum, but I am sure that our beloved friend would appreciate knowing that we could leverage this calamity into a corker of a science lesson.

Chris Randall taught science for more than ten years in Baltimore, MD, and Cambridge, MA. Currently at the Center for the Enhancement for Science and Mathematics Education (CESAME) at Northeastern University, he works with math and science teachers on program implementation.

The cork tree's very long, horizontal branch has been left in place on the ground, one end still attached to its foreshortened trunk, the other propped up by a log. The Arboretum staff sought to make the death of "Corky" an educational experience by describing the negative effects of soil compaction on tree health. When heavy loads—or lots of small loads—are applied over the tree roots, the pores between soil particles are compressed and the amount of oxygen available to the roots is diminished. Over time, the effect on a tree can be lethal.

The Arboretum was among a select group of American museums to receive a grant for general operating support from the federal government's Institute of Museum Services. The grant of $112,500 is awarded through a peer review process that evaluates general standards in collections management, education, and other areas of museum operation.

The New England Chapter of the Victorian Society in America recognized one of the Arboretum's most outstanding landscape features, **the Eleanor Cabot Bradley Garden of Rosaceous Plants,** with their 1995 Preservation Award. Funded by the late Eleanor Cabot Bradley, it was designed by Gary Koller and Stephen Spongberg in the spirit of the larger Olmsted/Sargent landscape.

Jack Alexander, Chief Plant Propagator, has been elected a Fellow of the Eastern Region of the International Plant Propagators' Society. He is one of twenty-six to receive the honor since it was instituted in 1990 to recognize outstanding contributions to plant propagation through research, teaching, or leadership.

Peter Del Tredici, Assistant Director for Living Collections, was awarded a Presidential Citation at the annual Presidents' Conference of the Garden Club Federation of Massachusetts, Inc., by President Arabella Dane, for his significant work in documenting, managing, propagating, and reintroducing the endangered *Magnolia virginiana* at its only verified Massachusetts location Peter reported on the initial stages of this work in *Arnoldia,* March/April 1981

Kim Tripp, Putnam Fellow, has won the 1996 Research Grant of the International Plant Propagators' Society–Eastern Region for a collaborative project with Dr. Anne Stomp of the Department of Forestry, North Carolina State University. The grant will be used to test the influence of *Agrobacterium rhizogenes* on the rooting of stem cuttings in woody ornamentals that do not respond to standard propagation techniques (for instance, *Cercis* and some *Prunus*).

Autumn Beginnings for Visitor Learning

Richard Schulhof, Assistant Director for Education and Public Affairs

As we began testing two new programs this fall, ideas about education at the Arnold Arboretum grew by leaps and bounds. Over the past ten years, the Arboretum has reached thousands of adult and elementary school students with classroom courses, lectures, and field studies in horticulture and life science. On a drizzly Saturday afternoon in October, we broke new ground by testing programs designed to provide visitors to the grounds with equally rich opportunities for discovery and learning

As part of our Fall Open House event, Candace Julyan and Diane Syverson of the Community Science Connection (CSC) project set out to enable parents and their children to explore the diversity of maples and the wonder of fall color change in leaves. The hands-on activity, called Reading

Maples, included a tabletop exhibit of maple specimens, products, books, and a treasure hunt map that guided families in the search for leaves and data from a number of maple species. Created for Arboretum visitors as well as CSC participants, the program tested strategies that utilize the living collections to foster exploration and the exchange of observations and ideas about the natural world.

On the same afternoon, outreach horticulturist Chris Strand asked visitors to help test new orientation signage for the grounds. Consisting of "you are here" maps and roadside location markers, the system is designed to encourage visitors—particularly those visiting for the first time—to more confidently explore the Arboretum's full 265 acres. With installation scheduled for 1996, we envision the new signs and maps greatly improving access to the diverse collections and natural sites of the Arboretum landscape.

In the jargon of the museum world, these efforts seek to support "informal learning," the kind of exploration that occurs around exhibits and in discovery rooms, in which learners investigate at their own pace, responding to their own curiosities and interests In keeping with Charles Sargent's vision for the Arboretum as a "great museum of public instruction," such are the kinds of experiences we wish to make available for our visitors and the surrounding community.

Remembering Buzzy

On a beautiful Sunday in October, well over a hundred friends of Albert W. Bussewitz gathered in remembrance at the Arboretum. Many spoke eloquently of Buzzy, who died of heart failure this past August. Included in this group were associates from his years with the Massachusetts Audubon Society in Sharon and Norfolk and his earlier years spent in Rochester, New York, as well as Arboretum staff, volunteers, and friends.

Director Bob Cook, who hosted the occasion, announced that the Bussewitz family will give Buzzy's many superb photographs of woody plants to the Arboretum. The collection will eventually be housed here and made available for educational use. The family asks that donations in remembrance of Buzzy be sent to the Arboretum, where they will be designated for the curation of his photographic legacy.

Arboretum Cleanup

As it has for more than a dozen years, the Arnold Arboretum Committee, a community support organization, recently coordinated a fall cleanup of perimeter areas of the Arboretum. Working with City Year, an organization for volunteer youth, over 125 volunteers removed woody weeds and general debris from the abutting state-owned parcel as well as the Arboretum's South Street tract.

We are indebted to volunteers from Keyport Life Insurance Company of Boston and to Mercer Management of Lexington, which contributed a second year of service. Compliments and thanks are also due to the staff of the State Laboratory Institute and to Arboretum staffers Julie Coop, Kit Ganshaw, Jim Papageris, and Patrick Willoughby.

Grow with us . . .

When you give cash, stock, or other property to a life income plan supporting the Arnold Arboretum, you will:

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There are several plans in which you can participate. For more information, please contact:

Lisa M. Hastings, Development Officer
Arnold Arboretum
617/524-1718 ext. 145

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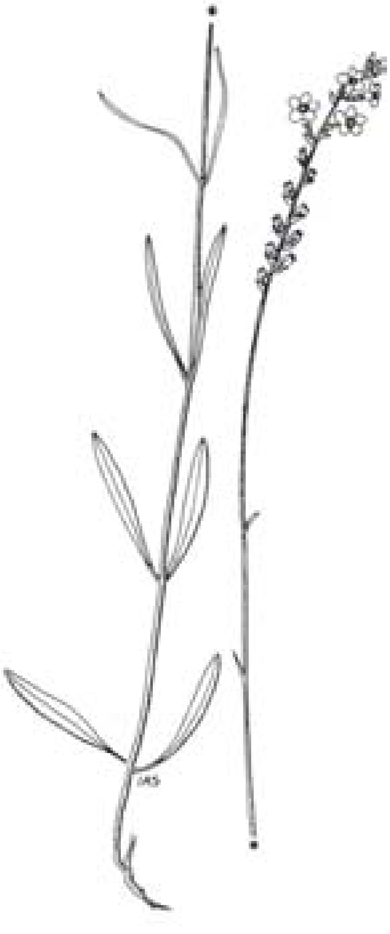

Flora of the Lesser Antilles

Copies of the six-volume *Flora of the Lesser Antilles,* a long-term project of Dr. Richard A. Howard, former director of the Arnold Arboretum, is still available in limited quantities.

These six volumes constitute the first comprehensive flora of the area, and the treatments present keys to the genera as well as the species for easy identification. For each genus and species a complete modern description is provided; it includes coloration as well as measurements of floral parts. The descriptions are followed by geographic distribution both within and without the Lesser Antilles. All volumes are abundantly illustrated with line drawings that are both botanically correct and highly artistic. All species known in the Lesser Antilles, both native and introduced, are included.

The six volumes are available either individually or as a complete set. For the complete set a special price of $260 is offered that includes shipping and handling within the USA. (Add $5 for shipping outside the USA.) For volumes 4, 5, and 6 only, the special price is $205.

Individual volumes may be purchased at the prices given below, plus $2 per volume for shipping and handling:

Volume 1: Orchidaceae	$20
Volume 2: Pteridophyta	$25
Volume 3: Monocotyledoneae (other than Orchidaceae)	$35
Volume 4: Dicotyledoneae 1	$75
Volume 5: Dicotyledoneae 2	$85
Volume 6: Dicotyledoneae 3	$85

Checks should be made payable to the Arnold Arboretum, and all orders should be addressed to the attention of Frances Maguire, Arnold Arboretum, 125 Arborway, Jamaica Plain, MA 02130, USA.