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Front cover Cedrus libani cones, rarely seen by most visitors since they are borne high on the tree, they are held erect above the needles, and they disarticulate while still on the tree in winter. The winged seeds are thus freed for dispersal high above the ground. Inside front cover A paper-bark birch (Betula papyrifera) against a late-winter sky. At the tips of the branches are the male catkins, which will open in early spring, freeing the abundant yellow pollen. Inside back cover A European beech, Fagus sylvatica 'Tortuosa', above Bussey Brook. This mature specimen differs from the species only in its dwarfed and contorted habit. Facing page Mature American beeches (Fagus grandifolia) at the base of Bussey Hill. Back cover The flaring trunk of the dawn redwood, Metasequoia glyptostroboides. The deep recesses mark the location of low branches that developed when the tree was younger. Most of these branches have since died and fallen away, but the trunk has not yet grown over their scars.

All photographs on the covers, as well as most of those in this issue, were taken within the Arnold Arboretum and generously lent by Istvan Racz, a member of the team working on "The Dendrological Atlas of Hardy Trees and Shrubs" in cooperation with the author, Zsolt Debrezyi. From the Botany Department of the Museum of Natural History, Budapest, Hungary, this group has been working in the Arboretum for the past year.

CURATING THE LIVING COLLECTIONS

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The Mission of the Arnold Arboretum

The Arnold Arboretum is held in trust by Harvard University according to the terms of the Indenture of Trust of 1872. This legal document provided for the creation of the living collections as a practical demonstration of the variety of plants that could be grown in this climate. It also mandated the appointment of the Arnold Professor to manage the Arboretum and to teach the knowledge of trees and related topics.

Although there have been many significant changes in the fields of botany and horticulture and the Arnold Arboretum itself has fulfilled many different purposes during the past century, the basic premises of the Indenture still hold. It is most appropriate to reemphasize the traditional strengths of the Arnold Arboretum through a strong focus on botany and horticulture.

The mission of the Arnold Arboretum may be outlined as follows:

(1) to develop, curate, and maintain a well-documented collection of living woody plants from around the world that are hardy in the Boston area;

(2) to study these plants and their relatives and associates in nature through the maintenance of a herbarium and library and through directly related research in botany and horticulture;

(3) to provide instruction in botany, horticulture, dendrology, and other fields related to the living collections.

As part of the City of Boston's park system, the Arboretum's Jamaica Plain site functions as an outdoor museum open to the public. The highest priority of the Arboretum's administration is the proper curation and maintenance of these living collections. Proper curation includes acquisitions through field expeditions and exchanges with other institutions as well as cultivation and propagation of existing specimens to enhance and maintain the scientific and instructional value of the collections.

The second priority of the Arboretum, the study of its collections and their relatives and associates in nature, directly benefits the curation of the collections. The preserved collections and the library are indispensable tools for this research, and their curation and maintenance are therefore essential. All of the Arboretum's resources—the living collections, the preserved collections, and the library—are available for scholarly research. The director of the Arnold Arboretum is responsible for ensuring that adequate and up-to-date materials are available for present and future scholars to teach and to pursue research in the areas represented.

Educational programs are the Arboretum's third-highest priority. The Arnold Arboretum offers a variety of programs for public instruction in horticulture, botany, dendrology, and landscape gardening and, in addition, disseminates knowledge of plants through its publications. The director and Arboretum professional staff may also offer courses, as appropriate, within other academic programs of Harvard University.

Behind the Scenes at the Arnold Arboretum

David C. Michener

The living collections are emerging from a decade-long process of renewal and verification in anticipation of a new era of activity.

Why does the Arnold Arboretum have living collections? Whom are they to serve, and how? How do we determine if the collections are meeting their own policies and goals? Such fundamental issues must periodically be addressed—and action then taken to ensure that the goals are met. This issue of Arnol-dia, focusing on the curation of the living collections, describes the substantial review and upgrading of the Arnold Arboretum's living collections that began nearly a decade ago. A portion of the review has been called the "verification project," but the work accomplished has been far more extensive and provocative than the sum of the individual grants and projects.

In this issue are ten articles, written by the people most actively involved with the review, that describe distinct but interlocking parts of the purpose and operation of the Arnold Arboretum's living collections. Our living collections are unique both for the diversity of hardy, woody plant material they contain and for their documentation. They are an extremely complex resource to curate and maintain—and much of the complexity is not evident even to the most appreciative visitor. The articles that follow stand as a snapshot of our living collections in the late 1980's: why they exist, why we maintain them as we do, and how we, the staff, interact to ensure that the collections are capable of serving their many audiences. By necessity this issue has focused on the review of the living collections, so many functions and departments of the Arboretum are mentioned only in passing. It is designed to take you behind the scenes to reveal our policies and motives in working as we do to develop, maintain, and present the Arboretum's living collections that you support and enjoy.

In the first essay, Peter Raven, director of the Missouri Botanical Garden and former chairman of our Visiting Committee, addresses the societal importance of living collections. Next, Peter Ashton, past director of the Arnold Arboretum, presents his perspective of the impetus that prompted the review of our living collections during the last decade; it was during his directorship that the verification project was begun. Rounding out the historical perspective of the development of the Arnold Arboretum's own living collections is the contribution by Stephen Spongberg, research taxonomist.

The verification project itself is covered by Sandra Elsik, curatorial associate, and David Michener, research taxonomist, both of the Arnold Arboretum. Their complementary articles explain the steps involved in the vouchering and taxonomic review of the Arboretum's living accessions. Much of this work involved volunteers, and in recognition of the more than 6000 hours they have contributed to the project, an illustrated series of quotes, comments, and thoughts from the volunteers themselves illustrates how the living collections have been brought alive and made special to them.

Little of the verification work could have been accomplished or maintained were it not for the Arboretum's records office and the
extensive documentation maintained for well over a century. The records and mapping functions have been or are now being fully computerized. This is an enormously complex task for which there was no appropriate commercial software. Kerry Walter, director of botany and information systems at the Center for Plant Conservation, explains how and why he developed the computerized database called BG-BASE as an international effort, using the Arnold Arboretum's records as a complex trial system. Jennifer Quigley, curatorial associate in the plant records office at the Arnold Arboretum, describes the functions and interactions of that office, both at present and in days past. Ethan Johnson, curatorial assistant in the records office, outlines the history of our mapping system, as well as the ongoing computerization of our detailed inventory maps. The final article, by Gary Koller, managing horticulturist of the Arnold Arboretum, discusses issues in collections development and management under the restrictions imposed by a scientific collection.

This issue of *Arnoldia* will raise many questions, which is understandable since it is uncommon to explain the underlying curatorial policies and practices of a major collection to public audiences. We hope your appreciation of the Arnold Arboretum will be deepened, and that you will support the continuing development of our unique and exciting living collections—the heart of the Arnold Arboretum—and the programs associated with them.

David C. Michener directs the Arnold Arboretum's verification project.
The Value of Living Collections

Peter H. Raven

Living collections in botanic gardens and arboreta are precious assets that we maintain in trust for future generations.

We base our livelihood largely on our ability to understand plants and to use them for our purposes: the Earth yields its rewards most abundantly to those who cultivate it best. At a time when human beings are using, diverting, or wasting more than 40 percent of total terrestrial photosynthetic productivity, saving plants has been converted from a harmlessly amusing pastime to a matter of life and death. In a global population that has doubled in size since the early 1950s, more than a billion people exist in a state of absolute poverty, and half that many receive less than 80 percent of the United Nations-recommended minimum caloric intake each day. Their situation, and our sustainable use of the planet's resources, can be improved only by a more complete knowledge of plants.

Only a few hundred kinds of plants are currently cultivated on a wide enough basis to be considered crops in world commerce; of these, fewer than two dozen provide more than four-fifths of human caloric intake. Surprisingly in the face of these numbers, however, economic botanists estimate that tens of thousands of kinds of plants may be usable as sources of food, and that many more could potentially satisfy the need for the fuel that supports the energy requirements of fully 1.5 billion people—well over half of those who live in the warmer regions of the globe. As devastation spreads through the remaining half of the Earth's forests and carbon-dioxide loading in the atmosphere accentuates the greenhouse effect, people are becoming increasingly concerned with the kinds of plants that they may be able to use to reforest the cleared areas and thus contribute to a sta-

Franklinia alatamaha, once endemic to a single location in Georgia, is extinct in the wild and is now seen only in cultivation. Although the majority of endangered plant species are in the tropics, Temperate Zone botanical gardens and arboreta can help preserve their climate's endangered species in living collections. Photograph courtesy of Rác and Debreczy.
ble and relatively prosperous world in the future. Nearly half of our prescriptions contain molecules initially derived from plants or microorganisms, yet only a very small percentage of such organisms have been examined for such useful products. The opportunities for future development, especially given the potential of genetic engineering, are virtually limitless. In this whole process, living collections, because of their accessibility and the potential for repeating diverse scientific observations on single, specified individuals, are of special importance.

With more than a quarter of the world's 250,000 species at risk of extinction over the next 20 years or so, it is a matter of great satisfaction that perhaps 75,000 species of plants are already in cultivation—most of them only in botanical gardens or arboreta. Even though in most cases these plants do not represent genetically adequate samples, they are protected to some degree in the gardens and do constitute a resource of incredible importance to future human progress. Unfortunately, most samples represent temperate plants, and a much smaller proportion of tropical and subtropical floras is currently cultivated. This situation should be rectified as a matter of urgent priority by the formation and world support of a network of tropical botanical gardens and seed banks, and it is encouraging that the International Union for the Conservation of Nature and Natural Resources is pursuing just such a goal. Even for the plants of temperate regions, however, the preservation of adequate samples is of critical importance, and many species will disappear forever within the next few years unless they are accorded special attention.

Building a stable world a century from now will be a daunting task, but the plants that we save in our time will constitute a major resource for this purpose. Viewed in this light, our living collections are precious assets, to be cherished and augmented not only because of their current usefulness, but for the sake of our children and grandchildren. In drawing wider attention to their potential, the current number of *Arnoldia* performs a valuable service; the implications of its message should be brought to the attention of policymakers at all levels because of their urgent importance for us all.

Peter H. Raven is the director of the Missouri Botanical Garden and an internationally prominent conservationist.
The Genesis of the Arboretum's Restoration and Verification Projects

Peter S. Ashton

The curatorial review of the Arboretum's living collections, although thoroughly modern in scope and method, is rooted in the original design by Sargent and Olmsted.

Some years ago, encouraged by the rediscovery of the original Olmsted plans, I wrote an essay (see Arnoldia, Volume 39, Number 5, pages 330–343, 1979) endeavoring to show that what Sargent and Olmsted had in mind when they created the Arnold Arboretum in the nineteenth century is consistent with its modern functions as a university educational and research collection and a public amenity. My interest was to define a curatorial policy, particularly an accession and deaccession policy, that would once again reconcile these potentially conflicting purposes and at the same time honor the historical landscape design. The uniqueness of the original concept of Arnold’s Arboretum is now recognized by its status as a National Historic Landmark, and we should do well to respect that.

Our inspection in the late 1970’s of the maps of current holdings confirmed that major plantings from the days of Sargent and Olmsted still provided the backbone of the living collections. Their family groupings, arranged along the principal drive according to Bentham and Hooker’s botanical classification, still not only suit the needs of botanical classes and researchers who require rapid access but also—and this is often not appreciated—are basic to Olmsted’s way of using trees in the landscape. Olmsted, following eighteenth-century English tradition, used copses and hangers of trees of similar form, rather than individuals, to set off the natural folds of the land as viewed from his majestic road system. Thus the Arboretum, though serving primarily an academic rather than a recreational function, was nonetheless part of an aesthetic unity with its stately neighbor, Franklin Park.

Unfortunately, though our propagation and location records were still superbly maintained, the confirmation of the identity of each accession had become less consistent and rigorous after the retirement in the 1940’s of Sargent’s celebrated collections taxonomist, Alfred Rehder. This was potentially serious, because without accurate identification of the plants the collections lose much of their academic utility. Errors in identification can arise by several means. Woody plants in cultivation can differ vastly in phenotype from their sibling plants in nature, leading to subsequent questions of identity. Earlier in this century cultivated material was obtained from other gardens and nurseries, and all too often it consisted of garden hybrids, backcrosses, and sports not found or persisting in nature. In addition, mix-ups can arise in the nursery if labels or locations are inadvertently switched and the error is not caught before the stock is planted in the permanent collections. Finally, confusion and redundancy can result
Mature trees of Cedrus libani in their native habitat near 1500 meters above sea level in the Taurus Mountains of Turkey. Photograph courtesy of Rác and Debreczy.

if the scientific nomenclature is not kept current or if inadequate attention is paid to reconciling botanical and horticultural names, which sometimes differ since they are covered by separate international codes of nomenclature.

In 1979 our preliminary surveys had already allowed us not only to confirm the contemporary validity of Olmsted and Sargent's scheme, but also to seek the assistance of the National Science Foundation in restoring the living collections to their former status as one of the world's best-curated living collections of woody plants. We can now say that this goal has largely been achieved. Indeed, thanks to computer technology, our living collections are better curated than they have ever been before, setting a standard that is once again being followed by botanical gardens throughout the world.

What has contributed to the success of this multifaceted review is not only the inspired and dedicated staff, but—far less obvious yet equally important—their effective coordination and interaction in identifying and accomplishing complex tasks. These interactions,
through not always without some (ultimately resolvable) controversy, have truly been the key to the project's success. Information about our plant accessions must be entered and updated, and it must flow seamlessly among the plant-propagation unit, the plant records office, the herbarium, and scattered members of the curatorial and maintenance staff. In a real sense, the computerization of the records was only an electronic modernization of exist-
ing channels of information flow, rather than the imposition of an experimental administrative structure.

The restoration of the living collections at the Arnold Arboretum and the reevaluation of curatorial procedures have come at the right time. The increasingly pressing need for gardens to play their part in saving species from extinction can only be achieved if the gardens maintain precise and comprehensive records. It is therefore no accident that the National Center for Plant Conservation, Inc., decided to establish its national headquarters at our Hunnewell Building. Furthermore, the imminent revival of tropical botanical gardens as tools for the introduction of new plants for contemporary development needs will certainly call on the experience now gained by our and other Temperate Zone botanical-garden staff, in propagation as well as in curation.

Living collections, even of long-lived plants, constantly change. Now, though, thanks to this dedicated team there is a defined policy—a curatorial template—against which future policy modifications must be consciously considered and measured.

Peter S. Ashton is a member of the Harvard University faculty and is a past director of the Arnold Arboretum. He is currently president of the International Association of Botanic Gardens.
Establishing Traditions at the Arnold Arboretum

Stephen A. Spongberg

Charles Sprague Sargent’s early planting schemes and the collections he developed still form the backbone of the Arboretum today

Sargent and the Arboretum’s Beginnings

On the twenty-fourth of November, 1873, Charles Sprague Sargent was appointed director of the recently established Arnold Arboretum by the President and Fellows of Harvard College. On the twenty-sixth of November, he married Mary Robeson of Boston. Within the space of two days, Sargent’s life was forever changed and set on a new course. The thirty-two-year-old Bostonian had committed himself to what would soon become two lifelong devotions: one to trees and the development of the Arnold Arboretum, the other to his wife and their enduring family life at Holm Lea, their home in Brookline, Massachusetts.

When Sargent accepted the directorship of the fledgling Arboretum, he was also director of the now-defunct Harvard Botanic Garden in Cambridge and professor of horticulture at Harvard’s Bussey Institution. The latter department was located on land in the Jamaica Plain section of Boston, which Benjamin Bussey had bequeathed to Harvard College on his death in 1842, the year that Asa Gray, Sargent’s friend and professional mentor, had come to Harvard and the Botanic Garden in Cambridge. When James Arnold, a wealthy businessman and philanthropist from New Bedford, Massachusetts, died in 1868, he left a portion of his residual estate to three trustees and thereby set in motion the series of events that would result in the establishment of another Harvard-affiliated botanical institution. After Arnold’s trustees had completed their negotiations with the Harvard Corporation, they agreed that the Arnold bequest would be transferred to the permanent trusteeship of the Corporation and that the income would be utilized for the establishment and support of an arboretum, to be known as the Arnold Arboretum.

With a small income from the trust to devote to the Arboretum’s development and 137 acres of the Bussey estate to use as its site, Charles Sargent was faced with the task of
bringing together a living collection of plants from all accessible corners of the earth for trial in the new Arboretum. The indenture of the institution, which had been drawn up and agreed upon by Arnold’s trustees and the Harvard officials, clearly outlined the purpose of the first university-affiliated arboretum. Both parties hoped to see a comprehensive collection of trees established that would stand as a living museum. Specifically, the indenture stated that “as far as is practicable, all the trees, shrubs, and herbaceous plants, either indigenous or exotic, which can be raised in the open air . . .” would be grown, and this all-encompassing collection should “be raised or collected as fast as is practicable. . . .”

With this overwhelming responsibility, it is in retrospect astounding that anyone was willing to undertake the directorship. Yet Sargent was ambitious and eager to begin the experiment. Wisely, and undoubtedly with approbation from Professor Gray in Cambridge, Sargent immediately narrowed his focus to include only ligneous taxa—trees, shrubs, and woody climbers—plants that would be the expected emphasis if the young institution was to develop into an arboretum, which is by definition a place grown with trees. Moreover, a rationale for this early policy decision was based on the fact that the seven-acre Botanic Garden in Cambridge comprised collections of herbaceous plants systematically arranged in family beds. What the University clearly needed was a collection of ligneous plants to complement the collections in Cambridge. Duplication of effort would result if the Arboretum focused on herbaceous plants, and the space required for establishing plantations of trees was available at the Jamaica Plain site, not in Cambridge.

Fortunately, Sargent had not only the backing of Asa Gray in this early departure from the letter of the law, but also his respect and friendship. As the foremost American botanist of his generation and for thirty years the director of the Botanic Garden, Gray had inaugurated Sargent’s botanical and administrative career when he engineered the young Brahmin’s appointment as his successor at the Botanic Garden. As Gray’s protégé, Sargent had been introduced to the network of American botanists and naturalists who turned to Gray as the ultimate botanical authority in North America. By means of letters of introduction and by virtue of his stature as dean of American botanists, Gray also provided Sargent with an entrée into European botanical and horticultural circles. On their honeymoon trip the Sargents sailed to England and traveled on the Continent, where they were cordially welcomed to Europe’s botanical gardens and museums, and where the foundations of many lifelong friendships with European plantsmen were laid.

Basing himself initially in the estate office at Holm Lea, Sargent launched into a prolonged planning phase for the Arboretum after returning from Europe in 1874. His first step was to inventory the trees that were growing naturally on the topographically diverse Jamaica Plain property. These trees ranged from the native hemlocks on Hemlock Hill, then known as Bussey’s woods, to the native stands of oak and hickory woodlands that had survived on several of the glacial drumlins, sites that in earlier years had proven inappropriate for Bussey’s fields or orchards.

The Early Development of the Living Collections

The trees and shrubs native to New England but not indigenous to the Arboretum probably constituted Sargent’s first list of desiderata. Exotic species growing in the Botanic Garden in Cambridge were also propagated for establishment in Jamaica Plain and were among the first accessions to be planted in the Arboretum. The early records indicate that Sargent began an active correspondence with the curators of European botanical gardens and nurserymen in England, France, and Germany, and many of the species long cultivated in Europe were thus established in the Arboretum nurseries for eventual transfer to the Arboretum grounds.

Sargent’s real emphasis during the first two decades of his directorship, however, was on gathering a collection of native American
trees and shrubs. Indeed, the diversity of American species was to form the backbone of the collection; Sargent based his planting plan for the collection he intended to obtain on the number of taxa known from North America and allocated space for each genus and family accordingly. In this work Sargent was again indebted to the influence of Asa Gray, who had recommended that he be given the responsibility of preparing a census report of North American trees for the United States government.

Prior to Sargent's benchmark contributions to the Tenth Census of the United States (embodied in his Report on the Forests of North America), information concerning the extent, condition, and species composition of American forests was largely conjectural. A study of forests of the scope of Sargent's had never before been undertaken, and no comprehensive flora of North America, let alone of the United States, had been published. But having a governmental appointment and the ability to travel the length and breadth of the North American continent with a view to collecting information, specimens, seeds, and cuttings for propagation, Sargent gathered a massive amount of pertinent data. As an indirect result of these activities, an extremely wide range of trees and shrubs from every region of the United States and Canada were soon incorporated into the Arboretum's living collections. Sargent had the assistance of a cadre of highly capable correspondents across North America in his census work, and hundreds of pleas for seeds of locally common as well as little-known species, many of narrow range, accompanied his steady stream of requests for data on the forest resources of various regions. Among his correspondents were such great botanists, plantsmen, and naturalists as George Engelmann in Missouri, Charles Mohr in Alabama, Michael S. Bebb in Illinois, Thomas Meehan in Pennsylvania, John Muir in California, Reginald Cox in Louisiana, and John Harbison in North Carolina. Due to their tireless efforts coupled with Sargent's, the living collections of the Arnold Arboretum began to become comprehensive in scope.

Encouraged by the results of his census work, Sargent began work on a natural extension of the project, and by 1890 a prospectus for his Silva of North America announced that this monumental undertaking would be published complete in 12 quarto volumes and illustrated with 600 plates. After the twelfth volume had appeared in as many years, however, two supplementary volumes were announced, which were needed to accommodate new species (primarily hawthorns) that had been discovered during the course of the work.

Acquisitions from Overseas
Sargent was occupied for more than a decade in the preparation of the Silva but still found time to stay abreast of botanical developments overseas, and he took every opportunity to broaden his network of correspondents to include botanically inclined residents of foreign lands. By 1878 this network had been enlarged to include William Smith Clark on the northern Japanese island of Hokkaido. In 1882 correspondence was inaugurated with Emil Bretschneider, a Russian physician who was stationed in Peking (Beijing), and during the last decade of the nineteenth century Sar-
gent was posting letters to Augustine Henry, an Irishman employed by the Chinese Imperial Maritime Customs Service and living in Ichang, a town on the banks of the Yangtze River in Hupeh (now Hubei) Province of central China.

With much of his personal field work in the forests of North America completed, Sargent turned to eastern Asia as the next region he meant to explore in his continuing quest for woody plants to stand trial as cultivars in the Arnold Arboretum. This decision was based in part on the successful acclimation of Arboretum plants that had been grown from seeds sent by his Asiatic correspondents. The new direction was also based on Sargent’s theoretical knowledge of the close phytogeographical relationship between the floras of eastern Asia and eastern North America, a biogeographic phenomenon that had first been fully investigated by Asa Gray in the middle of the nineteenth century.

Although Sargent traveled to Japan in 1892, personally surveying Japanese forests and making extensive collections of seeds and specimens, he did not visit China until he was in his sixty-second year. In 1903 he undertook a world tour but spent only brief periods in China, Korea, and Japan. Sargent returned to Boston, however, fully aware that he personally would be unable to undertake the time-consuming and arduous field work necessary to begin to understand and catalogue the ligneous flora of the Chinese empire. John Jack, Sargent’s right-hand man at the Arboretum, traveled to eastern Asia in 1905, and as Sargent had before him, he returned to the Arboretum with seeds and specimens of many Asiatic species never before cultivated in North America.

**Ernest Henry Wilson’s Expeditions to China**

In 1907 Sargent was finally successful in finding an explorer and naturalist who had previously proven his worth as a collector in the Middle Kingdom and was willing to undertake additional botanical and horticultural exploration in China. Ernest Henry Wilson, who had completed two expeditions in central and western China for the English nursery firm of Veitch, agreed to undertake a third expedition, this one under Arboretum auspices.

Wilson’s exploits on all four of his Chinese expeditions—the fourth, in 1910–11, was also sponsored by the Arboretum—are well known in the annals of botany and horticulture. Not incidentally, they had an enormous impact on the living collections of the Arnold Arboretum. Quantities of propagation material of many new plants arrived in Jamaica Plain from China, and the onus fell to the greenhouse staff to coax the seeds to germinate and the cuttings to root. Confronted with unknown material whose germination and cultural requirements had to be determined by trial and error, Jackson Dawson and his crew in the greenhouse had results as exceptionally fine as Wilson’s in the field.

When Wilson’s plants needed to be moved from the nurseries into the permanent collections, Sargent was faced with the fact that certain groups had not been allocated sufficient space in the overall Arboretum planting plan. The problem was that the Chinese and other Asian species of many groups had not been known when the planting plan, following the Bentham and Hooker classification, was devised, and Sargent and Frederick Law Olmsted had been unable to anticipate the floristic wealth of central and western China. But Wilson’s bountiful harvest was too good to be wasted, and exceptions to the original planting rules had to be made to accommodate the many new species that required testing in Boston’s climate. One parcel of land, which had recently been added to the Arboretum acreage on the south-facing slope of Bussey Hill, was given over to many of Wilson’s Chinese plants and is known today as the Chinese Walk.

**Sargent and Rehder Document the Collections**

While Charles Sargent was aggressively developing the living collections during the early years of the Arnold Arboretum, he was
also identifying most of the accessions, the majority of which were of known wild provenance. Sargent was a practicing taxonomist, deeply involved with the woody plants of North America, and the leading dendrologist of his era. Many others sought his advice in matters of identity and nomenclature, and he was extremely careful that the collection for which he was responsible would be correctly named and labeled. Moreover, he had described many of the taxa involved, and some of the individuals growing in the Arboretum collections were the very plants from which type specimens had been gathered.

Of the accessions received from European botanical gardens and nurseries, many comprised so-called “authentic” materials, meaning that the species involved had been described by the donating correspondent, or—as in the case of garden forms—the cultivar had originated and been selected and named by the contributing nursery. Lemoine hybrid lilacs and mock oranges come immediately to mind as examples. Although many of these are only of historic interest today, the original plants or their asexually produced propagants are still growing in the Arboretum collections; they serve as living reference points for the garden forms popular during the decades surrounding the turn of this century.

The identities of the Asian species that literally poured into the Arnold Arboretum as the result of expeditions by Sargent, John Jack, and E. H. Wilson were largely determined by Arboretum botanists who worked in the library and herbarium located in the Museum Building. Alfred Rehder, German born and a
The Bentham and Hooker Planting Sequence in the Arnold Arboretum

When confronted with the problem of how the various accessions of woody plants were to be positioned in relation to one another in the Arnold Arboretum, Charles Sargent and Frederick Law Olmsted chose to superimpose the natural classification system of Bentham and Hooker on the Arboretum landscape as a guide for the planting plan. In essence, Sargent and Olmsted intended to indicate the natural relationships between the various genera and families of plants represented in the Arboretum’s collection by placing related groups in close juxtaposition, thereby increasing the educational value of the collection and allowing for easy access and botanical comparison. The system they chose to follow was one widely accepted by British and American botanists toward the end of the nineteenth century, which had been proposed by George Bentham (1800-1884) and Sir Joseph Dalton Hooker (1817-1911) in their monumental three-volume publication, Genera Plantarum. Bentham and Hooker were leading English systematists during the nineteenth century and conducted their botanical investigations at the Royal Botanic Gardens at Kew, where Sir Joseph had succeeded his father, Sir William Jackson Hooker, as director. The Genera Plantarum, published in Latin between the years 1862 and 1883, accounted for all of the genera of seed plants then known to science and included precise descriptions of each. These genera were grouped together based on their overall similarities into “cohorts” (a grouping equivalent to today’s plant family), and the cohorts were similarly grouped into orders, classes, and three major subdivisions: dicots, gymnosperms, and monocots.

Following the Bentham and Hooker system, plants producing flowers with separate or free floral parts were thought to be less advanced, or more primitive, than those producing flowers with united parts. The magnolia family, the Magnoliaceae, was considered one of the least derived groups of plants. Consequently, the magnolias and the closely related tulip trees were established near the Museum Building (now the Hunnewell Visitors’ Center), where the planting sequence begins. Progressing through the collection from the Arborway Gate, one finds plant families of increasing morphological complexity (complexity that sometimes includes reduction, connation, or loss of floral parts). The conifers, which Bentham and Hooker placed together in a distinct group between the dicots and monocots, came last in the Arboretum’s planting plan and were located along Bussey Brook at the end of the original road and pathway system. Inasmuch as there are few woody monocots, Sargent and Olmsted could end their planting sequence with the conifers, and as if by a stroke of luck, the grove of native hemlocks on Hemlock Hill fell into place in the planting scheme.

Except for constraints placed on this plan by the ecological requirements of certain groups of plants, each cohort or family was allotted space in the Arboretum in a more or less linear sequence. Exceptions included the placement of the willows adjacent to the low-lying ground of the meadow, and the inclusion of ericaceous shrubs and flowering dogwoods in many locations because of their aesthetic appeal and their ability to knit the collection together into a harmonious whole.

Over the years the Bentham and Hooker planting scheme has not always been strictly followed. Beginning in the early 1980’s, however, restoration of the collections following the original plan has proceeded, so that today the major groupings in the collection adhere to the historic Bentham and Hooker classification.
self-taught taxonomist, arrived at the Arboretum in 1898 and was first employed to weed the shrub collection. Sargent, however, quickly recognized Rehder’s keen taxonomic judgment and facility with languages. Moving Rehder indoors, Sargent gave him the enormous task of assembling the bibliographic data required for the Bradley Bibliography, a five-volume, 3895-page publication that brought together references to all of the literature on woody plants published up to 1900.

At the same time he was involved with the Arboretum’s monumental bibliographic project—an undertaking that required a prolonged sojourn across Europe to visit libraries—Rehder was preparing the articles on the important woody genera for Liberty Hyde Bailey’s Cyclopaedia of American Horticulture. This work required intimate taxonomic knowledge of genera ranging from Abelia to Zenobia and Zizyphus. When E. H. Wilson’s shipments of dried, pressed specimens, which simultaneously documented his seed collections and the ligneous flora of central and western China, arrived at the Arboretum, Rehder’s interest in Asian plants was immediately aroused. He eagerly turned his attention to those rich and ample collections.

Plantae Wilsonianae, a three-volume publication edited by C. S. Sargent, resulted from the herbarium and library studies involved in naming Wilson’s plants. Although Sargent served as editor, Rehder did the bulk of the work required in preparing the taxonomic treatments of the genera represented by Wilson’s collections. In many instances Plantae Wilsonianae gave synopses of all the Asian representatives of a particular genus. Wilson himself contributed to the monumental effort, as did specialists in Europe. Thus the foremost authorities of the day identified Wilson’s Chinese plants now growing in the Arboretum and reviewed the pertinent nomenclature to determine their correct names. In many instances they established new taxa based on Wilson’s collections, and living plants grown from Wilson’s seeds were represented in the Arboretum’s living collec-
tions. The botanical descriptions published for these plants relate both to Wilson's specimens filed in the herbarium and to the growing accessions in the living collections. By 1920 the collection of living plants that Sargent was responsible for bringing together on the Arboretum's Jamaica Plain site was truly a comprehensive living museum of the ligneous flora of the North Temperate Zone.

With Sargent's death in 1927 and Wilson's tragic, premature death in 1930, the influx of plant materials intended for the living collections and generated by Arboretum-sponsored collecting trips slackened, but the ongoing curation of the living collections continued. Rehder had begun a card catalogue listing published references to north-temperate woody plants as he worked on the Bradley Bibliography. This index, which is referred to by Arboretum staff as the "Rehder Cards," was maintained throughout Rehder's lifetime, with the result that changes in taxonomic interpretation and nomenclature were constantly monitored. Those changes that pertained to plants in the living collections were noted by Rehder and Clarence Kobuski (Rehder's assistant in the herbarium) and given to the appropriate staff, who made the necessary changes in the living-collections records and on the labels on the grounds.

Another outgrowth of Rehder's ongoing involvement with the taxonomic aspects of woody north-temperate plants was his Manual of Trees and Shrubs Hardy in North America Exclusive of the Subtropical and Warmer Temperate Regions, the first edition of which was published in 1927. This treatise, based to a great extent on the Arboretum's living collections, quickly became the bible of horticulturists and nurserymen in the United States and abroad. Because of the great number of Chinese species described and included in its keys, the Manual also became the guide to woody-plant identification most frequently consulted by botanists in China! A second edition of the Manual appeared in 1940, and a concerted effort was then made to ensure that the identities and names of the plants in the Arboretum's living collections agreed with the treatments in the book. This task, undertaken by Rehder and Clarence Kobuski, constituted an earlier, comprehensive effort similar in purpose to the current National Science Foundation-funded project reported upon in this issue of Arnoldia.

After his retirement from the Arboretum in 1940, which occurred four days before his seventy-seventh birthday, Rehder continued to work in the library and herbarium and once again turned to bibliographic work. The result of his final labors, which were based on his all-inclusive card file of literature references for woody north-temperate plants, was his Bibliography of Cultivated Trees and Shrubs. Published in 1949, a little more than a month before his death, Rehder's Bibliography provided references for the accepted names and listed synonyms of each species and infraspecific taxon treated in his Manual. Also included were the names and synonyms of species new to cultivation—plants like Metasequoia glyptostroboides—that had been
The Arnold Arboretum’s goal is to cultivate all those woody plant species and their infraspecific taxa hardy enough to withstand the climate of the Boston Basin [Massachusetts]. Three individuals of each species are to be grown, and an attempt is made to include individuals originating from different points within the geographic range of the species to ensure genetic and phenetic diversity. Plants of documented wild origin are highly preferred to those of nursery or garden origin. Although the collections of the Arnold Arboretum are not complete by these standards, work continues towards the acquisition and maintenance of a collection that is as comprehensive as possible.

(Compiled from the Collections Policy published in Arnoldia, Volume 39, Number 6, pages 370–376, 1979.)
gave priority to obtaining authentic material from the originators to ensure correct identity. Since the names of cultivars are not as tightly tied to documenting specimens and published descriptions as are those of entities given botanical rank, errors are more frequent and determinations, often subjective, are more difficult to verify. With these considerations in mind, the Arboretum decided in 1979 to embrace an accessions policy that placed restrictions on the acquisition of cultivars and to reassert a collection policy that emphasized botanical taxa.

Until the current National Science Foundation–funded verification project began, Arboretum taxonomists continued to make annotations to the cards in the living-collections file in an unstructured fashion when undertaking revisionary, monographic, and floristic studies. Clarence Kobuski, who succeeded Rehder as herbarium curator, continued to survey new materials intended for the living collections to determine if they were accurately identified. A new system with regard to nursery materials was inaugurated after the Arboretum acquired the Case Estates property in Weston, Massachusetts. It became customary for the horticulturists to move plants to nursery rows in Weston after they had achieved an appropriate size in Jamaica Plain. Once in Weston, the plants were allowed to grow until they had flowered and fruited, at which time their identity could be checked for accuracy. Only after this precautionary step had been taken were the trees or shrubs in question placed on a planting list for establishment in their permanent location in Jamaica Plain. In more recent years this practice has been followed to a lesser extent, primarily because of the greater ease of growing materials in containers. As a result, most Arboretum nursery stock remains in Jamaica Plain until it is planted in a permanent location.

Several former staff members have been instrumental in living-collections development and the curatorial aspects associated with taxonomic and nomenclatural review. Carroll E. Wood has contributed greatly to the curation of the plants of eastern North America, a labor of love that has been an outgrowth of his efforts toward a Generic Flora of the Southeastern United States. Peter Green conducted in-depth studies of numerous genera of Oleaceae and Ulmaceae, while Richard A. Howard, Donald Wyman, Paul Sorensen, Burdette Wagenknecht, T. R. Dudley, Robert Hebb, and Gordon DeWolf made extensive annotations in the records as they discovered errors in identification or changes in nomenclature during their tenures at the Arboretum.

Current Arboretum staff continue to monitor nomenclatural changes and taxonomic revisions and to annotate the living-collections records accordingly. They have also played a major role in helping to develop the computerized format for the collections data and to inaugurate the N.S.F.-funded verification project. It is highly appropriate that the nomenclature and taxonomic identity of this historically and scientifically significant collection be reviewed as the living-collections records are computerized; the data contained therein will be available in a multitude of new formats for all those interested in the woody plants of the North Temperate Zone. Charles Sargent, Ernest Wilson, and Alfred Rehder would be pleased.

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From Each a Voucher: Collecting in the Living Collections

Sandra Elsik

Arboretum volunteers have been instrumental in collecting and organizing voucher specimens for verification

Tracking Down the Accessions
In January, 1984, the verification project presented us with the challenge of collecting multiple voucher specimens from over 14,000 accessioned, or catalogued, plants on the 265 acres of the Arnold Arboretum. How were we to organize, implement, and complete this monumental project within the six years granted by the National Science Foundation? Taking Director Peter Ashton’s suggestion to enlist the aid of volunteers for collecting specimens, we recruited, trained, and organized a large group into crews of three, each crew working three-hour shifts.

We made a priority list of genera to try to collect during the first season; it consisted primarily of those that were to be identified by an out-of-house authority. We decided to collect from only one plant within each accession lot. Although we began collecting from the horticultural cultivars, we later discontinued that practice to concentrate on the naturally occurring species and variants. In an effort to avoid revouchering accessions, we began a tedious, methodical herbarium search to record existing voucher specimens. We found so few that we abandoned the effort. Volunteers later resumed the search, looking for specific vouchers.

We knew the Arboretum had a good series of grid maps, with each accessioned plant’s location clearly marked. (See the article on mapping by Ethan Johnson.) I developed a color-coded system of symbols that manually tracks each plant’s collection status on the project’s copies of both the maps and the printout (the Plant Sciences Data Center’s computer listing of accessioned plants in our collection). The status of record labels on the voucher specimens of Abies nephrolepis. Voucher specimens are cuttings taken from a plant, including leaves, flowers, cones or fruits, and other significant parts. In addition to preserving vegetative and reproductive characters for identification purposes, the specimens also document stages or aspects of the plant’s morphology as it existed at a particular date. Note that modern labels record much more information. Photograph courtesy of Rácz and Debreczy.
plants and the accuracy of the maps are also tracked on this system. We have known all along that our tracking system could be handled very easily on a computer, but BG-BASE was still in the planning stages and our project's deadline prevented us from waiting for the system, which is now on-line (see the article on BG-BASE by Kerry Walter). The manual tracking system was the precursor for that portion of BG-BASE that tracks voucher specimens.

Translating a specific map location into ground reality was not as simple as I had hoped. Due to years of being seriously short staffed because of financial problems, the living collections had become somewhat less than perfectly curated despite the best efforts of the curatorial staff. Some groups, such as the maples and the lilacs, were very well labeled and mapped; others were a nightmare. Record labels were missing or had "traveled" to the wrong plant; plants on the map were not on the grounds and plants on the grounds were not on the map; map locations were inaccurate; large, spontaneous plants of the target group had not been weeded out; and shrubs had layered into each other, making their separation extremely difficult. The volunteers spent a lot of time "smelling the flowers" while I tried to determine which specific plant we needed to collect. It was enjoyable for them but not very efficient, so solo trips became the way to sort out this multiplicity of records and mapping problems, make decisions, and place temporary labels on the plants. Although not originally perceived as a part of this project, such status verification, accomplished through field checks correlated with the study of both current and archival records and maps, was essential to the validity of the project: without accurate status information, any subsequent taxonomic verification is useless. Much-needed assistance to field-check and remap the densely planted areas at the top of Bussey Hill came in the form of a one-year Institute of Museum Sciences grant. At the completion of the grant, one of the curatorial assistants remained on the plant-records-office staff and has continued to field-check and remap major areas. Additional assistance came from summer student interns and volunteers in the plant records office. It still requires all of us working in cooperation with each other and with the horticulturist, the grounds supervisor, and the grounds crew to make the grounds and maps workable. (See the article on plant records by Jennifer Quigley.)

Making the Voucher Specimens
To collect and make the voucher specimens, we use a crew of three: a staff map person (usually me), a volunteer press person, and a volunteer label person. The map person must first locate the desired plant, find its record labels, and make sure that the map information agrees with the surrounding plants and their record labels. When finally satisfied that the plant under consideration is indeed the targeted accessioned plant, the map person must then determine if the plant is ready to collect. (Usually this means that the anthers of a flower are shedding pollen, or that a fruit has reached its final color and its seeds are mature. Flowers may be very ephemeral, last-
ing no more than a day or two. Later, we are often in competition with squirrels, birds, and even humans to collect the fruit.) The map person announces the genus name and accession number, which are written, along with the date, on both the margin of a newspaper sheet and a field-label form.

The first volunteer, serving as the press person, examines the plant for branches with an ample sampling of reproductive material and then makes cuttings for (usually) three specimens. These specimens, arranged to show upper and lower surfaces, are placed inside the labeled, folded newspapers and are folded or trimmed to fit and to reduce overlapping. Large fruits are sectioned to reduce bulk and to show internal structures. The specimens inside the newspapers are stacked alternately with sheets of corrugated cardboard (corrugates) to make a plant press inside the collecting cart.

Meanwhile, the second volunteer, the label person, fills out the field-label form, recording name, number, and location of the plant. Any characteristics not visible in the finished specimen, such as height, habit, and DBH, are recorded. The DBH, or diameter at breast height (four and a half feet above ground level), is measured with a special tape that converts a circumference reading into a diameter measurement. It is measured on the largest stem of the plant, a simple task except when the stem is protected by sharp thorns or prickles or by a dense growth of poison ivy. We need not record characters such as the number of petals or the kind of pubescence because they will be visible in the finished specimen. Characters that are altered in the drying process must be noted; for this reason our field-label form reminds us to indicate the color of various parts and the presence of glaucousness (waxy coating), scent, or exudate.

One early concern was our ability to reach the reproductive parts on tall trees. Fortunately, most of the trees produced flowers and fruits on limbs easily reached with our 12-foot pole pruner. For the exceptions, we were lucky to have the assistance of two members of our grounds crew, who reached the specimens for us in the bucket truck or by climbing the tree.

If there have been no major problems up to this point, the shift progresses with the press person collecting the specimens, the label person recording the necessary information, and the map person determining the next plant to collect. At the end of the shift, the press is strapped down securely and the cart is loaded into the back of the car. (As we approach the end of the project and the collecting within various plant groups is completed, we find ourselves moving around the grounds to collect from scattered plants rather than making many collections in a single area. Since it is difficult to move the cart over long distances, we now usually collect into field presses in the back of the car rather than use the cart.)

Back in our basement workroom, foam pads may be inserted between thick specimens to maintain pressure on the leaves so that they

The collecting cart stores maps, a clipboard with blank field-label forms, stacks of single-fold newsprint, the press ends and straps (threaded so that the rods will not be caught in the strapped-down press), cardboard corrugates, and other supplies. Within the cart, the stack of corrugates shrinks as they are used to build the press, here Sandra Elsik and Volunteer Sue Avery lower the shelf to allow more room for the growing press. With its flaps chained shut, the cart is easily wheeled to a nearby collecting spot. When the work shift is over, the press is strapped down and is easily removed. Photograph by David Michener.
Construction Details for Collecting Cart

Our collecting cart carries supplies and organizes work space for a three-hour work shift within a restricted collecting area. The box, of ¼" plywood (or aluminum, if weight is important), is bolted flush to the base of a hand truck. Internal measurements were calculated to provide tight fit for a standard herbarium press. The fixed wood top shelf is recessed to form a work surface with three sides. All other shelves are corrugates or the work materials themselves resting on pairs of ¼" metal rods that are longer than the width of the box. Rods, stabilized by a 90° bend at one end and a cotter pin through a hole in the other end, fit into paired holes in the box sides, allowing the shelves to be moved up or down. The flaps and chain allow access yet prevent supplies and the press from falling out. A pencil sharpener and a digital clock are glued on the upper exterior back of the box. Cart design by S. Elsik, construction by R. Famiglietti, illustration by Le-zhong Wang.

dry wrinkle free. The press then lifts right out of the cart, ready for tightening and placing on the dryer. Plant dryers can be constructed of various materials and in different configurations. Ours is a long, low, rectangular, plywood box, open at the top and bottom. It is bolted together and fitted with a strip of incandescent light bulbs that produce just enough heat to flow upward through the channels in the corrugates. This heated air gently dries the specimens over a period of two days to two weeks (depending on their resistance to drying).

The labeled newspapers containing the dried specimens are removed from the presses by our volunteers, who sandwich together all
the sheets from the same plant. Packaged in plastic, the specimens are frozen to kill any potentially harmful insects or their eggs. The packages are labeled by date of collection and stored in banks of herbarium cases.

Meanwhile, the field-label form is matched with the corresponding entry in the printout in order to record the collection and its date. Several things are checked for accuracy: the scientific name and its spelling, the accession number, and the location. Any discrepancies must be resolved before the labels can be processed. Also copied to the printout are any notes on the record label or map questions encountered in the field. Later all problems of this type are reported to the plant records office.

The field-label forms are passed on to the project typist, who looks up the immediate source information for the accession and the author citation for the name. All the information is then typed into a label-printing computer that creates the required number of herbarium labels. Processing the labels in batches by date of collection makes it easy to match them to their specimens, which were also stored by date. Volunteers assist again by inserting one label into each newspaper/specimen. Specimens are then sorted and stored, this time by genus, in another bank of herbarium cases.

Once the collections representing a genus are complete, or nearly so, all the specimens of that genus are sorted by accession number so that the flower specimen can be matched to the fruit specimen. All the specimens from a given accession lot are spread across the table, and the accession numbers on the newspapers and the labels are checked to make sure that they agree. The specimens are checked against "listgen," the list of vouchers that the label-printing computer says we have collected for the genus; occasionally we have to search for missing ones. The specimens are sorted into sets, each containing one flower and one fruit. One set is for the Arboretum, one is to be used as a gift for the out-of-house authority if any [in return for an identification], and others are for exchange with selected institutions. Corrections are made to listgen, which then serves as a packing list and a record of what specimens were sent to whom. Eventually listgen's data will be incorporated into BG-BASE. The sets are then packaged, refrozen, and mailed out-of-house or delivered to our herbarium for mounting by staff and volunteers. Finally they are ready for taxonomic verification. (See David Michener's article on verification.)

**Sorting out the Accumulated Confusion**

With the specimens distributed, the final task is to resolve the various problems now recorded in the project copy of the printout. The variety of difficulties that can occur—everything from missing record labels or transposed accession numbers to very complex problems that involve searching the "dead" card file and archival maps—is always amazing. With misidentified plants being received and multiple chances for confusion to occur, any accurate record is a triumph. (BG-BASE on our new computer system will help prevent the repetition of many of these same errors.) After trying several other methods, we have found that it is most efficient to relay the problems in an entire genus or family en masse to the plant-records-office staff. They then make the necessary changes to all the records and prepare any needed metal record labels for us to hang on the plants.

Having all the collection activity recorded on the project copy of the printout allows quick scanning of a genus to determine which specimens still need to be collected. Often the targeted plant cannot be found on the map; further searches may reveal that the plant died some time ago but was never cleared from the records, or that the plant is still on the grounds although its map entry has been inadvertently deleted. The most frustrating and unresolvable problem is the number of plants that do not flower, or that flower but do not produce mature fruits. Whatever the reason for this functional sterility, we must look at the plant again and again, season after season, on the chance that it will eventually become reproductive.
Susan Hardy Brown prepares herbarium specimens by gluing the pressed, dried material to archival-quality rag-paper sheets. Susan, formerly a volunteer and now a staff member, advises the volunteers who perform this specialized task. Photograph courtesy of Rácz and Debreczy.

When we have both the flower and the fruit specimens from a given accession, its accession-number entry is highlighted on the project printout with a yellow marker. Since the accession-number entries form a column of their own in the printout, our goal is to highlight the entire column. Any entry needing a specimen is marked with a color-coded sticker, which makes the scanning procedure even easier. Volunteers copy the highlighting and the collection stickers to the project maps. The map stickers are especially helpful in seeing at a glance what is needed from a particular map. Often we write the expected date of collection on the sticker. Our volunteers particularly enjoy copying the highlighting to the maps, since it means that one more plant’s collections are complete. The goal is to highlight the entire map. As this process nears completion, occasionally a plant turns up on the map (and the grounds) that is not in the printout or the “live” card file—just one more way in which the dual tracking system allows us to double check, or verify, the
accuracy of our record entries. The concluding map procedure will be to compare our project maps to the official plant-records maps to assure that they are in agreement.

Realizing Our Goals and Looking to the Future
As the 1988 collection season came to a close, our collection goals, as originally defined, were essentially complete. We have made a total of 7480 collections averaging three sheets apiece. Immature plants, most cultivars, and certain hybrids were excluded. Now our volunteer crews eagerly anticipate fresh computer-generated lists and maps, complete with collection markers, as we begin collecting specimens from newly maturing plants as well as those previously sterile.

Highlights of five years of field-checking, status verification, and detective work have included resolving major problems with accessions on Peters Hill, in the Center Street Beds, in the Weld Street Tract, and along Linden Path. A variety of special collections, such as the honeysuckle family, the legume family, the rose family (especially the cherries, hawthorns, and mountain ashes), the hollies, the rhododendrons, and the willows presented complex mapping and records problems. As a result, by the end of the grant period, 1743 missing plants, 1346 plants needing record labels, and 1349 other miscellaneous problems will have been reported to the plant records office. There remain a few plants, mostly vines on fences, that are still mapping or records mysteries.

Working on the verification project has been very satisfying. Breaking the project into small parts gave us a multitude of small goals to accomplish and provided important built-in rewards for both staff and volunteers. Our achievements (complementing the work of the plant-records-office staff and everyone else working with our living collections), plus implementation of BG-BASE, have helped us realize an exciting and long-sought objective. How rewarding it is to be out collecting in an area that had previously been a problem and to be able to find our targeted plant, complete with record label, exactly where the map says it should be! Our future visitors, whether amateur plant lovers or professional plant researchers, will be able to access and use our living collections with ease and confidence.

Sandra Elsik supervises the collecting phase of the verification project.
Volunteer Keepers of the Arnold Arboretum: Effective Program Design Yields Reciprocal Benefits

Jeanne Christianson and Sandra Elsik

“Working in the program has transformed me from a devoted but passive domestic gardener into a fervent disciple of horticulture.”

Structuring for Success

This quote by volunteer Mary Harrison captures the spirit of commitment felt by the many individuals who, with their contribution of time, support the curation and management of the living collections at the Arnold Arboretum. In three separate but interrelated areas, they have collected specimens for the verification project, field-checked for the plant records office, and mounted specimens in the herbarium. Other dedicated volunteers work on virtually every aspect of the Arboretum. (See past and future issues of Arnoldia for articles on their work.) Although only about half of the Arboretum’s volunteers are described in this article, we are deeply indebted to all of them. Using the words of the volunteers themselves, we hope to make others aware of how much our volunteers have contributed and express our gratitude for their tremendous help.

There is no typical profile of the Arnold Arboretum volunteer; their backgrounds and interest in the program differ greatly. This diversity has added an element of interest and enjoyment for everyone involved. The group includes retired people now studying botany, horticulture, or home gardening as a second career; avid home gardeners who desire to help a worthwhile institution while gaining useful knowledge and contact with a professional staff; people working in related careers (as landscape designers, nurserymen, or arborists) seeking to enhance their knowledge of plants; others (secretaries, nurses, administrators, or homemakers/mothers of young children) who are involved in unrelated careers but are seeking a balance in their lives; and a few who simply enjoy the altruistic satisfaction of helping a worthwhile institution.

“To contribute in any small way to help at the Arboretum is rewarding to me,” reported Helen Hagopian. Some go to great lengths to find the time to help: one volunteers on his vacation days, one day at a time; a few work on limited weekend shifts. The amount of time worked by each volunteer ranged from ten to hundreds of hours. Many have become devoted to the Arboretum: some have worked in more than one area and ten have participated for the entire five years covered by this article.

Of the three interrelated areas, the verification project has required the most massive input of volunteer hours. (See the article on collecting by Sandra Elsik.) Without volunteer assistance, the project would have taken many years and been prohibitively costly. Fortunately, working with the plants on the grounds has proven a highly desirable volunteer position, so there has never been a shortage of enthusiastic assistants; since January, 1984, 84 volunteers have worked a total of 6809 hours. They have collected herbarium specimens, gathered the data needed for the specimen labels, and performed numerous less-excit ing, but equally important, associated indoor tasks. During the collection
phase of the verification project, teams of two volunteers and one staff member have worked a regularly scheduled three-hour shift each week of the collecting season. The number of volunteers needed for collecting has steadily decreased as this phase of the project has neared completion. The first collection season, in the spring of 1984, required 38 volunteer assistants; in the fall of 1988, only 13 were needed to collect the few remaining specimens.

In the plant records office volunteers have field-checked countless acres of the grounds, replacing damaged and missing labels and helping to provide the information necessary to the curation of the collection; they have assisted in records retrieval and maintenance and in the updating of nomenclatural reference files. Nine volunteers have worked in this department, three of them for the entire five years. (See the article on the plant records office by Jennifer Quigley.)

In the herbarium 15 volunteers have mounted herbarium specimens. The process of arranging and gluing a dried specimen onto a sheet of archival paper is meticulous and time consuming, requiring artistic and scientific sensitivity as well as great patience. It does, however, offer the opportunity to examine a number of interesting plant specimens closely. Elaine Foster noted that "volunteering... has made me much more aware of what goes on in an arboretum and given me a greater appreciation of plants and their importance to the environment, [as well as allowing me to work] with friendly, helpful staff in pleasant surroundings."

Volunteer satisfaction, productivity, and longevity has been unusually high on living-collections projects. "I never have had a more satisfactory or rewarding volunteer job," said Mary Wolcott, and Kathleen Warren felt that "the system appealed to my sense of order and to my training as an indexer." One factor contributing to this success has been the organization and structure of the volunteer work assignments. Clearly structured, sensitively supervised responsibilities have provided volunteers with room to grow into increasingly independent functions with a sense of accomplishment at the end of each shift. They have had the additional satisfaction of working on a long-term project that is making a very valuable contribution to both the institution and the science of botany. Susan Dumaine noted that she was "fascinated by and learned from the complex yet facile organization and resourcefulness of both the plants and the project's leader over the past five growing seasons."

Survey Elucidates Volunteer Motivations
To assess the feelings of our volunteers about their involvement in the project, we conducted an informal survey. We discovered that...
their sense of reward for their labors was far more than the tangible benefits of free membership and courses. The unique opportunity for detailed, experiential learning from a living botanical collection and a professional staff was frequently cited as a highly valued benefit. Below are some of the statements that we received:

As a student in the Radcliffe Landscape Design Program, [I have found that] the hands-on education has been invaluable. Rather than being intimidated by lists of plants in books, we were able to learn the plants one at a time while we collected their flowers, described them on the field label, and made mental notes about their ornamental characteristics. Later, collecting the fruits reinforced our knowledge.
—Sandra Jonas

[I remember] sitting on the grass dissecting a tiny flower to finally learn the difference between a bract, a petal, and a sepal, or finding and identifying the ovary, style, and stigma. [We had] lengthy team discussions to give an exact color: “Is it red?” “Scarlet?” “Try rust.” . . . I had resisted the metric system at the gas tank, but by using it in the project it became a part of my vocabulary and I could think in terms of it.—Barbara Epstein

[Volunteering gave me] the opportunity to pursue a love of botany and taxonomy with a staff who patiently answered all my questions and generously shared knowledge of nomenclature, plant lore, and botanical structures.—Roberta Zmman

Hard to summarize 25 years. In addition to the fellowship of working with the staff, the Arboretum has “opened our eyes” to what goes on with plants—a rare opportunity for anyone lucky enough to have access to it.—Richard Warren

Even after 15 years of volunteering, I find that I learn something each time I go—from the collection, and from contact with the staff and other volunteers. Where else could I find such an opportunity?—Marie Dempsey

Working at the Arboretum is a marvelous opportunity to observe plants at all seasons with an eye toward their use in landscaping: their forms, seasonal effects, disease and drought resistance, and hardiness. [It has been] a gold mine of horticultural information.—Ellen Bennett

Mounting leaf specimens for the Arnold Arboretum is a pleasant way to educate yourself about geography, botany, and artistry.—Lillian Hagopian

I loved learning the Latin names. It helped me to understand the value of classical Latin—its root words and descriptive terminology are universally understood.—Susan Hardy Brown

Volunteers sometimes became poetic when describing how the program allowed them to develop a greater sophistication in their perception of beauty, noting the subtleties in textures and shades within a monochrome, forms of bark, plant architecture, miniature designs, and fruiting structures. For Sophie Kulik these new images allowed her to “gain a greater appreciation of the Arboretum as a place of natural beauty for all to enjoy.” Others cited similar experiences:

Of course one could go on about the endless opportunities for discovering and appreciating the natural life in the Arboretum . . . I especially remember the amazement and joy that swept over me when I first saw a Populus and an Acer flower under magnification—the intricacy and splendor were beyond words!—JoAnn Whitehead

“After seeing the fantastic-looking acorns of Quercus variabilis, we purchased a seedling at the plant sale and gave it to some friends when their child was born” (Mima Weissmann). The large acorns of this species, an East Asian oak, are enclosed in a bold and dramatic cup. Such details, often overlooked by visitors, are frequently encountered by volunteers. Photograph courtesy of Racz and Debreczy.
"Observing a leaf pattern—the bark of a tree—it was a horticultural class hard to come by" (Genevieve Good). Shown here are the barks of a Japanese cherry, Prunus apetala (left), and an East Asian oak, Quercus variabilis (right). Photographs courtesy of Rácz and Debreczy.

Working as a volunteer in the verification project has provided me with a very special familiarity with the Arboretum, to meet plants at both flowering and fruiting times and to discover the amazing variety of forms that exist. It is truly refreshing to the soul to be outdoors each week, appreciating the natural beauty abounding in the Arboretum.—Anne Gamble

I have been introduced to so many wonders Stewarta, its exquisite branches decked with gardenias in July, the bright red seeds of Magnolia dancing on silken threads, the fruit of Cornus kousa, as safely edible as it looks, Calycanthus with its discrete dark red flowers blooming shyly behind the main borders of the roadway, autumn witch hazel quietly blooming in October unseen amid its yellowing leaves. These are the bounties of the volunteer... I have lived with the Arboretum on my doorstep for half my life and am grateful to the program for enabling me to get to know it intimately at last.—Mary Harrison

Working with the living collections gets you off the... beaten paths of the Arboretum. You see genera and species you might not otherwise see. And you get a chance to observe them closely, not just when they are blooming. How rewarding that can be! For instance, when we were checking the mapping and labeling in the Prunus collection, it was in October and the Prunus plums were fully ripe—yellow, purple, orange, and blue. Our job description did not call for fruit sampling, but taste them we did. Tiny in comparison to their supermarket relatives but much more flavorful. Shall we call this a fringe benefit?—Bob Siegel

Once while out collecting we stopped to look at the Symplocos, also known as sapphire berry. There it was, right on the road between the lilac beds and the greenhouse, and it was covered with the most incredibly blue berries! Apparently they only last a few weeks before the color darkens or the birds eat them. In 18 years of visits to the Arboretum, I had never walked by at the right moment!... Last week someone looked at one of the vases I had made and said it reminded her of water and trees—no drawings or any graphic representations—just the vase itself. I took it as a great compliment, and I know that being out on the grounds has been a constant inspiration to me.—Mima Weissmann
My five-year collection trip at the Arnold Arboretum—the landscape was spectacular, the species exotic, and the natives very congenial.—Sue Erwin

We would like to give special recognition to the following Arboretum visitors that we have observed on the grounds. The Globetrotter Award: to the Brazilian cardinal seen flitting around the Visitor Center in the fall of 1986. The Most Dedicated Workers Medal: to the rangers who stalked us as we were submerged in the ten-foot flowering Jerusalem artichokes. The Best Hunters: to the red-tailed hawks who routinely catch the odd snake and the not-so-odd Norway rat. The Most Perfect Timing Award: to the mystery picker with his rake who combs the lowbush blueberries under the pines just before we get there.—Nell Walker

The discovery of unusual fruits [such as] those tennis-ball-green osage oranges. To actually be allowed to pick the blossoms and collect the fruits at their peak of development was such a privilege. It was like being Eve in the Garden of Eden and being given permission to pick the apples. Collecting the silverbells (Halesia) was special. I had known about them from the poem “In Praise of Silverbells,” which my mother had written. To describe them on the label became a challenge. Was the flower “shell-pink, like a tropical atoll,” as my mother described?—Susan Hardy Brown

Volunteers and staff were challenged, both physically and mentally, by the rigors of working on the grounds (and in an old building lacking adequate climate control). Fortunately, such difficulties were usually perceived as part of the fun; camaraderie and dedication prevailed. Again, as our volunteers tell it:

Regardless of exhaustion from the rain, heat, or cold in which we might have worked, I still felt exhilarated over what we had accomplished.
—Barbara Epstein

There is life after retirement! It's good to be able to participate in something ongoing... and that in beautiful surroundings, out of doors, and in congenial company. The physical challenge is there for anyone aged 72, and a lot more fun than contrived exercises.—Ruth Griffin

The staff is fun to work with, rain or shine, hot or cold, grubbing on knees or high in trees.—Ellen Bennett

Volunteers also enjoyed working with a team that provided opportunities for socializing while the work was being accomplished. The friendships developed and ideas exchanged were a valuable bonus. In addition, the team format provided a predictable work environment and an interdependency that encouraged consistent attendance and involvement. In their words:

Pleasant work with pleasant people made my time here each week a special segment of my life; a time to be with nature and a time to learn.—Priscilla Ryan

Working with a team was great because it provided the opportunity to explore the deepest, remotest areas I wouldn't have felt comfortable exploring alone. The people were great. We seemed to speak a common language, loving nature and our environment. I've made very special friends who have taught me so much and brought a richer dimension to my life and to my art.—Susan Hardy Brown

Although many of the volunteers surveyed for this article reported deriving great benefits and pleasures from their work at the Arboretum, the interaction is clearly reciprocal. It is difficult to say who benefits more. In addition to the tasks accomplished, the Arbore-

“In my mind’s eye it is always January, the month of my first visit to the Arboretum, when the tree architecture and the distinctive colors and markings of the bark are most apparent. I now know it at every month of the year, each month with its own special beauty” (Pauline Perkins). Although this winter study shows them to have a wide range of branching patterns, all of these linden trees (Tilia) would have the same canopy profile in the summer. Since a living collection is located within a particular climate, these structural differences in cultivated specimens reflect genetic differences inherent in the plants rather than environmental factors. Left to right, top to bottom: Tilia × flavescens, T. paucicostata, T. cordata, T. neglecta, T. japonica, T. americana, T. tomentosa, T. petiolaris, T. platyphylllos. Photographs courtesy of Rácz and Debreczy.
turn gains another important, less obvious long-term benefit. The involvement of members and supporters educates them about the role and function of an arboretum. For Westy Lovejoy the frequent and intimate contact with the living collections, and the process of curation, gave her “a better understanding of the quantity and quality of the Arboretum’s collections,” as well as an appreciation for the scientific role of the institution and its importance to the world at large. Volunteers develop a sense of ownership and pride. For Caroline Blake her work meant “learning more of the Arboretum, and thus feeling more a part of it.” Thus they become more determined in their support and spread their enthusiasm to friends.

**Never-Ending Curation**

If the Arboretum is to flourish, it must continue to encourage this kind of involvement and commitment by the public as well as the scientific community. Part of the Arboretum’s mission must be to educate and inspire people to appreciate and make a commitment to their environment. Curation of a world-class botanical collection requires enormous long-term effort and resources. Although the effective management of a comprehensive volunteer program requires an investment of staff time and facility resources, the benefits to the organization make it clearly worthwhile.

In the words of Peter Ashton, “Each year new plants are tried in the Arboretum collections, some never before cultivated. Each year we must curate these introductions and celebrate their first flowering. So the greatest news of all is that the work will go on, and we will continue to need you, our volunteers!”

Jeanne Christianson is the membership, volunteer, and visitor-services coordinator at the Arnold Arboretum. Sandra Elsik supervises the collecting phase of the verification project.
Living-Collections Volunteers, January, 1984, to December, 1988

VERIFICATION PROJECT
Sue Avery, Medford
John Bailey, Dover
Ellen Bennett, Weston
Caroline Blake, Dover
Dick Brooks, Concord
Tony Bryan, Boston
Susan Burke, Brighton
John Carey, Norwood
Janet Christrop, Jamaica Plain
Tom Coulson, Chestnut Hill
Susan Davis, Boston
Carin Dohman, Weston
Margaret Donahue, Watertown
Paul Donnelly, Squantum
Jean Dricker, Brookline
Susan Dumaine, Weston
Susan Dwyer, Norwood
Barbara Epstein, Newton Centre
Sue Erwin, Cambridge
Don Falk, Cambridge
Esther Fich, Winthrop
Gerhold Fitz, Roslindale
Ruth Fried, Roxbury
Sandra Friedman, Wellesley
Barbara Frishkopf, Lexington
Anne Gamble, Brookline
Barbara Gard, Norwell
Niki Gilsdorf, Cambridge
Genevieve Good, Cohasset
Ruth Griffin, Brighton
Kathy Groves, Sherborn
Helen Hagopian, Wellesley
Susan Hardy Brown, Jamaica Plain
Mary Harrison, Cambridge
Laverna Haskell, Cohasset
Isabel Horan, West Roxbury
Shirley Hyland, Cambridge
Sandra Jonas, Newton
Anne Joseph, Whitman
Andrea Knowles, North Billerica
Amy Kosmidis, Roslindale
Sophie Kulik, Roslindale
Mary Jeanne Langevin, Milton
Anne Lomuto, Wellesley
Westy Lovejoy, Boston
Betty MacKenzie, Dorchester
Barbara Mahon, Jamaica Plain
Louise Makepeace, Warwick, Rhode Island
Phyllis Marx, Newton
Melinda McCall, Jamaica Plain
Melana McCann, Jamaica Plain
Terry McKiernan, Cambridge
Jane McKinnell, Boston
Peg Megowen, Carlisle
Jane Morris (deceased), Chestnut Hill
Melanie Moses, Cambridge
Vincent O’Gorman, Chestnut Hill
C. J. Patterson, Norwell
Pauline Perkins, Brockton
Robert Perkins, Jr., Cambridge
Karen Peterson, Cambridge
Margaret Pittzer, Boston
Betty Porter, Concord
Jean Rosenberg, Arlington
Liz Ruth, Brookline
Priscilla Ryan, Somerville
Liz Sargent, Boston
Anne Shuhler, Cambridge
Hiltrud Siegel, Belmont
Marjorie Smith, Cambridge
Magen Solomon, Northampton
Lester Stockman, Roxbury
Kathy Terzi, Jamaica Plain
Elaine Tsomides, Brookline
Jan Wampler, Jamaica Plain
Kathleen Warren, Dedham
Richard Warren, Dedham
Ann Waters, Jamaica Plain
Mima Weissmann, Jamaica Plain
Jan Whitaker, Jamaica Plain
JoAnn Whitehead, Jamaica Plain
Mary Wolcott, Manchester
Karen Wolkoff, Somerville
Roberta Zinman, Newton

PLANT RECORDS OFFICE
Betty Jacobson, Dover
Amy Kosmidis, Roslindale
Joseph Merriam, Brookline
Jean Rosenberg, Arlington
Donna Rowland, Jamaica Plain
Bob Siegel, Hingham
Nell Walker, Lexington
Jan Wampler, Jamaica Plain
Richard Warren, Dedham

HERBARIUM, SPECIMEN PREPARATION
Mary Ashton, Carlisle
Caroline Blake, Dover
Kathleen Daly, Jamaica Plain
Marie Dempsey, Lexington
Elaine Foster, Chestnut Hill
Sandra Friedman, Wellesley
Lillian Hagopian, Wellesley
Susan Hardy Brown, Jamaica Plain
Mary Harrison, Cambridge
Sophie Kulik, Roslindale
Barbara O’Connor, Auburndale
Ciba Vaughan, Cambridge
Kathleen Warren, Dedham
Mima Weissmann, Jamaica Plain
Karen Wolkoff, Somerville

Five-year commitment.
To Each a Name: Verifying the Living Collections

David C. Michener

Identifying the plants in the living collections is a challenging task requiring assistance from around the world.

Charles Sargent, founding director of the Arnold Arboretum, was determined that the newly established arboretum would have unrivaled living collections of woody plants native to all parts of the Temperate Zone. Also to be unrivaled was the documentation of each acquisition. This driving passion to amass the most and the best, so familiar to art collectors and often seen in founders of great institutional collections, was demonstrated early on in what can be called the “quest for wild ash trees.”

The Quest
Our case begins on March 12, 1878, when seeds of an ash (Fraxinus) were received from the Imperial Botanic Garden, St. Petersburg [now Leningrad], Russia. The seed lot was accessioned as number 1061, and if more than one seedling survived the early years we have no note of it. Although the resulting tree was listed in 1924 as missing, it remains on Bussey Hill, where it has matured into a magnificent specimen. Most botanical institutions would be pleased to have records as detailed as this [let alone the plant!], but our work on the verification project has shown that the records of the Arboretum are often a good deal more informative. Sargent’s passion was not so easily placated.

This ash tree represented no ordinary acquisition. On delving into our archives and library, we were led to our very rare set of the seed lists published by the Imperial Botanic Garden. The anonymous compilers of the seed list meticulously divided the listings in botanical Latin] into sections: those collected from within the garden first, and those from various czarist expeditions separately by expedition or region at the end. Our ash was recorded with the note of “Regel,” an obscure reference until one examines the seed lists from the 1870s and observes the recurrent section entitled Semina in regionibus Turkestanis ab A. Regel collecta. Our plant is thus evidently linked to, and representative of,
a wild population in Turkestan! Sargent had wanted authentic material of unquestioned identity; the seeds that could be obtained from trees already growing in the Imperial Botanic Garden (they are listed, too) were inadequate for his exacting vision of the Arnold Arboretum's collections. Only wild-collected seed would do.

One final confirming note appeared that depends upon details recorded in our original entry. Modern-day botanists consider the plant to be *Fraxinus angustifolia* Vahl subspecies *oxycarpa* (Bieb. ex Willd.) Afonso, but in Sargent's time other names were in use. This seed was received under the then-current name of *Fraxinus potamophila* Herder—exactly the name used in the list of seeds collected by Regel and distributed by the Imperial Garden.

**Why Verify?**
The purpose of verifying a research arboretum's living collection is to ascertain that the plants are what they are claimed to be. For the Arnold Arboretum the underlying questions concern each accession's source documentation (where and how we obtained it), its identity and name (what it is), and our confidence in the accuracy of the first two responses. Answering these questions takes one through a procedure involving the plants on the grounds; the records, inventory maps, and archives; references in the library; and a major herbarium. For some taxonomically difficult genera we have also enlisted the assistance of outside specialists. One important aspect of verification is easily overlooked: years hence, the collection will be verified again, and the current staff must leave a documented trail of how and why they did their review and made their decisions, or else much of their work will be uninterpretable to the next generation of curators, researchers, and serious visitors. The value of this "audit trail" has been learned through the omissions of others. If only the past could speak!

Answering the three questions posed above is the primary challenge of the verification project. In addition to distinguishing all the accessions that meet our standards of scientific significance (horticultural and historical significance are also important and will continue to be evaluated separately, although sometimes all types of significance are intertwined—see box), we are ensuring that the botanical names used in the collection are in keeping with current technical reference works. We are also attempting to make our approach to the collections consistent, regardless of staff interests, so that they can be critically evaluated for further renewal and development. Although not initially defined as a project goal, the development of *BG-BASE* became an operational necessity to tie together our curatorial information scattered among the records office, archives, library, and herbarium. This verification review will be used to focus the collection and acquisition of new plants, and to identify and aid in scheduling removal of existing plants that fail our criteria of scientific, horticultural, or historical value. As such, this project is a modern expression of the Arboretum's ongoing and episodic processes of renewal, more information on which can be found in Stephen Spongberg's article on the history of the living collections.

**The Verification Process**
Verification of our collections is a conceptually simple, four-step process of voucher collection, documentation review, taxonomic verification, and record updating. This may already sound dreadfully dry, but it is far from it. One has to replace a dull expectation of glorified inventory control with a probing mindset that is always querying whether each accession is fully documented and, if necessary, determining how more information can be resurrected. Then comes the excitement of the taxonomic chase and the constant learning caused by working with the plants themselves.

The first step in verification is to acquire high-quality reference specimens. These specimens are the focus of the subsequent verification activity. The curatorial issues involved in vouchering and specimen prepa-
History, Horticulture, and Science

Just as museum holdings are reviewed and verified so that the acquisitions can be recertified and directions for further development identified, so too are major living collections reevaluated. The focus of an art review may be on the piece’s authenticity (who created it) and cultural milieu (its relation to other works of the same period). In a living collection of international significance, be it an arboretum or a zoo, the focus is on the identity, provenance (wild collected or original horticultural introduction), and documentation of the organisms.

A collection based on wild-collected plants and seeds has been a fundamental strength of the Arnold Arboretum. Our wild-collected accessions form the core scientific collection, since new information about these plants can be extrapolated back to the natural population. This is an important intellectual link for some forms of research in ecology, population biology, and systematics—a link that is tenuous or nonexistent with material of garden or undocumented origin because such plants may represent hybrids, back-crosses, or subtle genetic recombinants that are unlikely ever to have been found in nature.

The verification project has clarified the wild-collected status of numerous accessions. Ascertaining the wild source of our plants can involve sleuthing in obscure and beautiful publications. One example involves our dove tree, Davidia involucrata var. vilmoriniana, accession number 5159. Its identity has never been questioned, but its records—“layer, Vilmorin, 1904”—were enticingly incomplete. A quick review of the French publication Revue Horticole turned up a series of notes and articles on Davidia and its introduction by the Vilmorin Nursery. Modest amounts of seed had been obtained from two wild sources in 1897 and 1898, but only one seed, from the lot collected in “Se Tchuen” [Szechuan, China, according to additional collection data now in our records], ever germinated. Also noted is the early propagation history of the solitary plant. “Four cuttings and a layer were made. Two cuttings rotted in the pots. Of the other two, one was sent to the Museum [implicitly Paris], the other to Kew. The layer will be sent to Mr. Sargent” [R. André, Davidia involucrata, Revue Horticole, 1902, p. 378; translation by the author]. Evidently our passionate collector of wild trees and shrubs, “Mr. Sargent,” was well enough known that no further identification was needed even in the French horticultural literature.

As a modern aside, we have a second accession of Davidia involucrata var. vilmoriniana that was received in 1911 from the English nursery of J. Veitch. This was the firm for which the Arnold Arboretum’s great plant collector Ernest “Chinese” Wilson had once worked. Does this accession represent a different population of Chinese Davidia collected on a Veitch expedition [possibly by Wilson], or is it a cutting from, perhaps, the plant Vilmorin had sent to Kew only a few years earlier? If the latter, then our two accessions are really just clones of one plant, and our Davidia collection is not genetically diverse and is very restricted for certain types of comparative intellectual inquiry. Questions of genetic identity are becoming important in modern curation and plant conservation, but few botanical institutions have yet addressed the genetic diversity (as opposed to the taxonomic diversity) found in their collections. In cooperation with a team at Iowa State University, we have a pilot study underway to resolve our Davidia questions through the use of protein electrophoresis. Under controlled laboratory conditions this methodology detects combined electrical and mobility differences in specific proteins synthesized by the plants; such differences can be interpreted to indicate genetic differences and similarities. This is the Arnold Arboretum’s opening foray into molecular methods of curation.
ration are discussed by Sandra Elsik elsewhere in this issue. The linkage of the plants on the grounds to the documentation kept in the plant records office is checked during the collection of these voucher specimens. Careful vouchering is absolutely critical to the success of the entire project, for if the specimens are gathered from the wrong plant, the accession numbers, records, and subsequent determinations will become almost hopelessly confused. If the voucher-records link is lost, then any subsequent taxonomic verification becomes useless. It should now be clear why the Arnold Arboretum invests such staff and financial resources in the records office and the mapping function, as well as in the development of BG-BASE (see the article by Kerry Walter): the quality of our records and their unambiguous linkage to the plants on the grounds define us.

Source Documentation
Documentation verification has one purpose: to find out all there is to know about the ultimate source of the plant in question. The ultimate source is where the plant was collected in the wild or, if a cultivar, the place or nursery where it was first found, described, or introduced. Once this ultimate source is known, many taxonomic and curatorial questions can be precisely refocused. The immediate source, by contrast, is the person or institution from which the Arnold Arboretum obtained the plant material. In the ash-tree example the immediate source was the Imperial Botanic Garden in St. Petersburg, while the ultimate source was in Turkestan. The records-office staff has a strong tradition of keeping increasingly detailed records of the ultimate, rather than just the immediate, sources of our plants. Many earlier accessions have only tantalizing notes from the immediate source—notes that indicate or imply that more was once known and may again be knowable about the accessions. Focused sleuthing in contemporary journals, seed lists, monographs, reference tomes, and archival materials yields occasional but invaluable results. It is satisfying to ferret out a significant ultimate source and thereby add one more plant to our list of wild-collected or horticulturally significant plants.

Identities and Names
Taxonomic verification focuses on determining the proper identity and correct name for each accession and, as appropriate, any former names of the plant. These former names, called synonyms, are the result of a variety of historical and philosophical factors. Resolving the proper name from synonyms is an important part of taxonomic verification, since different accessions of the same kind of plant can be listed under several names. This falsely inflates the nomenclatural diversity of the collection and leads the curators astray.

The basic operating procedure in taxonomic verification is the comparison of our voucher
specimens from the living collections to
known reference specimens or descriptions.
This process sounds easy enough, but in prac-
tice it is the most difficult and time-
consuming aspect of verification. Since
familiarity with obscure technical details of
plant structure and morphology is essential
in many of the taxonomically difficult genera,
we asked many out-of-house authorities if
they would accept a set of specimens from our
collection in return for their identifications.
Botanists from around the world have assisted
in this challenging task; without their help
this project would have been greatly com-
promised. Arboretum botanists have identi-
cied the specimens of the remaining genera.

Taxonomic verification is an exciting
challenge that keeps the heart young and the
eo in place. In the current project it is per-
formed genus by genus. Once the majority of
our voucher specimens of a particular genus
have been delivered to the herbarium and
mounted, they are sorted into accession-
number sequence without regard to their cur-
rent name. At this point any preexisting
vouchers for the same accession number
(some dating to the late 1800's) are pulled from
the herbarium and inserted into the same
numerically ordered stacks. The purpose of
this step is to gather together all the herbar-
iurn vouchers (flowers, fruits, leaves, and
winter twigs) that have ever been made for an
accession regardless of the particular name
under which each sheet may have been filed.
This way, once the material is reidentified, all
the sheets will have the same name and will
be refilled together in the herbarium. We are
then able to enter all the vouchers into the
data base. This “sort-by-numbers” step recti-
fies the drift in names that we have
experienced over time, when within a single
accession some sheets exhibiting the taxo-
nomically critical features have had their
names changed while other sheets that lack
these seasonally displayed features remained
under an old name (a synonym).

Genetic Lineages
Once the stack is in numerical sequence, we
work from the newest specimen back to the
oldest. This allows us to pick up the all-
critical genetic lineage, which is continued
whenever the greenhouse staff asexually
propagates a plant (as by cuttings rather than
from seed). The mother and daughter plants
are links in a genetic lineage. For some of our
accessions, there are many sequential links to
the lineage. By working with the newest
accessions, we can find all the vouchers of the
older ones that make up the genetic lineage
and compare them to each other. Since all
must be the same genotype, all must be mor-
phologically similar [allowing, for example,
for juvenility and differences between dry and
wet years]. If the mother and daughter plants
are too different at this stage, we presume that
some sort of a mix-up has occurred. The
daughter plants that do not match the mother
plant cease to be of scientific interest since
they are effectively undocumented specimens.
This sort of error is fortunately uncommon,
but it must always be guarded against.

Now comes the taxonomic fun. Taxonomic
determination has two parts: determining
what a plant is, and then which name is
proper. Notice that identity and name are dis-
tinct. Although any object has only one iden-
tity, it may pass under several names; under
the rules of botanical nomenclature, only one
name is correct [with few exceptions], and the
other ones that have been used are synonyms.
Deciding which name is the correct name and
which ones are synonyms often requires a
good deal of library and herbarium work.

Determining the correct identity of the
plant now represented by a suite of herbarium
specimens [all with the same accession num-
ber but often collected over a period of years,
and some sheets bearing old names] requires
access to a major reference library and herbar-
iurn. The Arnold Arboretum is fortunate in
being part of the Harvard University Herbaria
and the Botanical Libraries of Harvard Univer-
sity: superb resources are near at hand. Next
one needs to know the ultimate source of the
plant, since geographic origin is one of the
most critical keys to all the technical
references.

In our work we accept for the moment that
the plant name in the records office is correct.
We look at the immediate and ultimate sources to determine if the accession represents a wild population, and if it does we move directly to the floras of that part of the world. (A flora is a technical manual to all the plants growing within a defined geographic unit.) If there is no modern flora for the area, we use whatever monographs can be found in the library. (A monograph is a major work by one or a few authors that treats an entire genus or family on a regional, continental, or worldwide basis.) We check for monographs even if there is a modern flora in order to track down more synonyms and to find alternate treatments of the genus, since taxonomic concepts change over time and differ between philosophical schools. These books are entered into BG-BASE and cross-referenced to the genus and family names so that future curators will know which sources were consulted in making judgment calls. Finally, we check our understanding of the species by reference to wild-collected herbarium specimens and then make our taxonomic determinations. Why not proceed directly to the herbarium and skip the library work? With that course one runs the risk of mistaking one of several closely related species for the plant at hand—we need to know not only what the plant is, but also what is related or superficially similar and how to differentiate them. On rare occasions we discover that we need to see the accession under review in life, so we go out to look at the living plant, or postpone the determination until the season when the plant will be displaying the necessary characteristics.

Once we are satisfied with our determination (which by now may not be the determination given on the label), we have to find the proper name. Botanical nomenclature works on a system of historical priority, but this can become quite arcane. As an operating procedure, we usually defer to the most recent monograph or flora and use the nomenclature presented there. When the two (flora and monograph) are in conflict and essentially of the same date, we usually follow the monograph, since it was written by a specialist who should have resolved many of the nomenclatural problems.

**Records**

Records updating consists of putting the correct name on each voucher specimen (with an annotation label) and relaying the same information to the records office. As an internal check, a month is allowed to pass between the time when we make our report to the records office and the time when the report takes effect. During this month any staff member may query the determinations and comment upon them. From time to time, this system not only promotes an exchange of views, opinions, and observations about our plants but also allows real and perceived errors in the work to surface so that the final report is as accurate as possible. The final part of records updating is adding all the voucher specimens examined to BG-BASE so that it will be clear which specimens were seen in the course of the review. This completes the audit trail for those who will depend upon and review our work in the years ahead.

What is the result of all this work? Simply put, it is a well-curated reference collection in which one has confidence that the material is accurately identified and as fully documented as possible—a collection most capable of supporting the widest range of scientific, horticultural, educational, and aesthetic pursuits at all levels of intellectual rigor.

David C. Michener is the program taxonomist for the verification project.
Designing a Computer-Software Application to Meet the Plant-Record Needs of the Arnold Arboretum

Kerry S. Walter

The Arboretum's specially designed databases allow unprecedented ease in retrieving, updating, and sharing records.

For hundreds of years, botanical gardens and arboreta around the world have kept records on the plants in their collections, in fact, such records are often considered to be a primary difference between a botanical garden and a display, or public, garden. These records usually track the name of the plant; its provenance (wild collected or from cultivated material); the source, kind, and number of plants received; the location on the grounds, in the nursery, or in the greenhouse; and, often, related curatorial and maintenance information on plant health, size, flowering, and fruiting. Without a plant-record system, a botanical garden cannot manage its collection and in fact does not have a truly scientific collection.

However, there are almost as many different record systems as there are gardens using them; a recent survey by the American Association of Botanical Gardens and Arboreta (Bowden & Brown, 1988) showed a tremendous variation in plant-record systems, most unable to communicate electronically with one another. This article describes the development of international standards for transfer of plant records, and a software application built around those standards.

Manual Record Systems

Until the advent of electronic computers several decades ago, all records were kept manually, usually in accession books and/or card files; an additional method of organizing information is to maintain a collection of maps, so that plants can be found by where they occur on the grounds. There is no standard format for accession cards—some institutions use preprinted forms, while others write or type on blank cards. The trend today is to use preprinted cards, so that similar information will show up in more or less the same place on each card, making data retrieval faster and less prone to error. Such forms, however, are seldom flexible enough to track all desired information for all plants, especially those that have remained in the collection over a period of several decades or more; this often necessitates the use of follow-up cards clipped or stapled to the printed card. There is even less standardization in how accession books and maps are kept by different institutions.

Many gardens and arboreta, including the Arnold Arboretum, keep both accession books and a card file. Accession books are normally arranged in order of accession number, while cards are usually interfiled by the name of the plant. This allows the user to find information about a plant in either of two ways—by knowing its accession number or by knowing its name—and is better than keeping records in only one place and in only one order. However, there are still several problems associated even with this dual system. First, all data must be typed (or written) twice, once in the accession book and once on the card. Second, if information is subsequently changed in one place (for instance, if the name of an accession is changed), it must be altered...
[and re-filed] in the other place, too. Third, there is often only one copy of each set of information, thus restricting access [at the Arnold Arboretum, the current year's accession book is kept at the Dana greenhouse complex, about two-fifths of a mile from the Hunnewell Visitors' Center and plant records office, where the card file is maintained and the old accession books are located]. Fourth, there are numerous requests that cannot be readily answered with the information physically sorted and stored in only one or two orders; for instance, if a visitor only knows a common name or is interested in finding plants collected in a particular country or received from a specific nursery or botanical garden, the information is nearly unretreivable.

This last problem is really the most serious one: a card-based record system requires that the records [cards] be physically re-sorted for each category desired. Some botanical gardens have partially solved this problem by making one or more photocopies of each accession card and then filing the copies by common name, by country of origin, and so on; however, this solution exacerbates the problem of updating the records, since there are multiple copies of the same information, all of which must be changed.

An additional problem, common to all record systems but especially serious for manually kept ones, is that of security—in a fire or other catastrophe, the entire "institutional memory" could be destroyed.

What is ideally needed is a single centralized source of information with the records concurrently sorted in various ways and copies simultaneously available at many sites. Such a system ensures that consistent data will be presented in a variety of formats to simultaneous users and that the information is not prone to catastrophic loss. This is exactly what a well-designed computer database can do.

**Early Computer-Based Record Systems**

Botanical gardens took the first steps toward computerizing their plant records over 20 years ago. In this country, the University of Tennessee Arboretum, the Tyler Arboretum, and Longwood Gardens all moved their records to computers in the late 1960's; the Royal Botanic Gardens, Kew, computerized its plant records in 1969 [Anonymous, 1984].

Beginning in the early 1970's, many other gardens, including the Arnold Arboretum, filled out special accession cards and sent them to a centralized record center [now known as the Plant Sciences Data Center] managed by the American Horticultural Society [MacDonald, Olson, & MacDonald, 1967; MacDonald & Reed, 1967]. In the early days of mainframe computing, data entry was done laboriously through punched cards, key-punches, or paper tape; not surprisingly, the computerized versions of these plant records tended to be simple designs storing relatively little information. In spite of its limitations, computerization of plant records allowed the user to obtain answers to novel and often unanticipated questions, and interest in using computers to manage plant records increased.

The recent advent of powerful and relatively inexpensive microcomputers has made it possible for virtually all botanical gardens to maintain their plant records on desktop machines.

Computerization *per se* does nothing to correct incomplete or inconsistent information in a manual system; at most, it highlights the problem areas. The first generation of computerized plant-record systems often mimicked the format of the card or accession book from which the data were taken. Such an approach, while easing the user's transition from card or book to computer, resulted in the typing, storage, and manipulation of much redundant information. For instance, if a garden had ten accessions of yellowwood, *Cladrastis lutea* [Michx.] K. Koch, the words "Cladrastis lutea [Michx.] K. Koch," along with the family name "Leguminosae" and the common name "yellowwood," would have to be typed on every card and into every record in the computer; the nearly inevitable typographical errors and inconsistencies in punctuation, abbreviation, and capitalization would result in inconsistent data being stored. Computers are much less forgiving than
Example of a portion of a simple flat-file database design employing a fixed-length structure. Ten records and six fields (accession number, genus, species, family, source, source number) of a fabricated database are shown. Four problems are particularly evident: data redundancy (the family name must be entered for every record, yet it is determined by the name of the genus and therefore could be calculated for, not stored in, each record), data truncation and wasted space (a long generic name, *x Crataegomespilus*, had to be truncated because its field had not been defined long enough, while other records with the genus value *Acer* contain a great deal of wasted space—shown here as dots; the family fields for *Scrophulariaceae* and *Magnoliaceae* and the source number for accession 85-58 were also truncated), and data inconsistency (the various ways of citing “Hillier Nursery” and “Hiller’s,” and of citing and abbreviating the Arnold Arboretum, Kew, and the Holden Arboretum—as far as the computer is concerned, there are ten distinct plant sources here, not just four; the difference in spelling between “pseudoacacia” and “pseudo-acacia”; and the assignment of *Robinia* in different records to two apparently distinct families, *Fabaceae* and *Leguminosae*, which in fact represent different names for the same family).

humans when it comes to inexact information, so that a computer asked to find all “Cladrastis lutea [Michx.] K. Koch” would not find “Cladrastis lutea K. Koch” nor would it locate “CLADRASIS LUTEA (MICHX.) K. KOCH.” As noted above, if the name *Cladrastis lutea* had to be changed (as it has been, to *Cladrastis kentukea* [Dum.-Cours.] Rudd), every occurrence of that name would have to be updated in all the computer records, just as in a manual system; therefore, the early computerized records did little, if anything, to solve the problems of data redundancy and consistency.

Relational Database Design
As is true of nearly all disciplines, computer science has a large and specialized vocabulary; however, only a few technical terms are crucial to this discussion. A file or table is made up of a collection of records or tuples (for example, an accession file would contain a separate record for each accessioned plant). A record consists of a series of related pieces of information; these pieces are called fields, attributes, or descriptors [an accession record might have several fields—one for accession number, another for plant name, etc.]. Each record can be located by its key field, which must be unique within the file. A field can store a value [for example, the value for the field called ACC.NUM in the file called ACCESSIONS might be 80-47].

This simple, “flat-file” structure can be represented as a matrix of intersecting horizontal lines [records] and vertical columns [fields]. Each box so formed will either contain a value or be empty. Usually these boxes are of a predetermined length [fixed-length field structure]; a value that is longer than the allotted length [determined when the file is created] must be truncated, while one that is shorter than the length of the box must be padded with blanks to fill out the allotment.
There is nothing particularly simple or straightforward about plant records. These records are, by their very nature, complex things, far more complicated than the typical database records maintained by banks on people, accounts, and transactions, for instance. This complexity arises for a variety of reasons:

1) A scientific name is composed of a series of parts, some required, others optional, but each having to follow specific rules of nomenclature; these names become extremely complex in the case of hybrids and graft-chimeras.

2) The name of an accession may change due to an original error or later taxonomic revision, yet in many cases both the "correct" and the "incorrect" names must be maintained in the system.

3) The same kind of plant may have several scientific names applied to it, each at a different taxonomic level (for instance, species vs. variety) or within different genera.

4) A genus may be assigned to different families by different authorities.

5) Some families have two equally valid scientific names.

6) Many common names may be associated with a single scientific name, or the same common name may apply to many scientific names.

7) A single accession is often composed of many individual plants, each with its own history of propagation, curation, and location.

8) These locations—past and current—are dynamic, since plants are often moved, or they may sprout in a new location or resprout in one from which they had been removed.

9) A plant may die, but its progeny may still be extant, either with the same accession number or with a different one.

10) An accession may have multiple sources (for example, a plant may have come to the Arnold Arboretum from the Missouri Botanical Garden, which received it from The Holden Arboretum, each institution having its own accession number). Trying to manage this complexity within the flat-file structure, especially a fixed-length one, was nearly impossible and often resulted in designs that were so oversimplified that they could not capture the subtle interactions between the information in these fields.

In 1970 an IBM researcher published a paper entitled "A relational model of data for large shared data banks" (Codd, 1970) that was to revolutionize computerized database design. In it Codd laid out the mathematical model for implementing a series of files related to one another by shared fields, thereby reducing the amount of redundant information that must be stored.

Instead of having to enter the same information into several records, as was necessary in the earlier, flat-file approach to database design, in a relational model the designer creates a series of files and writes short programs to link them together. In the case of the Arnold Arboretum's database design, for instance, the NAMES file contains information on each plant name (regardless of any accession-specific information); the ACCESIONS file contains a record for each accession (regardless of any name-specific information); PSOURCES has a record for each plant source, and so on. Obviously, these files must be linked electronically, or one would never know what name went with an accession, but the database-management software (DBMS) handles that automatically.

Understanding and using (and certainly designing) a relational model is somewhat more difficult than understanding and using a flat-file model, at least initially, since information is stored in physically separate files, but the benefits of being able to enter information only once about a particular kind of plant (such as its scientific and common names, its natural geographic range, its hardiness or other horticultural characteristics) and then have that information available for all accessions of that name far outweigh these initial difficulties.

The Need for International Information Standards—a Brief History of BG-BASE

In March, 1985, before my involvement with either the Arnold Arboretum or the Center for Plant Conservation, I met with Hugh Synge, Duncan Mackinder, and others at the International Union for Conservation of Nature and Natural Resources (IUCN), housed at the Royal Botanic Gardens, Kew. We discussed the need for a mechanism whereby gardens anywhere in the world could share data, much as
Example of a portion of a relational database design employing variable-length structure. The ten records from the flat-file database in the previous figure are shown here as they might be stored in a relational database design; such records are hard for people to read but are very efficiently processed by a computer. Because fields can vary in length, there is no longer a series of fixed-length boxes. Fields are separated by a special field-delimiter character (shown here as "A"); two field delimiters next to each other indicate a field lacking a value. This system also allows for multivalue fields, and separate values within a field are separated by another special character, the value delimiter (shown here as "). Within a file, fields appear in the same order, and the first field is always the key field, which must be unique within the file.

There are four fields shown in the ACCESSIONS file: accession number (the key field), name number, plant-source number, and accession number of the plant source. Accession 32-187 and 48-1058 share the name number 434, which points to the record for Acer palmatum in the NAMES file (this record need only be entered once, no matter how many times it is referenced by the ACCESSIONS file). Accession 41-3000 has a name number of 5021, which points to Robinia pseudacacia, and so on. There are six fields shown for the NAMES file: name number (the key field), hybrid indicator, generic name, specific epithet, author, and common names (a multivalue field). There are five fields shown for the GENERA file: generic name (the key field), family, subfamily, common name for the genus (a multivalue field), and parental genera (another multivalue field). There are seven fields shown for the SOURCES file: plant-source number (the key field), name, international code for the institution, address (a multivalue field), city, state, ZIP code, and country.
they were sharing plants. We realized that it would be impossible—and unwise—to attempt standardization at either the hardware or the software level, with so many disparate systems already in existence, but that it would be practical and desirable to create a protocol for exchanging information. A meeting was called later that summer in London to devise what has since become known as the International Transfer Format (or ITF) for Botanic Gardens (Anonymous, 1988). At that first meeting, hosted by the Threatened Plants Unit of the IUCN, were computer scientists and plant-records experts representing many botanical gardens from several countries. Further work was done by a subcommittee headed by James Cullen, of the Royal Botanic Garden, Edinburgh, and a draft of the ITF was presented to an international meeting of botanical gardens, sponsored by IUCN, in the Canary Islands in November, 1985. At this meeting, the draft was enthusiastically endorsed by the 175 participants (representing 39 countries), and IUCN was asked to proceed with implementing a system designed around the ITF, a request that IUCN then made of me: to create a microcomputer database application for botanical gardens, both large and small, based on the ITF.

Some months prior to the Canary Islands meetings, Peter Ashton, then director of the Arnold Arboretum, had requested that I consider writing a computer application to handle the plant-records needs of the institution. I agreed, with the proviso that the application be made as generic as possible in order to meet the needs of many gardens, not just the Arnold Arboretum. The care taken in both manual and computerized record keeping at the Arnold Arboretum is probably unsurpassed by any other garden in the world, so the request to do a system at the Arboretum was both daunting and exciting—if it worked here, it should work almost anywhere. The difficult job was simplified, however, by the long tradition of many Arboretum staff using and contributing to the manual record system; thus, there was a pattern of information flow that could be emulated by the computer system, which would have to allow simultaneous access to all records from any workstation in two buildings.

Armed with a design for a herbarium and living-plant collection-management application written for the Asociación Mexicana de Orquideología in early 1985 and with experience gained in helping the Matthaei Botanical Gardens of The University of Michigan to computerize its records in 1973, I began in the summer of 1985 the work of creating an application that has since been named BG-BASE. From the beginning the design of BG-BASE has been a group effort; it has now involved more than 100 people from over 35 institutions.

The authors of other articles in this issue formed the core of specialists contributing most to the eventual design of BG-BASE. For about two years, a group of five to eight of us met over lunch nearly every week to plan and to discuss the design, and eventually to test and criticize the implementation. Ideas for new data fields, new files, and new reports were presented regularly for general discussion, resulting in some fairly heated debates.

The heart of the system was always understood to be based on the International Transfer Format, but since this format specified only 36 fields, we had a great deal of fleshing out to do. As it currently stands, BG-BASE comprises 564 fields spread over 12 major files. In addition to these major files, there are another ten index files that allow the user to look up information in a wide variety of ways.

Functions of the BG-BASE Data Files
The NAMES file is the central file to which most other files link, either directly or indirectly. There are 98 fields of information for each plant name, making this a challenging and time-consuming file for which to complete a record, although incomplete records are perfectly acceptable and usual. As is true throughout the design of BG-BASE, these fields are fairly finely divided; for instance, the scientific name of a plant is broken into 20 separate fields that are recom-
The file structure of BG-BASE. Instead of storing all information in one large and heterogeneous file, as many gardens' record systems do, BG-BASE employs the relational model, linking 564 fields in 12 major data files. Each box represents a file, figures in brackets refer to the number of data fields defined in each file. Words in lower case refer to selected fields within the file. Lines connecting boxes indicate linkages between files.
bined during output to create the name as we expect to see it. This division into separate fields allows the program to process generic names, hybrid indicators, and infraspecific rank and names [subspecies, varieties, cultivars, and so on] easily, as well as naming authors, and it is possible to retrieve a name record by typing any word or words from either the scientific or the common name(s). There is considerable logic built into the NAMES entry screens so that many of the fields are skipped automatically, depending upon what kind of name is being entered. In addition to the full scientific name, the NAMES file stores synonyms and common names, a full description, information on infrageneric classification, geographic range, hardness, conservation status, and so on. Through links to the ACCESSIONS and PLANTS files, a list of all accessions of a name is displayed, along with the location of each of these plants on the grounds. As of the beginning of February, 1989, there were 8292 records in the NAMES file.

The NAMES file links through its genus field to the GENERA file. For each genus in the collection, a record is created in which the genus is assigned to a family [family names in all other files are generated by looking up this information in the GENERA file, thus ensuring consistency of data]. If the genus is of hybrid origin, its parental genera are listed in the record. Additionally, any plant sources specializing in the genus [a list maintained by a link to the PSOURCES file] and a bibliography for the genus [maintained by the DS file] show up automatically in the record. There are currently 630 genera records in the file.

The FAMILIES file contains a record for each family of vascular plants (currently 694 records). Each record contains information on the higher taxonomic categories [for example, monocot or dicot, subclass, order], family common name(s), and so on. As is true for GENERA, FAMILIES records are linked to the PSOURCES and DS files.

The ACCESSIONS file has a record for each accession coming into the institution; with 120 fields in its dictionary, it is the most complex file [many plant-record systems that do not employ the relational model have a single file, the accessions file, in which all information concerning the accession, the name, the source, the country of origin, the location, and so on, is kept; in BG-BASE, information that is not specific to the accession is kept in other, related files]. An accession is a plant or a group of plants all bearing the same name from a single source; each accession is given a unique accession number. Besides this number, an accession record maintains a link to the correct name [stored in the NAMES file] as well as to the date of accession; the name under which the plant was originally received; how the accession was received [for instance, seed, cutting, division, tissue culture, and so on]; a complete source history of the plant [immediate, intermediate, and original sources, along with each source's accession number]; the provenance type [directly collected from the wild, from a cultivated plant of known wild origin, or from a cultivated plant not of known wild origin]; the country, exact collection locality, collector, and other collection data such as habitat notes and associated species if wild collected; propagation history [including hormones applied, stratification and scarification techniques, and germination results]. This file forms the basis of the accessioning system with two notable exceptions: all name-specific information is kept in the NAMES file, and all plant-specific information is stored in the PLANTS file. Currently, there are 13,560 accessions tracked [the more than 100,000 cards in the "dead file" are not yet computerized].

The PLANTS file is at first difficult to separate conceptually from the ACCESSIONS file. Since each accession may actually contain many separate plants, each in a different location and suffering different disease and insect problems, it was necessary to create a record for each plant [or massed planting] within an accession. If there is only one plant making up an accession, then there is only one PLANTS record; if there are seven plants in different places on the grounds, then there are seven PLANTS records, and so on. The key
field to this file is the accession number (which must already exist in the ACCESSIONS file), along with a letter that uniquely identifies the plant within the accession (for example, a plant number of “1010-57*C” refers to plant “C” of accession “1010-57” and “130-69*A” refers to plant “A” of accession “130-69”). This file stores information on all locations that the plant has occupied during its existence in the collection, as well as information on field checks, measurements, and curatorial problems. It is the file that links to the computerized mapping program—the exact coordinates of each plant, as determined by aerial photography, are stored, as are the location codes (map numbers) that link to the LOCATIONS file. This file also stores the verification and voucher-specimen information essential to verifying the living collections, as described by David Michener in this issue. There are currently 16,681 records in the PLANTS file.

The LINEAGES file is needed because at the Arnold Arboretum an accession is given a new accession number whenever it is propagated, either sexually or asexually. These “sister” and “mother-daughter” accessions share a common lineage number—that accession number under which the accession first came into the collection (for instance, lineage number 3786, representing Pyrus amygdaliformis var. persica, came into the collection in 1902 as a scion, was propagated as a bud graft in 1964 as accession 1046-64, and was propagated again in 1981 as a scion as accession 723-81). By maintaining a LINEAGES file, it is possible to ensure that all plants of a given accession lot bear the same name; without such a file, this would be a very difficult and tedious task, given the size, age, extensive propagation history, and complexity of the collection. There are currently 11,572 lineages represented in this file.

The PSOURCES file keeps track of all plant sources with which the Arboretum exchanges plants. For the 1684 records currently in this file, the system stores addresses and telephone numbers, staff names, generic and family specialties, and several other fields. A link to the ACCESSIONS file maintains a list of all accessions received from a particular plant source. Thus, the record for the Royal Botanic Gardens, Kew (plant source #408), shows that the Arnold Arboretum has received 266 accessions from Kew; for each accession, the Arnold Arboretum accession number and the plant’s name are listed along with the number of plants, how they were received (for instance, seed, cutting, division, and so on), the provenance type, and Kew’s accession number. This file is being expanded also to keep track of all accessions being sent to other institutions.

The LOCATIONS file currently contains 622 records. Each record represents a mapped area (usually 200 by 300 feet) whose key field corresponds to the code for the hand-drawn map. There is a description of the location by which the record can be retrieved (for instance, location #BRG-1-b reads “Jamaica Plain; Bradley Collection; Bed 1, Section b”), as well as two lists of plants (maintained by links to the PLANTS file): one list tracks all plants ever in the location, and the other tracks only those currently there. This file permits the production of inventory lists by location code for field-checking purposes.

The DS file has records for every data source used in the rest of the system. A data source is defined as any book, article, unpublished work, survey, conversation, and so on, from which information has been taken. Each data-source record (there are currently 270) contains information on author, date of publication, title, subtitle, source, call number, keywords, and abstract. For example, by referring back to this number in the NAMES file, it is possible to store very efficiently the fact that Hortus Third (DS #3) calls Alnus incana the “speckled alder” but that Krussmann (DS #7) calls it either “American speckled alder” or “common alder,” or that Abies alba is given seven different common names in Liu’s monograph of the genus (DS #73). There are links to the NAMES, COUNTRIES, STATES, FAMILIES, and GENERA files, and it is possible to create a bibliography for any record or group of records in these files. Since most fields in
the other files have an associated data-source field, virtually any piece of information can be credited to a data source.

The COUNTRIES file has a record for each country in the world, as defined by the International Standards Organization. Using the two-character country code, it is possible to store information about country of origin in the ACCESSIONS file, which then links to the COUNTRIES file. This permits the display of all accessions collected from a particular country in that country's record. There are currently 221 country records.

In the STATES file is a record for each state or dependency of the United States, keyed on the two-letter postal abbreviation. This file is used mostly to verify addresses in the PSOURCES file and to code geographic information in the DS file. Once codes are agreed upon for the political units for each country (preliminary approval was voted at the 1988 meetings of the Taxonomic Databases Working Group), this file will be expanded to include the subcountry units for all countries in the world, not just the states of the U.S.

The PHOTOS file arose from an Institute of Museum Services grant to computerize the data on photographs taken by E. H. Wilson in China, Korea, and other areas. It has fields for subject, country and province or state, date of photograph, and so on. There are currently 4994 photographs tracked in this file. Its structure is under revision to make it more generally useful and to link it more closely to the NAMES, ACCESSIONS, and COUNTRIES files.

Software Considerations
None of this would have been possible without a powerful and flexible software product with which to build this complex application. After working for several years with many other microcomputer database-management software (DBMS) products, I chose to use Revelation, then little used in the biological world, as a platform for BG-BASE because it puts very few restrictions or constraints on the designer of an application. A field can vary in length from zero to over 65,000 characters, meaning that there is no concern about either truncation or padding with blanks. In addition, a single field can store more than one value, a vital feature for fields such as common names for a plant, or field checks for an accession. These two features—variable-length fields and multivalue fields—combine to make this one of the most powerful database-management tools available for microcomputers.

As noted above, BG-BASE consists of over 560 fields, yet no one institution uses all of them. Although the master dictionary contains all of these fields, any particular garden might be using only half of them. A "blue skies" approach in the design of BG-BASE—creating a field for virtually every request from the various gardens using the system, regardless of whether others wanted to use that field—was possible since variable-length fields require only one character (a "field delimiter") of storage when they are not used, not the storage of vast numbers of blanks, as would be the case with a fixed-length field structure. This gives a garden the flexibility of utilizing a complex system at whatever level is appropriate to its internal record-keeping traditions; as the data-processing needs of the institution change, fields already defined in the master dictionary can be turned on or off without disturbing existing data.

The Way Forward: the Future of BG-BASE
Even though BG-BASE has been installed in 22 gardens in four countries, its design is neither complete nor static. Suggestions come from the Arnold Arboretum staff, from other institutions using BG-BASE, and from the many visitors who visit Jamaica Plain to look at the Arboretum's plant records, and enhancements are still being added regularly. Areas of active development include horticultural maintenance, scheduling, and herbarium-voucher modules. Database files are being designed to track insect pests, fungal and bacterial diseases, Integrated Pest Management systems, pesticides, and the like. New report formats for the production of hard-copy accession cards, the yearly accession
The Arnold Arboretum's Computer Network

In the mid-1980's, the Arboretum was given an anonymous donation that was used to install a network of microcomputers to handle the record-keeping needs of its living collections. Specifications were drawn up, computers were purchased, and in August, 1986, a trench was dug the two-fifths of a mile between the Visitors' Center and the Dana greenhouse complex, into which computer cable and telephone lines were laid. The exact location of this trench was then added to all affected maps of the collection. Cable was also run between the various floors of the Hunnewell Visitors' Center (not an easy task in an 1892 building with three-foot-thick walls) to connect the four IBM personal computers to the file server (the central microcomputer that stores all programs and data), which was placed in the basement next to the plant records office. The file server was installed with a 30-megabyte hard drive; this storage capacity was later increased to 110 megabytes when the education and membership databases were added to BG-BASE.

The system has now grown to include 11 microcomputers (with four more on order) linked to the original file server (which is slated for replacement in early 1989 by a machine that is three times faster and that has three times the disk-storage capacity). There are seven printers of various sorts, some shareable and others not, as well as a 24- by 36-inch digitizing table for mapping work.

Tape backups are performed daily by the system operator, and the tapes are stored off-site for maximum security against catastrophic loss, vandalism, and theft.

The work stations connect to each other and to the server through a Novell Local Area Network (LAN) operating system (a separate Novell LAN of eight microcomputers is used in the attic of the Hunnewell Visitors' Center by the Center for Plant Conservation's national office). All plant records, as well as the 12,125-record MEMBERS file, the 565-record COURSES file, and the 3223-record REGISTRATIONS file, are handled by the multi-user version of BG-BASE, which allows many people to access any file concurrently, although only one user can edit a particular record at a time (all records are date-stamped with the initials of the user who edits them). The network also serves most of the word-processing needs of the Arboretum, and there is a large-screen workstation used for desktop publishing.

Another important new link, discussed by Ethan Johnson elsewhere in this issue, is between BG-BASE and a computerized mapping program. The Arnold Arboretum received a $25,000 grant from the Institute of Museum Services to design and implement this link as a model for other gardens, a process that is currently in progress. When this link is completed, staff, and eventually the public, will be able to generate a map for any plant or group of plants based on virtually any of the hundreds of fields of data stored within BG-BASE.

As the mapping project progresses, BG-BASE is being converted from Revelation to Advanced Revelation to increase its power and flexibility further. Although the way the user interacts with the database system will be substantially altered, all the data will remain compatible between the two versions. Another major initiative, supported by the Andrew W. Mellon Foundation, is to standardize to whatever degree possible the data-
base structures of *BG-BASE*, the Center for Plant Conservation, The Nature Conservancy, and the Missouri Botanical Garden. Together, these various databases, all based on *Revelation* or *Advanced Revelation*, contain over one million records and several thousand fields. This is a first—but massive—step toward the eventual goal of establishing a global plant-information system, with Missouri's *TROPICOS* and *Flora North America* databases contributing vast amounts of information about native and exotic plants, The Nature Conservancy's *BCD* system supplying facts on plant rarity, biological attributes, and distribution, and *BG-BASE* contributing data on plants in cultivation in botanical gardens and arboretums around the world. Already, various standards have been proposed to and adopted by the Taxonomic Databases Working Group to ensure the greatest possible compatibility worldwide (a sample data set of all wild-collected accessions from the Arnold Arboretum was sent on diskette as an ITF file to IUCN's Botanic Gardens Conservation Secretariat at the Royal Botanic Gardens, Kew, to test the exporting and importing of ITF records between disparate computing systems). *BG-BASE* is thus one piece in an evolving matrix of interlocking databases.

The Arnold Arboretum hopes soon to be able to allow public access to the plant information stored in *BG-BASE* through a terminal in the Hunnewell Visitors' Center. Further funding is necessary before this and related projects—creating a visual database of the collection and providing on-line identification—can be undertaken. Digitized photographic images stored on laser disks linked to *BG-BASE*'s data and mapping coordinates will eventually allow the casual visitor as well as the visiting scientist to interact with the living collections of the Arnold Arboretum as never before.

### Bibliography


Kerry S. Walter is the director of botany and information systems at the Center for Plant Conservation and is the developer of *BG-BASE*. 
Chronicling the Living Collections: the Arboretum's Plant Records

Jennifer Quigley

The plant records office's high-tech functions are at the center of the Arboretum's newly integrated computer operation.

The Arnold Arboretum's plant-records system has evolved over the 116 years of the Arboretum's history, and although it has undergone many changes, it has retained its integrity as a curatorial record, the oldest continuously maintained system of its kind in North America.

The Development of the Records System

Jackson Dawson, the Arboretum's first plant propagator, kept a series of journals in which he recorded plants added to the living collections using a numbering system quite different from the year-coded system that we use today. It is unclear in what year these journals were begun, although they may have been intended to accompany the maps generated from Codman's 1887 survey. The earliest entries follow the Bentham and Hooker sequence that had been established for the collections and show no chronological progression, suggesting that the journals started as an inventory of plants already present in the collections. The numbering system used, in which each new taxon added to the collection was assigned a base number from which the numbers assigned to subsequent accessions of the same taxon were derived, likewise suggests inventory numbers rather than accession numbers as we know them in today's system. Source information was recorded in these journals and/or in a card file, suggesting the existence of a parallel record system that recorded all material received but was not at the time considered worthy of being kept once the information pertinent to the living collections had been transferred to the journals and cards.

As new material was added, it was necessary to check the existing records in order to determine whether the taxon was (or had been) already represented. If so, a sequential suffix number was added to the established base number. For example, the first recorded accession of *Magnolia acuminata*, seed received in 1874, was assigned the number 35. The next, a plant received in 1877, received the number 35-1, and plants received in 1879, 35-2. Incoming materials of taxa not already represented were assigned new base numbers.

When the identification of an accession was changed, its number was also changed in order to reflect the new taxon to which it was assigned. As the collection grew, so did the quantity of accessions representing the same taxon, and the use of the same base number for genetically unrelated accessions invited error and misinterpretation. It became clear that the system required a change, so a large proportion of the collection was renumbered: the first incoming accession of a taxon retained its number, but later accessions of the same taxon were assigned new numbers. Vegetative repropagations of material already in the collection continued to follow the suffix system, each bearing a number derived from either the original or the new base number assigned to the accession from which it
had been propagated. Although the system remained cumbersome, it was no longer necessary for numbers to change with new identifications, nor did the assignment of a number to a new accession require a thorough check of both current and dead records.

In 1916, when William Judd assumed the post of plant propagator, he initiated a new system, assigning a year-coded number that consisted of a sequential number with an appended year code [for example, *Fraxinus quadrangulata*, 52-16, was the fifty-second accession received in 1916], an accession number in the current sense, to each accession received. In the same year the greenhouse produced its first accession book, quite distinct from the earlier inventorylike journals. A chronological listing of all plant materials received, regardless of whether they were added to the living collections, the accession books now serve as our primary reference in tracing the histories of our plants.

As plants were added to the collections, however, they were assigned numbers in accordance with the older system and entered into the journals; both numbers appear on the records of material received during this period, although the inventory number has been the one used in curation of the collection. By 1934 it was apparent that the system was overly cumbersome. Base numbers had reached well over 22,000, and even in its new form, the suffix system was generating complications. Since that year the accession number assigned at the greenhouse has as a rule been retained throughout the recorded history of the resulting plants.

Still, until the mid-1970's, it was common practice for material that did not fit the standard accession pattern to be assigned an inventory number. Plants resulting from the hybridizing work of Karl Sax during the 1950's, representatives of the Arboretum's spontaneous flora deemed worthy of curation, and individuals selected from their accession lots either because the accession lot was found to include more than one taxon or for introduction as cultivars [for example, *Hamamelis* 'Arnold Promise', selected in 1963 from accession 1173-28 and assigned number 23167] were among the exceptions to the system.

A card file maintained at the greenhouse contains the information available upon accession of new material [name, date of receipt, immediate source, original source if known, quantity, type of material, locale of collection if collected from a wild population, and any additional information concerning growth habit, flower color, or other characteristics of the material being accessioned]. This information is copied into the annual accession book. In addition, the greenhouse file is annotated with the methods used in propagating the accession [if seed, whether it

Jackson Dawson, 1841–1916, the first superintendent of the Arnold Arboretum, had been passionately interested in seeds since childhood. During the American Civil War, some of his wounds were supposedly received while he was searching for plants and seeds. A distinguished plant propagator, he was noted for "seemingly impossible" accomplishments in grafting, seed germination, and plant culture, as well as for hybridizing the Farquhar, W. C. Egan, Dawson, Lady Duncan, and Sargent roses.

Photograph from the Archives of the Arnold Arboretum.
was stratified, if cuttings, whether hormones were used to induce rooting, and so on). This file provides information used by our propagation staff in determining the most effective means of propagation for additional incoming material (or of repropagation for material already in the collections), and in responding to inquiries from the public or other professionals.

A second card file, maintained by the plant records office, chronicles the living collections. This file, containing the accession information already recorded in the greenhouse files and the accession book, lists individual plants representing the accession lot and their locations on the grounds; it is annotated with information regarding the status of these plants each time a staff member checks on them.

It is the responsibility of the plant-records-office staff to perform regular field-checks in the collection to determine that all plants are properly mapped, recorded, and labeled (a full discussion of mapping procedures and our map system can be found in the article by Ethan Johnson in this issue). We conduct these field-checks map by map, with a full remapping cycle of the grounds requiring approximately ten years, and volunteers and seasonal interns have played a major role. In addition, other staff members working with the living collections report to the plant records office any discrepancies that they encounter between records information, maps, and plants on the grounds. In the course of their work, verification-project personnel have checked the collections in a pattern very different from the one traditionally followed by records-office field-checks. Timing their collecting activities to coincide with flowering or fruiting seasons and working with related groups at diverse locations on the grounds, they have been able to identify problems that had not been apparent during traditional field-checking. The information gleaned from records-office map checks, the verification project, and other staff members, together with any nomenclature updates or additional information obtained through library references or correspondence, is used to update the maps, the card file, and a computerized record maintained out-of-house.

The Arboretum and the Plant Sciences Data Center
Since 1972 the Arnold Arboretum has been one of many North American gardens providing collection information to the American Horticultural Society's Plant Sciences Data Center (PSDC), located in Alexandria, Virginia, and designed to function as a central databank. Initial input to the system was performed by staff of what was then known as the Plant Records Center from copies of our living-collections card file. Much of the data entered was incomplete or incorrectly interpreted during input, resulting in errors and omissions that continue to confuse and confound those who work with the printouts generated from these records, despite the number of corrections made to them in subsequent years.

We update the PSDC records twice yearly with information concerning plants added during each of the Arboretum's planting seasons and with changes in status for existing material, which we type on standard forms and mail to PSDC for entry to their computer system. We note all additions, changes, and deletions on the current printout maintained in the plant records office, and each year when a new printout is received from PSDC, we check item by item to ascertain that all information has been properly recorded.

The format for entries in the PSDC database requires that much of the information that we have maintained in our card file over the years be abbreviated or ignored entirely, since the system uses a flat-file structure and fixed-length fields. Despite the limitations imposed and the additional work necessitated for the plant records office, use of the database has provided us with a needed check on the accuracy of the card file and has served as a method of sharing our inventory information with other gardens through the PSDC's microfiche listing of the holdings of all gardens in the system. An additional benefit
Display and record labels provide different types of information. The display labels are for the public and now list common and Latin names, plant family, and the species' geographic range. The trunk display labels (scotch pine) are nailed to the trunk, while hanging display labels (black poplar) are suspended from a branch. Older display labels provided less information. The record labels (one shown with wire attachment) are used by the staff and list curatorial information applicable to that specific accession. Photograph courtesy of Rác and Debreczy.

has been that, unlike the card file, the printout generated by PSDC is available in multiple copies and can be provided to numerous staff members for reference use. The standard printout (PSDC's General Information Listing) is arranged in alphabetical order by taxon, but special-use printouts have been generated in various formats, including listings by map location, year of receipt, and family. Listings of particular genera have been provided for use in research studies.

Other Plant-Records-Office Functions
When plants appear on a seasonal planting list for addition to the collection, plant-records staff trace their lineage to determine whether they meet collections standards, verify their nomenclature through literature search, check the records to ascertain whether the taxon is already represented by the three wild-collected accessions mandated by collections policy for each naturally occurring taxon, make recommendations concerning whether the accession should be added to the collections and whether existing plants not meeting our standards or in poor condition should be removed as the new plants are added, and assign each individual a letter designation that differentiates it from others of the same accession lot. Embossed zinc record labels are produced for each plant and attached to it while it is still in the nursery. A record card and a PSDC entry form are completed for each, leaving only the map location to be filled in once it is determined. As planting progresses, individuals are added to the maps and their records are annotated with planting locations coded to the map system.

The plant records office is also responsible for display labeling in the collections. In fact, it is only within the past two decades that the responsibility for maintaining the records has been with this office, and within the past one that the files have been housed here. Previously it was the horticulturist who held prime responsibility for the records system, and what we now know as the plant records office was concerned primarily with mapping and labeling duties. Display labels were produced in-house until 1985, many of them by a member of the grounds staff during the winter season. The process by which labels were made was time consuming, involving applying automotive primer and top coats on a custom-cut sheet-metal plate, setting rubber type and printing display information on the label, and using a final protective coat of automotive varnish or polyurethane. Display labels are now produced out-of-house using the metalphoto process, in which a photographic negative is printed on sensitized aluminum. These labels are more durable than the earlier painted ones, since the image and the metal are fused in a manner that resists the cracking, chipping, and rusting that plagued the older labels.

In January of 1949, Donald Wyman completed a listing of all taxa then represented in the Arboretum's collections, with their common names and natural range, to be used as a reference in preparation of display labels. This enumeration has been expanded and
Mindful of the Past, Considerate of the Future

The Arnold Arboretum maintains substantial archives of documents, photographs, and objects to record its history and the development of its collections. Of special significance to the verification project has been material pertaining to E. H. Wilson. Wilson, active at the turn of the century, was the primary plant collector responsible for the diversity of Asian species found in our living collections. A recent grant from the Institute of Museum Services, supervised by S. Connor, has made this material far more accessible to the curatorial staff. We are now able to determine all the living accessions that trace to a Wilson collection, regardless of their current accession numbers, read his newly transcribed field books for wild-source information that had not originally been recorded in the plant records office (his hand-written books are nearly indecipherable), and find the associated photographs linked to these plants and expeditions. Undoubtedly, some of the materials deposited in the archives were not considered terribly important at the time, but fortunately they were saved; this has allowed us to unravel and better understand part of Wilson’s work. Archives are a quintessential element for the curation of collections that span generations and changing institutional priorities.

updated over the years by the records-office staff; since 1979, we have also used it to record family, author, and the reference used to document the nomenclature, as one facet of an attempt to centralize the information required for the effective curation of the collections but previously scattered through files maintained in various offices or available only through library research.

The Role of the Plant Records Office in Verification

In 1979 the Arboretum applied to the National Science Foundation for funding that would enable us to begin a comprehensive verification of the collections and establish an in-house computer system for plant records. This application was funded, and work began with the documentation of all nomenclature in use in the collections. The Living Collections Committee had established a policy regarding nomenclature (see Arnoldia, Volume 39, Number 6, 1979, for a discussion of this policy with regard to infraspecific taxa), and a person was hired to review the collection records and perform a literature search to verify the validity of each name, under the supervision of the plant records office. Some names had already been researched in the course of normal curation; others required extensive library work; still others proved impossible to document. We purchased an Onyx computer (the smallest computer then available that would accommodate so large a database) and two terminals, installed them in the plant records office and at the greenhouse, and established a connection between them using modems. After development of a database format using the Logix database system, input from the existing records began. Repeated failures of the Onyx hardware, however, forced the abandonment of the computer just as data entry was completed. Although the Arboretum bought Digital Rainbow personal computers soon thereafter for a number of applications including the recording of accession information and the maintenance of nursery inventories, they were not suitable for the full plant-records database. It was not until July of 1986 that the generosity of an anonymous donor permitted us to purchase and install a new computer system, and we made a new start on internal computerization (refer to the article by Kerry S. Walter
The present verification project was designed as a continuation of the original grant project, and a usable database had been anticipated in planning for it.

The unavailability of computerized records for the verification project necessitated changes in the way the project proceeded. The project personnel worked with printouts obtained from the Plant Sciences Data Center, which provided far less information than would have been immediately available through the computerized database and necessitated much cross-checking to the plant-records card file. Notations made to the working printout (concerning, for example, missing or dead plants, plants that did not appear on the printout but were present on the grounds, plants in poor condition, plants needing replacement labels, and plants whose map locations needed adjustment), as well as identity determinations resulting from the project, had to be communicated to the records-office staff for updates to the records, instead of being immediately incorporated into the database. This increased the amount of labor on the parts of both verification-project and records-office staff, since notations had to be made in several formats to various systems, especially as computerization progressed and updates to the database were required. Further duplication of effort became necessary when the nomenclature guidelines established for the earlier grant project were discarded, and name changes that had been processed during that project had to be processed again, but in reverse.

**BG-BASE: a Long-Awaited Transformation in Record Keeping**

For many years there was a weak connection between the herbarium and the living collections. Although voucher specimens of plants in the collections had been made since the Arboretum's earliest days, it is only in recent years that they have been consistently identified by accession number. Taxonomists on the Arboretum staff have traditionally conducted a continuing review of both herbarium specimens and living material, annotating the living-collections records as well as herbarium vouchers with changes in nomenclature. When visiting taxonomists annotated vouchers, however, the inclusion of their determinations in the records of the living plants was not guaranteed; often it was not until a staff taxonomist discovered these herbarium annotations in the course of his own work that living-collections annotations were made. Likewise, changes in the living-collections records based on horticultural rather than taxonomic review were rarely reflected in the herbarium. Although nomenclature in the living collections was updated as monographs, checklists, and manuals were published, such systematic annotations were seldom undertaken in the herbarium collections or in the records of accessions no longer represented by living material. Number changes in the living-collections records were not related to existing herbarium specimens, making the task of matching early specimens to the collections records or to living material of the same lineage increasingly difficult.

In designing our second computerized database, we were fortunate to have the personnel for the verification project already present. This enabled us to obtain input from the verification-project taxonomist in our efforts to link the herbarium with the collection records. Our previous experience with database design also proved beneficial in our cooperation with Kerry Walter in the design of **BG-BASE**, since some of the problems inherent in the development of a plant-records database had been addressed in the earlier attempt.

Entry of information to **BG-BASE** began very early in the system's development because of its design as interrelated modules. The first entries made were to the FAMILIES file, then to GENERA, PSOURCES [plant sources], and NAMES [taxa], and finally to ACCESSIONS and PLANTS [individuals representative of each accession lot]. Data entry was an involved process, necessitating repeated passes through the existing records (one for the sources from which our plants had come, another for the taxa included in the
collections, a third for accession information, and a final one for individual plant locations and field notes). Had the database been fully developed prior to the beginning of data input, these functions might have been incorporated into a single pass through the files, but the completion of data entry would have been significantly delayed, and the modification of problem areas in the database would not have been the evolutionary process that it was. In working with each module of the system independently of the others, we were able to identify problems before subsequent modules compounded them, rendering them more difficult to revise; our weekly meetings provided a forum for discussing alternatives and additions to the design. Serving as the testing ground for the database proved to be a challenging and exciting experience for all involved.

The plant-records card file and PSDC records have been maintained throughout the process of computerization, serving their original functions while the database was growing and now providing a check on the accuracy of the information in the database. Soon the card file will be replaced by one generated from the computerized records, a "hard copy" reference to the collection much easier to interpret than the old hand-annotated cards. The greenhouse card file, as well as the annual accession book and a number of reports for curatorial purposes, will likewise be computer generated. We will save countless hours at the typewriter copying information from one place and one format to another (thus eliminating the possibility of errors in the process), yet our curatorial information will be more comprehensive than ever before. We have started to computerize the Arboretum's photographic archives, allowing reference to yet another of the resources that will aid in the curation of the collections and increase their value for research and public education. The map system, currently in the early stages of computerization, will be integrated with the database, enabling maps to be updated automatically when changes are made to the records and opening a range of possibilities for special-purpose maps generated from a selected subset of the full collection. Plans for future expansion of the system include public access to the database through a terminal at the reception area and graphic-display capabilities to increase the value of the database to the public.

When I joined the staff of the Arnold Arboretum in 1976, we all looked on the days of Charles Sprague Sargent as the Arboretum's "Golden Age". We now find ourselves at the dawn of a new Golden Age, with a comprehensively verified collection, access to which is enhanced by a computerized system linking departments and interests to make the collection usable in ways that Professor Sargent could never have imagined.

Jennifer Quigley manages the plant records office and serves as system administrator for the Arboretum's computer network.
Cartographic Records of the Living Collections

Ethan W. Johnson

The Arboretum's new maps will ultimately interface with the computer database, allowing extremely accurate tracking of accessions on the grounds

The first map documenting the placement of trees planted in the permanent systematic arrangement was made by Henry Sargent Codman in 1887. Only two years before, Charles Sprague Sargent and Frederick Law Olmsted had decided upon the final planting plan and landscape design, and implementation had begun in the spring of 1885. Codman, a cousin of Sargent, prepared a series of genus or group maps on a scale of 20 feet to the inch, showing the actual position of each tree with the number that appeared on its label. The question of preserving the identification of every tree in the collection in a more secure manner than that afforded by the labels used in the living collections was therefore resolved at an early stage of the Arboretum's development.

The Second Wave of Survey
León Croizat, using a 150-foot tape and a plane table equipped with an alidade, resurveyed the entire grounds between October 1, 1937, and October 5, 1938. He established a grid system that was aligned to conform with the boundaries of the Arboretum instead of being set on the usual north-south axis. The standard maps were again made at a scale of 20 feet to the inch, each representing an area 400 by 600 feet, but there were still some that did not conform to the grid. These maps, done to show a specific genus or other group of plants, were made at a scale of ten feet to the inch (or sometimes five or even two feet to the inch) when the areas were densely planted. From 1938 to 1970, the living collections were field-checked and the maps traced and revised by Heman Howard. Howard field-checked the entire collection on a two-year cycle and revised the maps on a six-year cycle; his efforts produced results that were unparalleled by his contemporaries. From 1970 to 1979, the mapping duties fell in turn to three separate individuals. Following the departure of Donald Wyman, horticulturist, in 1970, the maintenance of the card-file plant-records system and the responsibility of providing records information to the Plant Sciences Data Center (see article by Quigley) became part of the duties of the individual performing the mapping function. Field-check rates decreased, and the cycle of map revision was set at ten years. Since 1979, the Arnold Arboretum has actively sought an alternative to its antiquated system of maintaining cartographic records.

A New Age
In 1987 the Arnold Arboretum was granted $25,000 by the Institute of Museum Services for the development of a model computerized mapping system. The goal of the project is to remap accurately the 14,500 plants in the Arboretum on a system that will interact with its plant-records database (BG-BASE) to produce continuously up-to-date, computer-generated maps that reflect the topography of the Arboretum's diverse landscape.

With the help of Bradford Washburn, then the director of Boston's Museum of Science, the Arboretum contracted a photogrammetric survey of the grounds by Swissair Photo + Sur-
Our detailed inventory maps show every accession. Here, on the summit of Bussey Hill, the base map (right) shows the major plantings and specifies which inset maps cover thickly planted areas. The aerial photograph (above) is used in conjunction with the current maps and a computer-linked digitizing tablet to find the true coordinates of every accession distinguishable on the photograph. The photographs will help remove distortions caused by the irregular topography. Storing all the information on a database will allow us to update and print standard and specialized maps as needed.

Photograph by Swissair Photo + Surveys, Ltd.

On a cloudless day in April, 1979, the survey crew took a series of aerial photographs, which were then transformed into orthographically corrected images displaying an exceptionally accurate picture of the Arnold Arboretum at a scale of 100 feet to the inch. A ground-survey team was hired to complete the contours in certain areas of the Arboretum that are covered by an evergreen canopy. Swissair provided the Arboretum with a base map of the grounds that illustrates true north, contour lines at intervals of ten feet, physical features (roads, paths, walls, and buildings), and reference points. This information was also provided in electronic form on floppy disk requiring a format conversion of the data from Intergraph to AutoCAD, the computer-aided design software obtained by the Arboretum for the mapping project. Hardware purchased for the project includes a Compaq Deskpro 286 computer equipped with a monochrome monitor, Nth Engine Graphics, an Intel 80287 math coprocessor, a 24-by-36-inch Calcomp 9100 digitizing tablet, and an NEC Multisync II monitor for color graphics display. A Safe Standby Power System was obtained as insurance against computer crashes due to power failures.

An interface between AutoCAD and the plant-records database software [Revelation] is being written by Jung/Brannen Research and
Development Corporation of Boston. The Arnold Arboretum will construct a mapping system that is interactive with BG-BASE, wherein attributes and changes in the plant-records database will instantly be reflected in the mapping component (AutoCAD). Location data for specimens in the aerial photographs is entered into the graphics database by taping a photograph onto the digitizing tablet, calibrating the reference points, and digitizing the center of each plant visible on the photograph. The accession number for each specimen is entered at this point by comparing the photographs to the existing hand-drawn maps, thereby linking the graphics database with the plant-records database. This linkage will open the door to the production of specialized maps based on any number of fields of data stored in BG-BASE, including plant family, genus, species, age, origin, and collector.

Great Expectations
We look forward to taking advantage of the computerized mapping system, the benefits of which will begin to be realized when the project reaches completion. Before we can generate maps, though, we must finish entering the data for all accessioned plants on the grounds—a task scheduled for completion by August 31, 1989. Acquiring our own plotter will greatly facilitate map production and will eliminate the need for costly out-of-house services. Considerably less labor should be necessary to keep the computerized cartographic records current, since we will no longer have to draft the maps by hand. Specialized maps tailored to needs of individual staff
members and visiting scientists will be produced with speed, accuracy, and precision. Furthermore, in the future we expect that a much greater range of visitors will have access to the cartographic records that are a key to unlocking the intricacies of the Arnold Arboretum’s living collections.

Ethan W. Johnson is a curatorial assistant in the plant records office.
Landscape Curation: Maintaining the Living Collections

Gary L. Koller

Modern-day maintenance at the Arboretum must respect history and taxonomy while allowing easy access and unhindered future growth of accessions within an Olmsted landscape.

Design of the Collections
At the Arnold Arboretum our goal is to collect all of the temperate woody plants that are hardy in the Boston area. This task becomes yet larger when we impose upon it our desire to include three examples of each plant, of three different ages and from three different geographic locations. In essence, for each taxon we wish to have young, middle-aged, and mature specimens that can demonstrate long-term changes in architecture and form and seasonal alteration in chemistry.

Both initial design and long-term maintenance affect our ability to curate a collection. In the past we thought that everything we planted needed to be provided with both the space and the resources to develop into a specimen plant. Later the grounds became cluttered because we planted in every available space. Established plants grew to enormous sizes, obscuring views, squeezing out neighboring accessions, interfering with access, and ultimately leading to the feeling that certain areas were unsafe because of the dark, hidden spaces thus created among the plantings.

At the Arboretum we try to integrate new plantings within the concept of the historic planting scheme. The master plan, based on late-nineteenth-century concepts and arranged according to Bentham and Hooker's system of plant taxonomy, grouped plants by genus. It attempted to accommodate special-}

ized environmental needs of groups such as the willows, which were planted at the edges of a wet meadow rather than strictly according to their taxonomic placement. Today we strive to achieve a compromise among con-
siderations of strict taxonomic grouping (for easy study and comparison), optimal environmental conditions, ease of curation and maintenance, and aesthetics. We place the majority of plants of a genus together so that they are quickly found, allowing easy comparison of the different taxa.

Trees
We always plant trees in groves, which are intended to be reminiscent of a New England landscape. For example, maples, lindens, and horse chestnuts are near one another. Over time, these trees are relatively easy to keep track of since they usually have one discrete stem that can be readily found using our inventory system. If weed trees invade, they are nearly always of another taxon and do not correspond to what is shown on the map. We generally mow the grass around the trees to lessen the likelihood of weed intrusion. However, hundreds of Rhamnus, Malus, Phellodendron, and Kalopanax seedlings inevitably appear in the unmown, uncultivated space beneath trees. Many of these weeds become quite large before being removed, and in some cases they compete with the crowns of smaller trees, eventually distorting the form of the accessioned plants.

Labels on the trees allow us to check field maps to determine whether a particular tree should or should not be there. Display labels nailed to the trunk are far more permanent than record labels affixed to a branch with bell wire; the latter are frequently lost during maintenance or a storm and are easily removed by small children and vandals. Visitors sometimes find a stray label lying on the ground and, in an attempt to be helpful, rehang it on the nearest—but incorrect—plant. It may take us years to discover the inaccuracy, even if the error is a seemingly obvious one. Meanwhile, visitors (as well as interns, volunteers, and inexperienced staff members) are relying on incorrect information.

With any collection of trees, it is important to consider the future. Many of the existing trees at the Arnold Arboretum are a century or more old. This is still young for many species, but what will their condition be in 50 years? In a collection with so many trees of the same age, we need to be careful that all will not enter a period of decline or senescence at the same time or become especially vulnerable in old age to drought or storm damage. For example, the great storm that struck the Royal Botanic Gardens at Kew in October, 1987, devastated large numbers of trees, many of which were hundreds of years old. Here at the Arboretum we attempt to conduct a programmed yearly harvest of poor-quality, inadequately documented, duplicate, or declining plants, with an emphasis on trees. This means that the staff must survey the tree collections on a periodic basis to determine their quality and to assess the need for maintenance, repagation, and—eventually—removal. Requesting, coordinating, and monitoring this care are tedious and time-consuming tasks that have been and will continue to be greatly facilitated by our electronic inventory system.

We have determined that it is not cost effective to maintain plants that are in a state of active decline. In the past we have made extraordinary efforts to rescue declining plants; this ended up being a waste of time and money since we were seldom successful in doing anything more than prolonging the decline. In an attempt to keep a plant looking good physically, we would prune out the dead and dying wood, slowly dismembering the tree and giving it an increasingly grotesque appearance. Maintaining plants that are unattractive representatives of a species also reflects poorly on the image, dynamics, and vitality of the institution.

A garden staff must be diligent in its review of long-existing collections to assure that health, vigor, and representation are being maintained. There is a tendency in gardens for the current staff to be so caught up in its own discoveries and introductions that it neglects the curation and care of plants introduced earlier and/or by others. It is understandably difficult to get excited about curating a decrepit, 110-year-old, wild-collected Picea
A majestic white oak, *Quercus alba*, in an early stage of decline. Rather than focusing on costly and heroic efforts to save particular trees or limbs, crew efforts are directed to maintaining the overall health and vigor of the collections. Photograph courtesy of Rácz and Debreczy
abies when new species await discovery in exotic far-off lands. We believe that the Arnold Arboretum maintains a healthy balance, hampered only by lack of personnel, between acquisition of new material and vigorous management of old.

Shrubs
Many shrubs are difficult to track over time. Large shrubs with one or more trunks are as easily tracked as trees, but problems arise from those that form thickets or colonies by means of underground stolons or by rooting in where branches touch the soil. When two plants of the same colonizing shrub are planted side by side, it often becomes impossible to tell where one ends and the other begins. In just a few years they intermix and become physically inseparable. An example in the Arboretum's collection is provided by the Leitneria swamp, where four separate accessions were planted years ago. Today they have all merged, and since it is impossible to tell which is which, they are virtually useless in scientific research where their provenance is important. In another area we planted various species of the genus Rosa. These plants have slowly sent up sucker growth or tip-layered into adjacent space, forming neighboring thickets that have penetrated one another. To compound the problem, birds have eaten the fruits, and the seeds contained in their dropings have resulted in unknown seedlings among the known accessions.

Where similar plantings are tightly grouped into a planting scheme, an institution must be strongly committed to frequent rounds of field-checking, marking weeds for removal, and reducing the number of layers that render long-term retrieval of specific individuals difficult. Without constant curation and maintenance, important collections quickly deteriorate, becoming little more than a mass of pretty flowers at bloom time. Such indistinguishable masses become candidates for elimination when we need space to add properly documented plantings. We have often lost important accessions in this way.

From experiences such as these, we have learned that we must never place plants of the same taxon side by side unless there is vigorous annual maintenance curation to keep them apart or some type of in-ground barrier to maintain their separation. It is also important to insert marker or reference plants. For example, in a bed of Philadelphus this might be a plant of the same genus that is distinct enough in some attribute to be recognizable at all times of the year, or a member of the genus Deutzia, which is in the same family but can be easily distinguished.

During the past several years we have acquired a huge collection of Sorbus taxa from documented wild sources. To ensure that we can track individual plants efficiently for future retrieval, we are integrating them in a naturalistic style with the conifer collection. In this situation, the Sorbus plants and the conifers will serve as markers for each other.

A current problem in the shrub collections is the overmaturity of many plantings. Many

The Leitneria swamp was originally planted with several different accessions. The plants have suckered and fused into an indistinguishable mass that accurately portrays the species but is of limited use when retrieving material linked to the original sources is important. Photograph courtesy of Rácz and Debreczy.
are 100 or more years old. This means that they grow more slowly, are more prone to pest and environmental problems, and are more easily invaded by weeds. We are attempting to redress this situation quickly by two methods.

With shrubs that are multiple stemmed and form a thicket, we cut the plant back to soil level in early spring, lift the root system out of the ground with a backhoe, and divide off four to six healthy layers near the outer perimeter of the plant, much as one would divide a herbaceous perennial. The plants are reaccessioned and relabeled to reflect their renovation. They are then planted in large containers and provided adequate water, fertilizer, and time to allow them to recover and establish strong growth. Most plants lifted and divided in the spring of 1989 will be ready to go back into the collection in the fall of 1990. We have improved our methods, shortened the production cycle, reduced the mortality rate, restored health and vigor, and gained new replanting opportunities.

With single-stemmed shrubs or those that do not respond well to division, we often take cuttings or grafts. Due to the small size of the initial propagation material, this method frequently requires a production cycle of three to five years before the resulting plants are large enough to put into the permanent collections.

Vines
From a long-term identification standpoint, vines have been the most problematic group in the Arnold Arboretum. Planted along the perimeter fences to screen them and to provide visual softening of the mechanical enclosures, our vines have grown enthusiastically, climbing over neighboring shrubs and outcompeting them for light. They have clambered up into nearby trees, strangling the trunks and tangling with adjacent vines. Branch layering and spontaneous seedlings have worsened the problem. When planted near walkways, vines such as Wisteria and Actinidia seem to reach out and snag pedestrians. Keeping these rampant growers under control and in bounds is a maintenance chore that is often done infrequently, ineptly, or incompletely; as a result, tracking individual vine accessions has become next to impossible.

The Arboretum used to have a vine trellis, which provided a more efficient system of locating individual plants. Each kind of vine was planted next to a leg or an upright of the trellis, which was numbered in our mapping system. This way, one could always go back to the same numbered post. Two problems occurred, however. First, as birds sat on the trellis eating fruits (of Celastrus, for example),
they left droppings containing seeds of practically every other accession on the trellis, resulting in such a tangle that it was practically impossible to separate the intruders from the desired plant. Second, the vine trellis became old and structurally unsound; legs had rotted off and sections had tipped over. During a landscape revision of the entire area, we decided to remove the collections from the trellis, and at the time we did not have the resources to reestablish a new trellis at another location.

As we expand and extend our vine collections in the future, we need to keep better track of what plants we have and what they are doing. We believe that it will be best to grow clinging vines up trees that will then become marker plants for them, and to grow twisters and twiners, which we can curate and maintain better, on a trellis.

**Propagation**

Management of an existing collection involves propagating selected high-quality plants and conserving them over the long term. Plantings must be periodically surveyed to figure out which plants to propagate and when. We make a special effort to determine what material is unique or historical and take steps to increase its population for long-term safety.

Reproduction by seed results in an individual genetically different from its parent or parents and thus does not constitute a direct replacement of a specific individual. (Seeds, especially those from a garden collection, are genetically unknown because of open pollination.) Therefore, most of our replacement plants need to be produced by vegetative methods. This requires an experienced propagation staff equipped with the right facilities and resources to ensure success. When a plant, such as a willow or an arborvitae, can be reproduced by cuttings, we need only determine the appropriate time and technique; with many plants, however, we must resort to layering, grafting, tissue culture, or another specialized technique.

Once a request for propagation is made, our methods of tracking the targeted individual or individuals is still imperfect. Collectors occasionally harvest propagation materials from the wrong mother plant because of close similarity among neighboring plants or inexact mapping coordinates. Difficulties can also occur in the propagation chambers. It is important to pay close attention during the first potting because it is easy to mix up the plants as they are lifted from their propagation flats. This sometimes happens when cuttings are grown in adjacent rows that are not clearly separated from one another. The cuttings are removed and—in haste, or if our attention is diverted—confused. In a row of several plants where only the first one is labeled, if someone rearranges them the order may be changed and the plants mixed with similar accessions such that none of them except those bearing labels can be identified with certainty. To reduce the possibility of such mix-ups, we supply each plant in a container with an accession-number label that is inserted in the pot at the time of transplanting or repotting.

Propagation is not as simple as making a request to have the work done. We may graft an oak tree only to have all the grafts fail or the young plant perish at transplanting. We therefore need to maintain the parent plant for months or years before we can guarantee that the specific genetic individual will survive. Unfortunately, the slow, often obvious decline of a plant can lead visitors to wonder why it has not been removed and replaced and even to suspect that we maintain our collections poorly. If we allowed ourselves the expediency of going to a nursery and purchasing replacement plants, the process would be much simpler; we could quickly rip out the old plantings and install new ones. However, since we wish to preserve specific plant lines, old plants must be retained until the replacement generation is successfully established.

In the past, our lack of effective inventory control in the nursery often led to confusion. We would repeatedly repopulate the same
A General Schedule for the Grounds Staff

**January–March:** repairing equipment and preparing it for a new season, cleaning up major problem areas, harvesting poor-quality trees, pruning trees, chipping brush, mulching planting beds, applying preemergence weed killers, fertilizing plantings, lifting and dividing plants scheduled for rejuvenation.

**April:** planting for spring, mulching beds, removing tree stumps, pruning, mowing.

**May:** completing spring plantings, beautifying grounds for our primary visitor season, with particular attention to the lilac collection, mowing, and pest and weed control.

**June–August:** mowing, pest and weed control, watering, routine pruning, preparing beds for fall plantings, removing plants.

**September:** mowing, pest and weed control, correcting problems in beds and plantings, repairing and upgrading poor-quality lawn areas.

**October–November:** planting for fall, removing spontaneous weeds at bases of trees and exotic invaders in natural areas, fertilizing selected plantings, aerating lawns, mowing, removing poor-quality plants scheduled for harvesting, mulching planting beds, spraying young evergreens with an ugly mixture to prevent their theft for holiday greens.

**December:** removing trees (especially evergreens scheduled for recycling as Christmas greens), cleaning up problem areas, mulching planting beds.

**Year-round:** surveying collections to determine needs, repropagating, removing plants and providing specialized care, cleaning up trash, controlling vandalism, making minor repairs associated with visitor wear and tear.

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declining individual over successive years, ending up with multiple replacements and wasting our limited resources. Modern electronic tracking has allowed us to determine more quickly which propagation requests have been carried out in the past year and which attempts have been successful. In addition, electronic file-sorting allows us to determine the present condition of the parent plant, find duplicates within our nursery holdings, and prevent repeated plantings of the same lineages.

**Adding Plants to the Permanent Collections**

Twice each year, in spring and fall, we move plantings from the nurseries to our permanent collections. A major task, this involves identifying what is ready to be planted out, reviewing each plant’s records to make sure that it is needed, preparing labels and accession information, finding a planting location suitable from both collections and environmental standpoints, digging and replanting the plants, making sure that each one is mapped, and providing aftercare including staking, pruning, and watering. The process is cumbersome and labor intensive because we deal with small quantities of so many different plants.

We have become efficient at producing large numbers of plants new to the collection, as well as high-quality replacement plants. At the same time the mortality rate associated with transplanting has dropped substantially. Such increased efficiency has created a logistical problem, however, for there are too few hands to deal with this semiannual process.
As a result, plants have backed up in the system, becoming too large for our staff to manage with available resources; they have often crowded and damaged neighboring plants in tightly spaced rows. We have streamlined the process by growing the plants in containers, but this causes problems in inventory control. Although such plants are more easily shifted about in the nurseries to allow additional growing space, they are more difficult to keep track of. Furthermore, when plants of the same lot are separated, additional records work is necessary in preparing for the plantings.

In the past many young replacement plants went out without there being a plan to remove the parent plant. After a season or two of overlap, the parent plant should have been removed to make space for others and to simplify the collection. In a number of cases, the removal request has only been partially implemented. Sometimes the records and mapping information have been removed from the files, but we have forgotten to remove the plant; alternatively, the accession information has sometimes remained in the active files although the plant has been removed.

The Changing Landscape
Given 117 years of planting, it is not surprising that areas of the Arboretum have become crowded, both physically and aesthetically, and that habitats in certain areas have changed as the young trees of the late 1800's have become the towering canopy trees of today. Regrouping young plantings allows us to use shrubs to create, divide, and separate space as was typical in the Olmsted landscape. By integrating different taxa, we can vary form, color, texture, flowers, fruits, and autumn foliage, allowing both separation of easily confused taxa and long-term access to individual accessions. If these steps are followed carefully and creatively, they can result in more interesting year-round spatial, visual, and aesthetic effects, adding to the gracious informality that characterizes the historical landscape style of the Arnold Arboretum.

Gary L. Koller is managing horticulturist at the Arnold Arboretum, as well as an instructor for a course entitled "Plants in Design" at the Graduate School of Design, Harvard University.

CORRECTIONS
In the final paragraph of the article “Dr. Robert E. Cook is New Director of the Arnold Arboretum” in the Fall 1988 issue of Arnoldia (Volume 48, Number 4, page 3), the first sentence should read: “Dr. Cook’s own research interests are in plant population biology in general and in the biology of clonal plants in particular.” The last sentence should read: “Dr. Cook has also been program director of population biology and physiological ecology at the National Science Foundation.”

In the Fall 1988 article “‘So Near the Metropolis’—Lynn Woods, a Sylvan Gem in an Urban Setting,” by Elizabeth Hope Cushing, all illustrations except the map on page 49 were used through the courtesy of the Lynn Historical Society. On page 51, the biographical paragraph should read: “Elizabeth Hope Cushing is a Ph.D. candidate in the American and New England Studies Program at Boston University. She serves as landscape historian for the Lynn Woods and High Rock projects of the Olmsted Historic Landscape Preservation Program (Department of Environmental Management, Commonwealth of Massachusetts) and is the author of the project reports for both parks.”
Past and Present Arboretum Staff Involved with the Renovation, Records Computerization, and Verification of the Living Collections between 1978 and 1988


Specific staff contributions ranged widely.

J. Alexander, plant propagator, is substantially involved in the computerization of the plant records.

P. Ashton, director of the Arnold Arboretum from 1978 to 1987, originated the restoration projects. He is the principal investigator for all three National Science Foundation grants for the computerization of plant records and the verification of the living collections.

D. Boufford is one of the staff taxonomists who provided assistance.

V. Burley, verification-project typist, handles the production of herbarium labels for the project and much of the herbarium-based data entry.

J. Christianson, membership chairman, oversees visitor services and the volunteer program.

S. Connor, archivist, assists in tracking source information and in locating old plans and photographs; she has emphasized both the archive’s resources and their function as the repository for modern records.

P. Dalton, curatorial associate, worked to document plant nomenclature during the initial phase of the verification project.

P. Del Tredici, assistant plant propagator, interacts with the verification project, especially on names that can be interpreted as cultivars or forms.

C. Dohlman, archival trainee and volunteer, assisted in finding Wilson’s material and in interpreting his handwritten texts in the archives.

S. Elsik, curatorial associate, is responsible for the vouchering phase of the verification project. She also trains and supervises volunteers for numerous jobs performed in conjunction with this project.

H. Goodell, superintendent of buildings and grounds, coordinated day-to-day work activities associated with maintaining the living collections.

S. Hardy Brown, herbarium technician and former volunteer, prepares herbarium specimens at Jamaica Plain and assists with volunteers who work in this capacity. Before she assumed these duties, A. Eisenberg, H. Fleming, and A. Sholes served as specimen preparers for various periods in Jamaica Plain.
I. Hay, curatorial associate, oversees the herbarium of cultivated plants in Jamaica Plain and the addition of verification-project specimens to this collection. She has led many teams of volunteers on their half-day collecting forays.

E. Johnson, curatorial assistant, first worked on the curatorial review of the Bussey Hill collections and then transferred to the plant records office, where his focus is on mapping, labeling, and documentation.

K. Kane, archive assistant, worked with the materials in the Wilson archives.

A. Kelly, typist, helped with the Wilson archives conservation project.

G. Koller, managing horticulturist, has planned, designed, and guided the renovation of the living collections since his arrival in 1976. Major accomplishments are designing and implementing the Bradley Collection of Rosaceous Plants, restoring the lilac plantings and the Olmsted path system, and extending shrub plantings to Peters Hill.

C. McMurtrie, volunteer coordinator, helped recruit volunteers during the initial phase of the project.

D. Michener, research taxonomist, is responsible for most of the taxonomic determinations in the verification project and coordinates the work with out-of-house taxonomists. Involvement in computerization of the records, grant-writing, and organizing this issue of *Arnoldia* became allied functions.

J. Quigley, curatorial associate, participated in writing the initial proposal, designed our first plant-records database, integrated verification-project data into the records system, and coordinated our input in the development of *BG-BASE* and its interface with computer mapping functions. She serves as computer-system administrator.

S. Spongberg, research taxonomist and chairman of the Living-Collections Committee, is one of the staff taxonomists involved with verification.

K. Walter, director of botany and information systems at the Center for Plant Conservation, serves as our primary consultant for the computerization of plant records and is the developer of *BG-BASE*.

R. Williams, superintendent of buildings and grounds, worked with the collections during the initial phases of the restoration work.

R. Weaver, horticultural taxonomist, was one of the organizers of the initial proposals to restore and verify the collections.

P. Willoughby, acting superintendent of buildings and grounds, coordinates the ongoing maintenance and care of the living collections.

In addition, we would like to acknowledge the help of G. Carty, M. Hill, R. Lane, and J. Low, short-term grant-supported staff who have functioned primarily out of the plant records office.
Acknowledgments

Our decade-long process of review and verification has been strengthened by the generous assistance of individuals and institutions throughout the world. In addition to our volunteers, we wish to thank R. Adams, for comments on our Juniperus collections; S. Anagnostakis, for notes on selected Castanea accessions; V. Bates, for writing the computer programs that print labels; C. Burnett, for assistance with the Wilson archives as photographic conservator; Z. Debreczy, for challenging the determination of some accessions; E. DeVoto, for help in editing this issue; R. Famiglietti, for building the collecting cart; J. Gurevitch, for queries on Acer determinations; J. Hutchinson, for assistance with the original Olmsted plans; R. Keen, for comments on our Taxus cultivars; K. Klier, for ongoing work with Davidia isozymes; J. Nickerson and M. Walkama, for collecting fruits and cones from the tops of trees; J. Procter, for assistance with titles and headers for this issue; W. Punch, for assistance with turn-of-the-century European seed catalogs at the Massachusetts Horticultural Society library; I. Racz, for challenging determinations of accessions and providing most of the photographs contained in this issue; E. Schmidt, for editing this issue of Arnoldia; E. Schofield, for early assistance in organizing this issue of Arnoldia; Swissair, for converting aerial photographs to a machine-readable form and producing a topographic base map; R. Warren, Arnold Arboretum Associate, for his dedicated work over many years on the identification of our conifer collections; and B. Washburn, for facilitating the aerial photography and production of base maps.


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