

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

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

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

While following these dialogues, I was puzzled by the absence of botanic gardens and arboreta—long-standing members of the col-

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

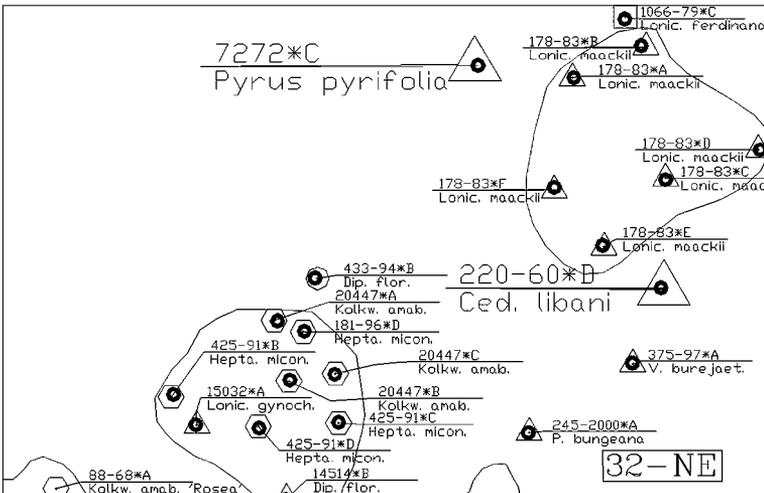
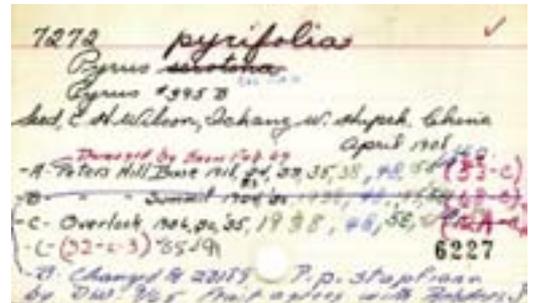
## **Research in the Collection: Why is it Important?**

There are many reasons why research is important to botanical gardens, and I would like to highlight but a few. Because of their original missions and mandates, many institutions are obligated to engage in research activities, even if it is only to accommodate requests for material by off-site researchers. At one time it was argued that "no institution is privileged to call itself a botanical garden unless it is doing research of some kind and to some degree" (Steele, 1969). Estimates of the number of gardens and arboreta whose collections are used in research vary considerably, from 10% (Raven, 1981) to nearly 50% (Sacchi, 1991; Watson et al., 1993), depending upon the type and nature

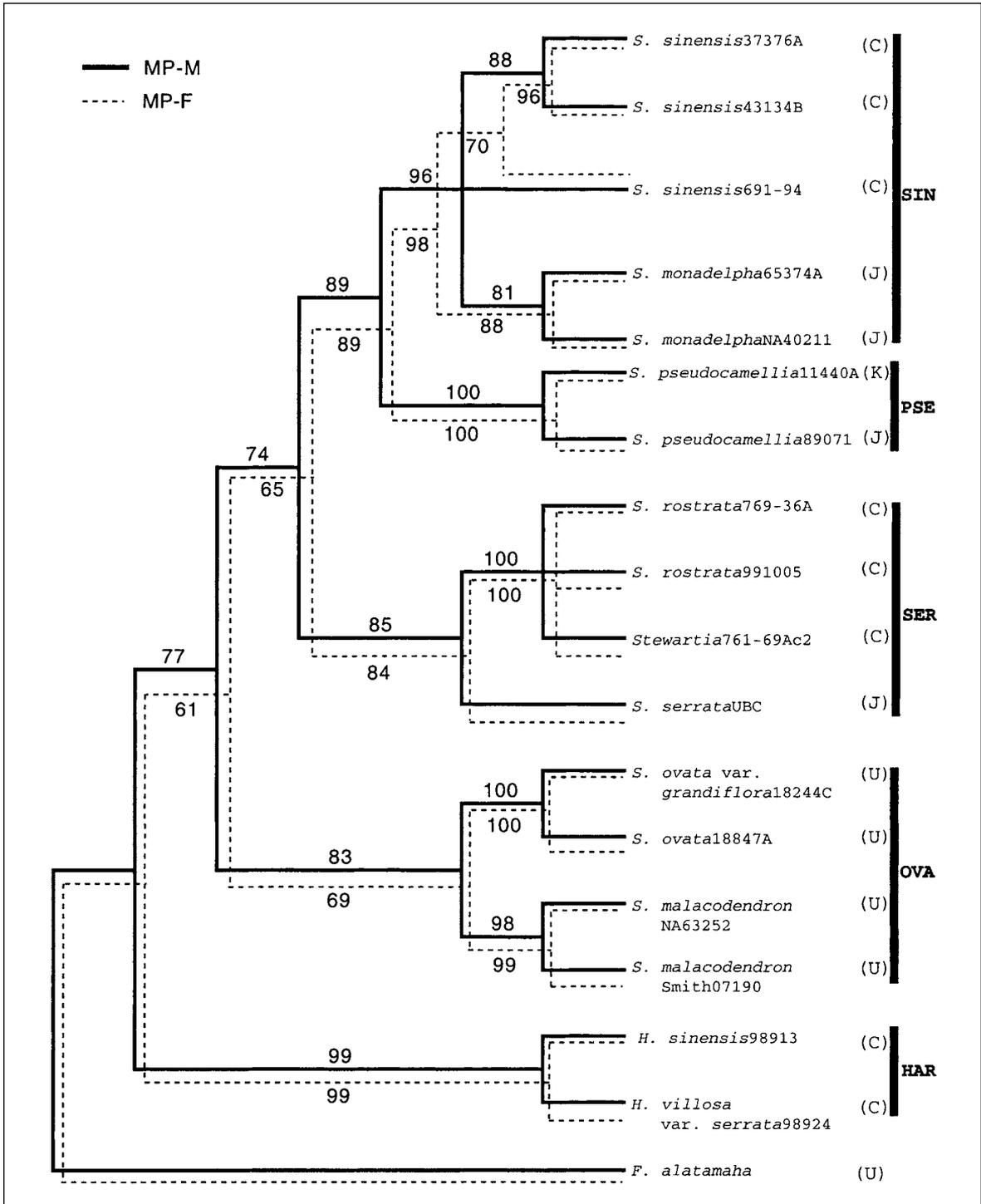
of the institution. Regardless of the percentage, a common perception among curators is that their collections are underutilized for research (Rae, 1995). It should be noted that while research may play a central role in numerous gardens and arboreta, oftentimes that which is lauded is field-based floristics and genomics rather than collections-based and could occur in the absence of curated living collections (see Marris, 2006; Nature, 2006).

Due to trends within academia, gardens and arboreta are some of the last bastions where collections-based research can occur because

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



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



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

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

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

### Research in the Collection: Making it Happen

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

qualified yes: we must be better collection advocates, and we must work to increase their demand among a range of users.

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

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

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

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

More recently, Arboretum leadership has lauded the use of living collections in meeting research needs and goals. In his maiden report as new director, Peter Ashton wrote in 1979: "We have, perhaps, thought of the herbarium as our principal center of research, but we must not underrate the research potential offered by the living collections. . . . Opportunities exist here for basic research to bridge the traditional divisions between biology, horticulture and forestry." This mantra launched a vigorous restoration of the Arboretum's living collection, as well as a modernization of its curatorial

practices (Ashton, 1989). And now, this well-documented collection of woody plants is first among several anchors as the Arboretum positions itself to achieve preeminence in studying the evolutionary history and functional biology of trees.

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

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

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

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

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

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

In addition to advocating and redefining their collections, gardens must concomitantly advocate and redefine perceptions of collections-based research. As I consider the Arboretum's living collections, I see research potential across a wide swath of disciplines—far too many to list here. For certain, taxonomic and horticultural research will continue to be important areas of

study, as will work in plant conservation and natural products. I also foresee the collections becoming more valuable in areas not traditionally studied using living plant collections, such as ecology and developmental biology. For these and other fields, our concept of collections-based research must be broad, spanning a scale that includes the multiple genomes residing within a given accession, genotypic responses to the abiotic environment, and interactions between plants and other organisms.

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



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

mentation, he (1981) went on to state “There is no doubt that future research must be directed increasingly at developing the technology required to expand this dangerously slender base, and competently curated collections, particularly of living plants, will prove invaluable.” As we seek to apply the lessons gleaned from *Arabidopsis thaliana* and other models to the diversity within the plant kingdom, the Arboretum’s collection is well positioned because of the genetic diversity it comprises. Our accessions of documented wild origin will continue to be important in illuminating mysteries related to genetic variation, adaptation, and biogeography. We should not discount the research potential of cultivated taxa—particu-

larly those cultivars that are aberrant forms of the botanical species—as they may find new footing in the research of the future. Just imagine the typical ornamental border: a colorful circus of cuticular waxes, pigment combinations, bizarre leaf and floral morphologies, contorted habits, atypical growth rates, and unusual tolerances to environmental stresses. These ornamental mutants, in many ways similar to those found in the contrived collections of *Arabidopsis*, could well become important research collections of tomorrow.

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

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

Living plant collections are no different, and those amassed for one reason frequently become useful for others. Countless synoptic collections assembled for taxonomic comparison have been extremely practical in the screening of natural products for medicinal use, an area of research that will become more important as natural populations of plants become threatened in the wild. Harrison Flint (1974) recommended plant collections would be ideally used to study phenology, and recently they have been—not to examine genealogy as he suggested but to study climate change (Primack et al., 2004; Wolfe et al., 2005). Sometimes the unanticipated use is the result of unfortunate events, leading to the application of the adage “When life gives you lemons, make lemonade.” Ongoing research at the Arboretum on the hemlock wooly adelgid includes studies on forest floor regeneration, biogeochemistry, and the identification of replacement hemlock species. When it comes to the last, it is doubtful that when

E. H. Wilson collected a single plant of Chinese hemlock, *Tsuga chinensis*, in 1911, he had in mind that this accession would play a key role in understanding the behavior of the insect (Del Tredici and Kitajima, 2004).

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



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

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

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

Beyond access to the living collections themselves, the Arboretum can provide scientists with a wealth of other things, including affiliated collections (records, archives, images, herbarium specimens), expertise, greenhouse and lab space, and even financial assistance in the form of grants and fellowships. Although the institution may be the primary provider in this relationship, there are also things that researchers can do in return for collection access. One of the most basic is following-up when the project is completed, which includes sending updates and/or reprints of any published work. I have found that while nearly all gardens and arboreta request this, it unfortunately occurs

less than a third of the time. It is also important that results that did not make it into publication because of their anomalous or questionable nature be reported, particularly when the study is taxonomic in nature, as they may indicate that the name on the label is not correct. Researchers are also able to assist with the development of the living collection by donating well-documented plant material. By understanding and valuing the mutually beneficial relationship between the Arboretum and researchers, we can more ably respond to, and meet, the future needs of science.

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

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