We are now one year into the Campaign for the Living Collections, a ten-year initiative that will expand and refine the Arboretum’s historically and scientifically valuable plant collections. Additional collecting trips this summer and fall have brought in new seed and plant accessions that will go through the Arboretum’s propagation facilities, as described in the last issue of Arnoldia. In this issue, Manager of Horticulture Andrew Gapinski completes the Campaign article series by describing the process involved in moving plants to permanent locations on the grounds and the ongoing challenges of keeping the collections healthy and growing.

From its origin to the Arnold Arboretum’s propagation facilities, much time and many resources have been invested in the planning, acquisition, and production of an accession in preparation for its ultimate installation in the permanent collections. Successful establishment of new accessions and care of the Arboretum’s 15,000 existing specimens takes a dedicated team of highly skilled horticulture professionals who are involved in aspects from site selection and planting to aesthetic and corrective pruning, soil health management, and attention to various plant stressors as part of the Arboretum’s holistic Plant Health Care Program. Across our 281-acre landscape, we are preparing the grounds for a surge of new material as part of the Campaign for the Living Collections (Friedman et al. 2016)—an initiative to acquire and cultivate 400 target taxa over the next ten years.

The Arboretum’s historic collections scheme is based on the Bentham and Hooker system of plant taxonomy, devised in the late 1800s, with species grouped by genus in an evolutionary progression starting with the earliest of flowering plants, e.g., *Magnolia*, placed at the Arboretum’s main gate. While taxonomic systems differ today, the Bentham and Hooker blueprint for incorporating new material into the permanent collections is generally still followed. Continued and expanded attention is also placed on utilization of the unique microenvironments, with their variable factors such as temperature, moisture, light, and soil type, that can be exploited for the successful cultivation of particular species. The Explorers Garden, nestled on the south side of Bussey Hill, represents one such area, long known as the spot for evaluating marginally hardy species not typically grown successfully in New England.

New landscapes continue to be added, including the Lev-entritt Shrub and Vine Garden, dedicated in 2002, which arose out of a need for a space to feature shrubs and vines requiring full sun, and the landscape surrounding the Weld Hill Research Building, completed in 2011, which provides an opportunity for development of a new plant collection at the hub of the Arboretum’s research programs. Whether sited in a particular location for taxonomic, thematic, aesthetic, or practical cultivation purposes, the placement of each new specimen into our historic landscape is part of the Explorers Garden’s protected microclimate makes it an ideal site for trialing new accessions of unknown cold hardiness. This view shows (foreground to background) *Rhododendron yedoense* var. *poukhanense*, *Chionanthus retusus*, and *Fothergilla* hybrids. Photo by Richard Schulhof.
a well-thought-out decision making process, executed with sound horticultural practice.

**Measure Twice, Cut Once**

After being cultivated in the Arboretum’s Dana Greenhouses and surrounding nurseries for about three to seven years, the process of determining which specimens are ready to find their place in the permanent collections starts in August of each year. A review by greenhouse staff of all accessions in the production facilities is undertaken and recommendations are made as to whether an individual plant is large and healthy enough for installation. With this information in hand, the Managers of Plant Production and Horticulture and the Curator of Living Collections visit each specimen for a final determination. Ideally, multiple individuals within an accession have been successfully grown to ensure the best chance of that lineage surviving the production cycle and many years in the collections. A comparison between these siblings for overall health, vigor, form, and root development is made, and individuals are assigned a ranking based on their overall condition. At this point, it is also determined whether spring or fall transplanting is most appropriate for the species under review. For example, many oaks (*Quercus* spp.), beeches (*Fagus* spp.), and hornbeams (*Carpinus* spp.) can fare poorly when transplanted in autumn, while other plants, including many conifers, acclimate just fine. For the past several seasons, fall planting has been limited or deferred altogether because of prolonged summer droughts that have persisted well into autumn. When conditions are favorable, getting a jump on the transplanting list in fall helps with the work
load of the busy spring season. Nevertheless, the vast majority of transplants occur in the spring when warming days, cool nights, and abundant precipitation create favorable rooting conditions. Depending on how many sibling individuals are needed for the permanent collections (typically three or four), surplus plants may then be offered up to other botanical institutions. The sharing of specimens at this stage of the process offers yet another opportunity for material to be “backed-up” elsewhere in the event of loss at the Arboretum.

With the list of graduates in hand, the process of finding planting locations begins. After nearly 150 years of collections development, finding locations for the approximately 250 annual plant additions to the permanent collections is no easy task. On paper, specimens are first loosely assigned to particular areas of the Arboretum. A number of different parameters are considered, including the species’ taxonomic group (family, genus, etc.), known winter hardiness, moisture requirements, collections value of that particular lineage, and aesthetic and functional qualities of the species for use in various landscape projects across the grounds. Since our museum specimens are living organisms exposed to many environmental influences (drought, disease, winter storms, etc.), lineages of high value are sometimes duplicated across different parts of the Arboretum landscape as a means of internal backup. However, as a general rule, most of the plants within an individual accession are planted in the same collection area, with an occasional planting in an alternative section. Some designated areas, such as the Carpinus collection near Valley Road, are rather full of high-value trees and leave little room for development. When siting new accessions here, we may plant just one in this core collection area, and then plant the remaining two or three siblings together in another area. To avoid the look of random plants dotted through the landscape, we’ve recently begun to identify and designate nodes where new accessions within a genus can be sited together outside of the core collection. For example, we have been clustering individual Carpinus specimens at a few nodes on Peters Hill.

The Arboretum is divided into 71 horticultural zones, each of which is assigned to one of seven horticulturists responsible for the daily care of the collections within. Continuing into fall, field selection of the specific planting location for each specimen involves the Manager of Horticulture, Curator of Living Collections, and the horticulturist assigned to that zone. Each planting location is marked with a wooden stake and is labeled with the taxon and accession number to be planted. With the majority of planting scheduled for the following spring, horticulturists will follow up before the ground freezes and turn the soil in place to further mark the planting location, because stakes can easily be lost over winter. This step also provides an opportunity for soil amendments to be added as needed and makes for easier digging in the spring as the freeze and thaw of the season loosens the turned soil.

The planting locations of the qualifiers (individual plants assigned identification letters A, B, C, etc.) of accession 637-2010, a Yunnan red-
The Campaign for the Living Collections is under way and seeds from both near and far are sprouting in the Dana Greenhouses. As Manager of Horticulture, I can't help but feel a bit of anxious excitement as I await the challenge of growing new taxa from around the world. As stewards of the Campaign we face many questions including “Where will we find the space and how can we prepare the grounds now to receive new material?” As a horticulture team, we are viewing the grounds through an opportunistic lens—what is the value of each specimen to the collection, how can we better utilize the various environmental conditions we find across our landscape, how can we benefit from issues that affect the health of our collections, what areas need additional attention, and how can we gain “new” ground?

Although not necessarily novel questions for collections managers to be considering, these concepts are at the forefront of our decision making across the landscape:

**Addition through subtraction**

Not every specimen in our collections holds the same value, and making tough decisions to deaccession and remove otherwise healthy plants is not easy, but for the building of any museum collection what is taken away can be just as important as what is added. We seek to utilize our limited resources, including space and staff time, in the most effective way to achieve the Arboretum mission. The decision-making process for the continued stewardship of every accession considers many factors, including total opportunity costs, and is ultimately guided by our Living Collections Policy [Arnold Arboretum 2016].

The deaccessioning and removal in 2015 of these four cultivars of Norway maple (*Acer platanoides*), which had low collections value, freed up valuable acreage in the heart of the Maple (*Acer*) Collection for new high priority taxa. In the opening created by the removals, a purpleblow maple (*Acer truncatum*, 629-2010-A), wild-collected in Shaanxi, China, during the September 2010 North America-China Plant Exploration Consortium (NACPEC) expedition, was planted.

**Reclaiming areas of deferred maintenance**

Of top priority is the reclaiming of areas in which maintenance was deferred at some point. The Horticulture staff is undertaking an aggressive cleanup effort in collections areas that have been reabsorbed into adjacent natural lands and succumbed to invasive weeds.

Over the past several decades, the southwest edge of the Hickory (*Carya*) Collection (seen here) has been slowly reclaimed by the adjacent Central Woodland—this area represents over an acre of valuable territory that will be available for collections expansion once it is cleared.
With loss comes opportunity: making lemonade out of lemons

Our collections of trees, shrubs, and vines face continuous and ever-changing biotic and abiotic influences. When faced with events beyond our control, triaging the situation to prioritize and safeguard the most valuable holdings and finding opportunity in the loss is of utmost importance.

The emerald ash borer (EAB), introduced to the United States from Asia via wood packaging material, has decimated ash (Fraxinus spp.) populations across central and eastern North America since its discovery in Michigan in 2002. Through the establishment of an early detection program in partnership with the Massachusetts Department of Resource Conservation, the Arboretum was the first detector of EAB in the City of Boston. A triage approach to evaluate the 146 accessioned ash trees in the permanent collections was undertaken. Fifty-one individuals were determined to be of low value, not warranting long-term preservation efforts. Of these, fifteen were immediately removed because of poor health, and the remaining thirty-six trees are being utilized for further EAB monitoring efforts. The remaining 95 high-value accessions are part of a preservation program that includes prophylactic treatments and clonal propagation efforts. Branch sections (including buds) from a select number of lineages were also sent to the USDA-ARS National Laboratory for Genetic Resources Preservation for potential long-term storage via cryopreservation. The photograph shows Arboretum Horticulturist Scott Grimshaw treating a high-value ash specimen.

Exploring the potential of environmental niches

Across the Arboretum, differences in environmental conditions from soil moisture to annual minimum temperature exist and are key considerations when selecting locations for species requiring particular niches. We are taking an aggressive approach to clean up these areas in preparation for harboring new accessions to come.

The group project for the 2016 Isabella Welles Hunnewell Interns was to advance the development of the “The Rockery,” an area with exposed rock outcroppings along Valley Road (seen here, Arboretum Horticulturist Greg LaPlume removes excess soil from the site). Taking advantage of the natural geology of the site, the Arboretum seeks to develop an environment that supports species adapted to rocky mineral soils, with characteristically low nutrient and organic matter levels, such as those found in scree type habitats. Prickly-pear cactus (Opuntia humifusa), several ephedra (Ephedra) species, regal lily (Lilium regale), and a number of other species on the Campaign for the Living Collections list of desiderata are potential candidates for cultivation in such an environment.
bud (*Cercis glabra*) collected by Michael Dosmann, Curator of Living Collections, on the September 2010 North America-China Plant Exploration Consortium [NACPEC] expedition to Shaanxi, China, serves as an example of the basic thought process for site selection. Having attempted to grow the species at the Arboretum several other times without success, the limited history of its cultivation here made planting decisions more difficult. Particularly in cases in which hardiness of the species is questionable, such as *C. glabra*, we use knowledge of the Arboretum’s long studied and utilized microclimates to give us the best chance of success [Dosmann 2015]. With the rolling topography, cold air drains down from the tops of the Arboretum’s highest points including Bussey, Hemlock, and Peters Hills to the valleys below. In a typical year, these “hot spots” of the higher elevations experience minimum temperatures representative of a Zone 7 (average annual minimum temperatures 0 to 10°F [-17.8 to -12.2°C]), with Zone 6 (-10 to 0°F [-23.3 to -17.8°C]) conditions being most prevalent throughout the grounds.

With six individuals of 637-2010 ready for the planting in the spring of 2015, what was the planting approach? Three were planted that spring: one (637-2010-A) in the microclimate of the Explorers Garden, located along Chinese Path on the south side of Bussey Hill, and the two others (B and C) among its relatives in the Legume Collection. The three remaining (D, E, and F) were held back in the greenhouses as reserves in case hardiness turned out to be an issue. The winter of 2015–2016 would turn out to be a true test of hardiness, with a season low of -14.5°F (-25.8°C; Zone 5) recorded in the Bradley Rosaceous Collection—the lowest temperature recorded at the Arboretum in 57 years. Spring 2016 came and observations were made; the Explorers Garden specimen leafed out fully with no dieback and the Legume Collection plants experienced only moderate branch dieback of 1 to 2 feet (30.5 to 61.0 centimeters). Success! With hardiness a non-issue, the three remaining plants were sited and planted in the landscape surrounding the Arboretum’s Weld Hill Research Building for the species’ ornamental value, its botanical and taxonomic interest, and the exploration story it brings to the newly developing Weld Hill landscape. The Weld Hill planting also is separated from its previously planted siblings by nearly a mile. That distance is a key part of the idea of internal back-up.

**Planting Season**

As spring approaches, we pay close attention to the thawing soils and moisture conditions and begin the transplanting process as soon as the timing is right. In preparation, planting lists and locations are reviewed, and a final walk-through of the nurseries is performed to document and adjust plans based on damage that may have occurred to plants over the winter. For example, following the record breaking snowfall—110.6 inches (280.9 centimeters) measured at Boston’s Logan Airport—during the winter of 2014–2015, significant damage in the nurseries occurred as the snow melted and refroze during the spring thaw. Many young trees with low branches were pulled apart with the shifting snow and ice that covered them. Evaluations completed the (continues on page 12)
In order for the nearly 400 taxa we intend to collect in the Campaign for the Living Collections to have a lasting legacy here at the Arboretum, we seek to provide specimens with the most favorable habitat possible. In preparation for the arrival of these new taxa, the horticulture department is investigating all aspects of plant health care and landscape management practices to ensure we are providing the highest of horticultural standards that will give these new accessions the greatest chance of success. Evaluation of the current conditions of our soils and the development and implementation of strategies to improve soil health across the Arboretum is a high priority.

Awareness of the importance of soils, especially in relation to plant health, has been increasing; this was recently reflected in the United Nations-designated International Year of Soils in 2015. We as a global society are now more aware of how precious soil is, and also how often this resource is mismanaged. In addition to serving as a substantial terrestrial carbon sink, storing carbon that would otherwise be released into the atmosphere and further contribute to climate change (Dungait et al. 2012), soil provides important services that promote plant health, such as nutrient supply, water regulation, and physical support for roots (United States Department of Agriculture 2016). Therefore, proper stewardship of our soils will enhance the health of our valued Living Collections.

The first step in caring for our soils is to fully understand their current state. In the late 1990s and early 2000s, an intensive program of soil assessment and management at the Arboretum identified highly acidic and nutrient deficient soils, which were at the time contributing to substantial tree decline in certain areas. In the years that followed, liming and nutrient applications were made, and some plant recovery was noted. Through staffing changes over the past decade, work on soils health waned, with only isolated issues addressed as plant decline was observed and investigated. With the onset of the Campaign, the Arboretum has renewed its commitment to understanding and managing the factors that affect soil health across our landscape.

In 2015, with the help of that year’s Isabella Welles Hunnewell Interns, Arboretum-wide soils testing that measured an assortment of nutrients and chemical characteristics was completed, as were analyses related to microbial processes. Initial recommendations for remediation were prescribed and executed. These soil testing data were recently mapped; the Geographic Information Systems (GIS) layer housing these data makes it possible to visualize all of the soil characteristics measured in the samples throughout the landscape. Having these data displayed spatially reveals landscape-wide patterns in soil health that we might otherwise overlook when referring only to a spreadsheet. We have also started to map the location of amendments that we apply to the soil; we hope that by continuing to measure and map soil characteristics and management efforts we can detect trends in soil health over time and determine the effectiveness of various management actions. We can use this new knowledge to adjust our practices and make more informed management decisions in the future.

In addition to looking at these data ourselves, the formation is underway of a Soils Advisory Committee composed of soil science experts who can help us to further interpret these data and inform our management plans. Members of this committee contribute expertise from a wide range of topics in soil science and management, including bedrock geology, forest soil ecology, composting, and agricultural cover cropping. This committee will help connect us to academic research at Harvard University and beyond, enabling us to consider new ideas and to address with evidence the questions we have in our attempts to provide the best substrate for our expanding collections.
The Arnold Arboretum of Harvard University pH measured in 7/2015 and 7/2016
We are also evaluating our compost and mulch operations and are investigating the potential value of cover crops in our parklike setting. This fall, for example, we are testing the feasibility of growing tillage radish (*Raphanus sativus*) in the landscape as a no-till method for reducing the soil compaction that has resulted from increased foot traffic and equipment. Tillage radish is an agricultural cover crop known for its long taproot that “drills” through the soil, reducing compaction in a natural way; this taproot can grow as long as 6 feet (1.8 meters), and the first 12 to 20 inches (30.5 to 50.8 centimeters) can have a diameter up to 2 inches (5.1 centimeters) (United States Department of Agriculture 2012). When planted in fall, the radishes are winterkilled and decompose, thereby producing large cavities in the soil and releasing nutrients for surrounding plants to take up (United States Department of Agriculture, 2012). If you have been to the Arboretum since mid-August, you may have noticed four 20-by 20-foot (6.1-meter) fenced plots in our landscape. In each of these plots we are testing four sowing methods (broadcast seeding, broadcast seeding after aerating the soil, slice seeding, and slice seeding after aerating the soil), with and without a leaf compost cover, to see if we are able to grow this cover crop in an urban, partially shaded setting and, if so, which of these eight methods works best. If successful, we may integrate tillage radish into our management. We intend to continue exploring options and testing them in the landscape, learning from our trials to develop best management practices.

Managing the health of our soils to provide the best growing conditions for the over 2,000 diverse taxa that we cultivate from temperate biomes across the world is an essential component to the Arboretum’s Plant Health Care program. We hope that our adaptive management approaches will help us develop well-informed ways to steward the next nearly 400 taxa to join our Living Collections and improve the habitats of our current collections, as well.
previous fall comparing siblings were revisited and adjustments were made in ranking based on their overall condition.

Once all is checked, lists referred to as “planting bulletins,” which include accession numbers, names, and current nursery and final planting locations, are systemically issued to Living Collections Managers once final checks are complete and species’ transplanting priority is established. The issuing of a bulletin first triggers the Manager of Plant Records to initiate important database updates and in turn create permanent labels for each plant being transplanted. Before plants leave the production facility, permanent labels are attached and double checked against temporary nursery labels to avoid mix-ups. When those tasks are done, horticulturists are given the green light to start the digging process. Ideally the goal is to complete transplanting before the plants break bud. Taxa such as birch (Betula spp.) and apple (Malus spp.) that leaf out early are the first priority of the digging season and thus will be listed on early bulletins. Others such as ash (Fraxinus spp.) and oaks (Quercus spp.) tend to break dormancy later and can remain in the nursery longer. Containerized plants are the last to be planted as root loss tends to be less severe.

The transplanting method known as “balled-and-burlapped,” or B&B, starts with digging soil out from around the trunk of the plant. As a general rule, the ball radius should be 1 foot (30.5 centimeters) per 1 inch (2.5 centimeters) of trunk diameter. For example, a tree with a 1.5-inch (3.8 centimeter) trunk diameter would have a ball that is 3 feet (91.4 centimeters) across. When digging, larger roots are cut with pruners to avoid tearing, and imperfections in the root system are noted and addressed as needed. Once the ball has been defined and the majority of soil excavated, burlap sheets are placed over the ball and twine is used to hold the ball tightly together to prevent the ball from falling apart and drying out during transplant. When complete, B&B plants are lifted out of the holes and taken to their final planting locations as soon as possible.

Once on site, the planting hole is dug paying close attention to the height of the ball to avoid making the hole too deep. The root flare, the transition zone between trunk and root system, should be at or slightly above the existing grade and never be covered with soil or mulch since it is a key zone of gas exchange for the plant. Covering the root flare can also lead to the development of a secondary root system and the occurrence of girdling roots. With burlap and twine intact, the ball is placed in the planting hole and final adjustments to planting depth are made, and the tree is viewed from all angles to ensure that the plant is straight. The majority, if not all, of the burlap and twine is then cut away from the ball and the planting hole is backfilled with the excavated soil. A 3- to 4-inch (7.6- to 10.2-centimeter) layer of mulch is applied, making sure not to cover the root flare or trunk, and plants are watered thoroughly to hydrate roots and ensure good soil-to-root contact from.
Living Collections

Arboretum Horticulturists Scott Grimshaw and Rachel Brinkman lace twine around the burlap covered root ball of a Magnolia amoena (accession 385-2012-A) in preparation for moving it out of the west nursery to its new home along Chinese Path in the Explorers Garden.

Arboretum Horticulturists Mark Walkama and Wes Kalloch plant a specimen of black cherry (Prunus serotina, 602-2008-B), carefully removing twine and burlap from the root ball before replacing excavated soil.

the start. New plantings are provided with regular watering during their first year of establishment and also in subsequent years when drought conditions occur.

Once the transplanting of all accessions on a particular bulletin is complete, the Manager of Plant Records is notified and each plant is visited to collect accurate GPS coordinates. In addition, all temporary marking materials (nursery labels, flagging tape) are removed and permanent labels are repositioned as needed.

Caring for the Curated Landscape

Although much planning and many resources have gone into all phases of collections development from the

Watering is key to successful establishment of newly installed accessions. The Arboretum deploys both hand-watering and automated irrigation systems such as this one being installed in the renovated planting area in front of the Hunnewell Building by Horticulturist Greg LaPlume.
point of acquisition to establishment on the grounds, the work to preserve and steward these holdings both curatorially and horticulturally has just begun. The Arboretum’s curatorial team maps, labels, and regularly inventories and evaluates all accessions, noting such observations as growth, health, damage, and various other metrics. Horticulturally, we seek to keep specimens vigorous and thriving through regular aesthetic and corrective pruning, reduction of weed competition, soil health management, and the evaluation, prioritization, and mitigation of various plant stressors, from pest and disease pressure to drought. With the goal being to maintain the germplasm represented by our collections into perpetuity, plant production staff continue to play a key role in preserving important lineages through the collection of vegetative propagation materials, such as cuttings and scions for grafting, from existing accessions. A lineage may be propagated because of the decline of a specimen or to create clones for distribution to other institutions around the world. As we complete our second year of expeditions for the Campaign for the Living Collections, with new lineages and taxa growing in the greenhouses, we anxiously await transplanting the first of the Campaign material into the Living Collections and the challenges and opportunities that will follow.

References


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