2019 ANNUAL REPORT

The Arnold Arboretum
of Harvard University

The ARNOLD ARBORETUM of HARVARD UNIVERSITY

Erik Gehring

About Us

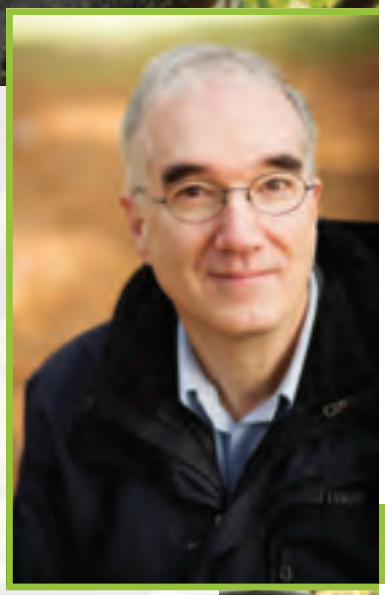
A historic and contemporary public garden and an international center for the study of woody plants and biodiversity, the Arnold Arboretum of Harvard University disseminates knowledge and pursues a mission defined by excellence in horticulture, research, and education. Operating as a public-private partnership between the City of Boston and Harvard University, the Arboretum stewards one of the world's most comprehensive and best-documented collections of woody plants with particular focus on the ligneous floras of eastern North America and eastern Asia. The Arboretum's 281-acre landscape in the heart of Boston was designed by Charles Sprague Sargent and Frederick Law Olmsted and is on the National Register of Historic Places. Funded entirely through endowments, annual gifts, and membership support, the Arnold Arboretum is nonetheless a free community resource for all and a jewel in Boston's Emerald Necklace of parks.

Deborah Blackwell

Note from the Director

WILLIAM (NED) FRIEDMAN

DIRECTOR AND FACULTY FELLOW OF THE ARNOLD ARBORETUM
ARNOLD PROFESSOR OF ORGANISMIC AND
EVOLUTIONARY BIOLOGY, HARVARD UNIVERSITY



When we began planning this annual report on the activities of the Arnold Arboretum of Harvard University for 2019, we could not have foreseen how different our lives would be by the following spring. For as I write this, the Arboretum and its staff have operated through several months of social-distancing. The COVID-19 pandemic has closed our classrooms and laboratories, transferred our pedagogy and research to the web, and relegated most of our staff to work in the safety of their homes. We continue to expand and cultivate our collections this growing season, but under a new set of guidelines: fewer staff working on the grounds, shifts rotated, facial coverings and distance maintained at all times, and a host of other precautions. Importantly, we have endeavored to keep the Arboretum landscape open as a refuge where unfathomable grief and stress in this crisis can be overcome by the embrace of nature.

However, those are stories for another time and another report. Many of the things we share in these pages from 2019 represent real progress as the Arnold Arboretum continues building a more ambitious, robust, and sustainable institution as we approach our sesquicentennial anniversary in 2022. Some of the stories you will read illuminate how our historical mission continues to grow and resonate in the twenty-first century, such as the continuing need for plant exploration to inventory our vanishing biodiversity and to preserve more rare and threatened plants in our landscape. You will also see some of the things we have accomplished to improve the general health of our plants and to make our landscape more resilient to the climate challenges that are reshaping our relationship with trees and our environment. From an enormous new solar and battery array at our Weld Hill Research Building to bringing drought-relief infrastructure to our collections, we have (with the considerable generosity of donors, members, and foundations) invested significantly in making the Arboretum a more sustainable institution for the challenging years ahead.

The Arnold Arboretum has adapted and thrived through many difficult periods in the past. We've sustained our world-class collections through the influenza pandemic of 1918-1919, the Great Depression, and two world wars. This is due in no small part to the extraordinary people who have brought our historical mission to life, from the horticulturists, arborists, and propagators who keep our collections growing to the scholars, educators, librarians, administrators, volunteers, and so many others whose critical contributions have shaped who we are and what we do as an institution. This adaptability is also a testament to the faith and confidence of thousands of individuals just like you, who believe in the essential value of trees and our need to protect them, preserve and study them, and ultimately, illuminate their essential role in our biosphere.

Erik Gehring

Growing a More Sustainable Arboretum

Inset: Stephen Hill

Solar Power and Battery Array

at Weld Hill

Embodying a unique, nearly 150-year-old partnership between the City of Boston and Harvard University, the Arnold Arboretum strives to help both entities build resiliency in the face of climate change and reach ambitious goals to eliminate carbon emissions by 2050.

In 2016, the Arboretum launched a major sustainability initiative to reduce our carbon footprint and cut energy costs. In August of that year, the Arboretum installed its first solar panel array on the roof of the Hunnewell Building maintenance garage, comprising a 30.8 kilowatt system providing an estimated 30 percent of the building's total energy needs. Shortly afterward, a second 31.1 kilowatt array was installed at the Dana Greenhouses, leading to a 32 percent drop in energy costs for this facility.

Financed by Harvard's Green Revolving Fund, the Hunnewell and Dana Greenhouse systems will offset an estimated 1,144 metric tons of carbon dioxide equivalent (CDE) over 25 years—comparable to 1,250,650 pounds of coal burned. In addition to reducing the Arboretum's dependence on fossil-fuel and nuclear-generated electricity, the solar arrays produce approximately $20,000 annually in energy savings, providing valuable funds for horticulture and education following loan repayment.

With its completion in fall 2019, the Weld Hill Solar Project represents the Arboretum's most ambitious sustainability initiative to date, projected to generate over 25 percent of the total energy required to support word-class research and education at the Weld Hill facility. The system comprises 1,314 solar panels capable of producing an estimated 566,409 kilowatt-hours annually. Working in tandem with the panels, a unique battery storage array reduces peak demand charges. Projected annual energy savings from the system exceed $200,000, and offset an additional 401 metric tons CDE per year. At a cost of roughly $2.5 million (again financed by Harvard's Green Revolving Fund), this solar installation represents the largest and most technologically-sophisticated array in Harvard history.

To support local insect biodiversity, the project design will incorporate a natives-focused pollinator meadow beneath the panel arrays. Together, the Weld Hill PV system, battery array, and pollinator meadow will serve as the basis for ongoing educational programs focused on climate change, renewable energy, and sustainable design—offering visitors a chance to learn about the importance of renewable energy and environmental stewardship.

The Weld Hill Solar Project represents the Arboretum's most ambitious sustainability initiative to date, projected to generate over 25 percent of the total energy required to support world-class research and education at the Weld Hill Research Building.

Jeffrey Blackwell

Top: Contract irrigation specialists and Arboretum staff work together to install a main line through the oak collection, part of a comprehensive plan for drought preparedness.

Bottom: The Committee to Visit the Arnold Arboretum tour the Bradley Rosaceous Collection with Arboretum staff.

"The fundamental imperative of our work as an Arboretum is to safeguard the living collections so they continue to inform and inspire, from generation to generation."

Photos by Danny Schissler

Preparing Our Plants
for future challenges

Scientists predict that incidents of drought are likely to become more frequent and longer in duration in coming years. The consequences could spell catastrophe for the living collections of the Arnold Arboretum without safeguards in place. In response, in 2019, the Arboretum completed the first stage of a plan to bring water where and when it's needed through an automated irrigation system.

"The fundamental imperative of our work as an Arboretum is to steward the living collections so they continue to inform and inspire, from generation to generation," said Arboretum Director William (Ned) Friedman. "Just as a museum of art must protect its treasures with the right environmental controls, the Arboretum must act now to shield ours from the growing threat of extreme drought."

Irrigation as a tool for drought mitigation is not new to the Arboretum but was previously limited in scope to high-maintenance areas like the Bradley Rosaceous Collection and the Leventritt Shrub and Vine Garden. With this new initiative, the Arboretum is investing in a multi-phase expansion of this infrastructure, beginning in 2019 with landscapes and collections clustered near the Centre Street Gate and the Explorers Garden on Bussey Hill.

"Our goal isn't to use more water, but to water more with less," said Andrew Gapinski, head of horticulture. "Through new points of access and use of automated irrigation systems where appropriate, we will be able to fine-tune our water use during extreme drought and maximize the effectiveness of every drop."

With this initiative—spurred by a challenge from members Lawrence K. Fish and Atsuko T. Fish and funded entirely by the generosity of donors—the Arboretum takes an enormous step toward improving stewardship of the living collections and boosting its resilience in a rapidly changing environment. When needed, our automated irrigation systems will dramatically increase the efficiency of watering our plants and recover thousands of hours of horticultural labor, reduce compaction caused by moving equipment through the landscape, and uphold our commitment to sustainable development and practices.

Visiting Committee
meets in April

Representing the Board of Overseers of Harvard University from a host of scientific, educational, and cultural institutions, the Committee to Visit the Arnold Arboretum* met to learn about the Arboretum's current and planned activities and to report their impressions to the University. In addition to in-depth discussions with staff and program leadership, the Committee's visit included learning tours of the Weld Hill Research Building, the living collections and landscape, and the propagation facilities at the Dana Greenhouses.

Content for the meeting was organized into themes reflecting the core institutional values of the Arnold Arboretum. Beginning with the Arboretum's commitment to protect and celebrate global biological diversity, the Committee learned about the Campaign for the Living Collections and its goal to increase the diversity and value of the Arboretum's research collections. Scientific discovery and research centered at the Arboretum has built strength since the Weld Hill facility opened in 2011, as the Arboretum has become one of the few botanical gardens to offer both world-class collections and advanced facilities for their study.

The Committee learned how the Arboretum is making inroads to social and environmental justice through improved outreach, resources, and points of entry for underserved neighborhoods on our perimeter. The Committee also explored the institution's value for exceptional and progressive horticulture. The Arboretum's multi-phase, cross-departmental efforts in this regard were outlined in master planning and development around the sustainable development, growth, and lifetime care of the living collections, particularly in mitigating global change.

*see full list of Visiting Committee members on page 27

Pursuing Excellence in Collections

NACPEC Expedition

In a historic and global expansion of its work to preserve biodiversity, the Arnold Arboretum coordinated an expedition of the North America-China Plant Exploration Consortium (NACPEC) in the Appalachian Mountains with an international team of collectors. While representatives from the Arboretum and other botanical institutions in the United States and China have collected plants in China on eighteen expeditions since 1991, the fall 2019 trip invited Chinese botanical institutions to explore the botanical riches of North America with Arboretum staff.

Coordinated by Andrew Gapinski, head of horticulture and chair of NACPEC, and Kang Wang, research horticulturist and director of education at the Beijing Botanical Garden, the 2019 Appalachian Expedition marked an important opportunity to further the group's mission of building international partnerships to support the study and conservation of Earth's temperate flora. Focusing on species disjuncts that occur in eastern North America and eastern and central China, the group—including Tao Deng of the Kunming Institute of Botany; Xinfen Gao of the Chengdu Institute of Biology; Angela Magnan of the U.S. National Arboretum; and Sean Halloran and Jared Rubenstein of the Arnold Arboretum—compiled a list of target taxa for the expedition, including piratebush (*Buckleya distichophylla*), the oldest wild-collected plant in the Arboretum's living collection.

The three-week expedition covered 3,500 miles and crossed five states—Ohio, Kentucky, Tennessee, North Carolina, and Georgia—and brought explorers to some of America's most biodiverse forests. Along with local guides, the team forded the Red River in Daniel Boone National Forest to find seeds of American sycamore (*Platanus occidentalis*), descended to the base of a waterfall in Georgia to collect buttonbush (*Cephalanthus occidentalis*), and climbed Roan Mountain to gather seed of the endangered green alder (*Alnus viridis*). In addition to harvesting seeds and branch samples for herbarium vouchers, the team captured photographs of each plant collection, mapping coordinates, and information about the geology and plant communities of each site.

Arboretum Director William (Ned) Friedman joined the expedition at the Lula Lake Land Trust, where he was delighted to collect root cuttings of one of his favorite plants—winged elm (*Ulmus alata*). "To be in the field with Kang, Xinfen, and Tao—literally an all-star botanical team from China—along with our Arboretum explorers and domestic colleagues was a remarkable experience," he said. "After many times being so generously hosted in China, this expedition felt like perfect way to deepen our sense of reciprocity—and share some of the evolutionary bounty of North America with gardens in China."

Sean Halloran

At left, Professor Xinfen Gao of the Chengdu Institute of Biology plants a rose collected on a NACPEC expedition with the help of Horticulturist Scott Phillips. Above, the 2019 NACPEC expedition team included (from left) Andrew Gapinski, Jared Rubinstein, Tao Deng, Xinfen Gao, Kang Wang, and Sean Halloran.

Manager of Plant Propagation Tiffany Enzenbacher sorting seeds in the Dana Greenhouses.

Kathleen Dooher

Propagating
for tomorrow's Arboretum

The Dana Greenhouses and Nursery made great strides in 2019, cultivating some 156 accessions acquired from expeditions, institutional partners, and *Index Seminum* requests. Plant production staff recorded accession details, cleaned seed, distributed excess to collaborators, and researched germination protocols. Many 2019 targets have already germinated as a result of customized propagation treatments, including *Acer diabolicum* (devil maple; collected in Yaita, Tochigi Prefecture, Japan) and *Acer pycnanthum* (collected in Nakatsugawa, Gifu Prefecture, Japan). In all, more than 1,200 individuals collected for the Campaign for the Living Collections are now growing at the Dana, 537 of which are on the Campaign's target list.

Concurrently with seed propagation, plant production advanced lineages for many historic Arboretum specimens through clonal propagation—processes whereby resulting progeny are genetically identical to the source plant. Staff made approximately 138 repropagation attempts, including grafting, layering, and stem and root cuttings. Stem cuttings from the Arboretum's oldest lineage of *Eleutherococcus henryi* var. *henryi,* a shrub first collected for the Arboretum by Ernest Henry Wilson on his 1907 expedition in China, are among repropagated plants that will be cared for at the facility until they are large enough to join the living collections in the Arboretum landscape.

Plant production staff have provided fundamental support to its role in public education and outreach—from mentoring interns to providing experiences for the community through tours and hands-on learning. In collaboration with staff of the Mary B. Wakefield Charitable Trust in Milton, Massachusetts, Isabella Welles Hunnewell plant production interns propagated a number of *Cornus kousa* (kousa dogwood) specimens in June 2019 for replanting at the Estate. This experiential opportunity for our interns not only enhanced their own training, but also strengthened our long-standing connection with a local partner for horticulture and education.

Jeffrey Blackwell

2019 Hunnewell interns Grant Hughes (left) and Lane Diesa prepare cuttings of *Cornus kousa* as part of a joint project with the Mary Wakefield Estate.

Spring Expedition
to Japan

In May, Keeper of the Living Collections Michael Dosmann participated in the first 2019 expedition for the Campaign for the Living Collections—journeying to Gifu Prefecture, Japan, in search of one of the world's rarest maples, *Acer pycnanthum*. Only about 1,500 individuals of this species remain in the wild, limited to growing in special wetlands (seeps and floodplains) in central Honshu between 300 and 600 meters (1,000 and 2,000 feet) in elevation. Unlike a majority of the trees the Arboretum collects during autumn expeditions, the fruit of this species—the characteristic winged samara—ripens in mid-to-late spring.

Rare in cultivation in the West and represented in gardens worldwide by a handful of introduced lineages, *A. pycnanthum* has proved incredibly difficult to cultivate in Boston. Although ten previous attempts to grow the species in our nurseries and landscape have failed, the Arboretum—as a leader in plant conservation and the repository of one of the world's most diverse collections of maples—keeps trying and rigorously documenting its attempts. The spring 2019 trip—with expert collaborators Professor Mineaka Aizawa and his student Tatshiko Shibano of Utsunomiya University—focused on collecting germplasm from among the few remaining natural populations of the tree. These collections will play a number of pivotal *ex situ* conservation roles at the Arnold Arboretum and beyond—from joining our permanent living collections to being shared with other gardens and the USDA's National Plant Germplasm Repository.

Dosmann described encountering the tree in the wild: "Even from a distance, I could distinguish our maple from other broadleaved trees due to their grayish-green foliage color, particularly as the wind ruffled the leaves—the leaf undersides display a waxy, white bloom, much like those of its close North American relatives red maple (*A. rubrum*) and silver maple (*A. saccharinum*). The species' similarity to these two native maples is uncanny—it was like sauntering up to a Massachusetts swamp and visiting familiar friends."

"The species' similarity to these two native maples is uncanny—it was like sauntering up to a Massachusetts swamp and visiting familiar friends."

Fall Expedition
to Japan

The Arboretum journeyed to Japan for a second expedition in mid-September 2019, collecting plants in Wakayama, Mie, Tochigi, Gunma, and Honshu Prefectures. Director of Operations Stephen Schneider represented the Arnold Arboretum on a trip hosted by Mineaki Aizawa of Utsunomia University, along with his student Tatshiko Shibano, Tony Aiello of the Morris Arboretum, Ian Jochems of the Polly Hill Arboretum, and interpreter and consultant Keiko Satoh. Over 10 days, some 30 collections representing 28 different taxa were gathered to be shared among the participating institutions.

The team revisited Hokkaido University Forest after a successful expeditionary trip there in fall 2018, collecting the umbrella pine (*Sciadopitys verticillata*) among other important targets across very challenging mountainside terrain. On Serpentine Island in Mie Prefecture—home of the unique stone that bears its name, cultured pearls, and a fearsome population of wild boar—seeds of *Rhododendron sanctum* were a prized acquisition of the trip. First discovered on the grounds of Japan's revered Ise Shrine, this extremely rare shrub can only be sourced in the wild via ferry and extended mountain climb and represents a key addition to the Arnold's rich collection of rhododendrons.

Another notable collection made on this expedition was *Acer diabolicum*, the devil or horned maple, so named for the hornlike appearance of the stigmas of its flowers, a characteristic retained on its winged seeds. Repropagation protocols for this species have bedeviled Arboretum propagators for decades, so seed propagation appears key to its continued cultivation outside its native range. Fine hairs covering the samaras can be a major skin and respiratory irritant, so gloves and facial coverings were required to collect and clean the seed. These and other plants collected on the fall expedition in Japan were sent to the staff at the Dana Greenhouses, where they will germinate, grow, and join the living collections in our landscape in coming years.

Michael Dosmann

Accessing and Sharing
our historical correspondence

Correspondence between Arnold Arboretum staff and explorers in the field, collaborative institutions, and scholars and supporters around the world has long been an important archival resource, and library staff has brought much of this material into the digital space in recent years. In 2019, the Horticultural Library and Archives implemented a new version of their Correspondence Database to improve how these materials are shared with researchers. Spearheading this project was IT team member Victoria Lin, who migrated all the content from outmoded systems and created a user-friendly public search interface for the Horticultural Library website. The database provides an index to the correspondence of all the early figures from the Arboretum's history, including Charles Sprague Sargent, Alfred Rehder, Elmer D. Merrill, and Ernest Henry Wilson.

Top left: *Ormosia hosiei* (Hung-tou-shu) tree photographed by E. H. Wilson near Chentu City, China, in November 1908.

Bottom left: A "typical lane" (verso notation) in Chentu Fu, China, photographed by E. H. Wilson in August 1908.

Kathleen Dooher

DNA to Go:

Dried Emerging Leaves (DEL) Collection

Significant collections and documentation work in 2019 will allow the curatorial department to unveil the Dried Emerging Leaves (DEL) collection to the public in 2020. A research collaboration project started in 2015 by then visiting scholar Daniel Sullivan, the project has developed through the meticulous efforts of curation and Sullivan—who continues to collect and process samples. This exciting new collection will provide researchers access to dried emerging leaves throughout the year, making seasonality less of an obstacle for requests when fresh leaf material from the living collections is unavailable. The collection contains emerging leaves, from which it is easier to extract and amplify DNA for molecular research than leaves in the mature stage of their life cycle. Our hope is to provide not only access to the accessioned plants in the living collections year-round but also to provide scholars with prime samples for their research.

The DEL collection currently represents approximately 700 accessions and 5,000 packets (multiple packets per accessioned plant). Accessions prioritized for the collection include species of conservation concern including those held in collaboration with the Plant Collections Network (PCN), plants collected from the wild, and accessions identified as important based on internal review. These criteria allow staff to effectively schedule collecting work throughout the year. The DEL Collection will be documented using our database of record *BG-BASE* and made available via our website as an online reference for research. The Arboretum looks forward to growing, maintaining, and providing access to this important new collection for scholars.

Making and Sharing Discoveries

Faculty Fellows
of the Arnold Arboretum

Faculty Fellows of the Arnold Arboretum of Harvard University are Harvard professors who contribute meaningfully to the Arboretum's research and education mission. In 2019 there were four Faculty Fellows, William (Ned) Friedman, Arnold Professor in Organismic and Evolutionary Biology and director of the Arnold Arboretum; Robin Hopkins, associate professor in organismic and evolutionary biology; Noel M. Holbrook, professor of organismic and evolutionary biology; and Rosetta Elkin, associate professor of landscape architecture in the Harvard Graduate School of Design.

The Friedman Lab is based at the Arboretum and focuses on reconstructing the evolutionary origin and early diversification of flowering plants, Darwin's so-called "abominable mystery." Additional investigations include work to understand the evolution of structural patterns of winter buds in temperate woody plants and a study of the functional consequences of the diversity of water-conducting tissues among ferns.

Also based at the Arboretum, the Hopkins Lab studies the evolutionary and genetic processes underlying the formation of new plant species. Projects focus on plant genomics and the role of reinforcement in speciation, self-incompatibility and inter-specific incompatibility in plant reproduction, and the role pollinator behavior plays in driving speciation and floral evolution. Professor Hopkins received a major grant from the National Science Foundation Panel of Plant Biotic Interactions to study how *Phlox* species select their mates.

Noel M. Holbrook conducts research using the living collections and the Weld Hill facilities; mentors and supports Arboretum DaRin Butz interns, graduate students, and postdoctoral fellows; and is an instructor for the Arboretum's summer short course in organismic plant biology. Primarily based on the Harvard University campus in Cambridge, the Holbrook Lab conducts investigations at Weld Hill focusing on functional aspects of the water and sugar conducting tissues of plants.

Rosetta S. Elkin teaches landscape architecture at the Harvard Graduate School of Design, and her research explores the role of plants in design, especially the adaptations inherent to climate change. She and her students explore public projects at the Arboretum that prioritize public accessibility while maintaining the ambitions of the Olmstedian landscape. In 2019, she was awarded the Provost's Climate Change Solutions Award, to support her fieldwork in expanding knowledge of case studies whereby retreat is offered or instigated as a viable community driven initiative and as an adaptive force.

In addition to research and academic activities, Faculty Fellows and their lab groups are actively involved in Arboretum outreach and education programs. They lead Tree Mobs™, share botanical knowledge with Boston public school teachers in the Arboretum's Summer Institute, and provide insights into their research with visiting STEM groups. They also welcome students into their labs to conduct independent projects under their mentorship as part of the DaRin Butz Foundation Undergraduate Research Program.

Ned Friedman

Robin Hopkins Recognized

by two major grants

Robin Hopkins was awarded two major grants by the National Science Foundation (NSF) in 2019 in recognition of her research on the evolutionary forces driving plant speciation, and her efforts to teach and inspire investigation by students and the public. Hopkins, who was promoted to associate professor of organismic and evolutionary biology at Harvard University at the beginning of 2020 and a faculty fellow at the Arnold Arboretum, received funding from the NSF Faculty Early Career Development Program of the Division of Environmental Biology to investigate *Phlox* as a model system of how plant lineages evolve to become distinct species. The grant will also underwrite a research experience for first-year Harvard College students in molecular biology and research methods, and expand learning resources for students in grade 3 through 12 through the development of self-guided activities for the Ware Collection of Blaschka Glass Models of Plants at the Harvard Museum of Natural History.

"Plants are responsible for every bit of energy that is consumed by all life," Hopkins explains. "But as humans, we don't necessarily see our connection to plants and we have limited educational resources to teach about them. The goal of this grant is to help scientists incorporate their research into the teaching curriculum, and to find ways through that curriculum to inspire the research." A second grant from the NSF Panel of Plant Biotic Interactions will advance Hopkins's ongoing work to identify and characterize the behavior of the molecular signals stimulated by pollination—illuminating how plants select their mates. According to Arboretum Director William (Ned) Friedman, mate choice in plants represents one of the most fascinating and under-studied topics in evolutionary biology. "Few realize how incredibly sophisticated plants are at the molecular level when it comes to siring the next generation," he said. "Robin has a spectacular study system and the results of this research will almost certainly become classic examples of the evolutionary process."

Jeffrey Blackwell

Putnam Fellows at the Vanguard

of collections-based research

Established by George Putnam in 1988 in memory of his mother, the Katharine H. Putnam Research Fellowship Program at the Arnold Arboretum of Harvard University supports fellowship stipends and research expenses for post-graduate research. The goal of the program is to facilitate research using the Arboretum's renowned living collections of woody plants—thereby stimulating their use within the larger scientific community—and to generate and share new knowledge about the plant kingdom. Putnam Fellows work for up to two years on their projects as full-time members of the scientific community at the Arboretum and Harvard University.

In 2019, the Putnam Fellows Fund supported investigations by Elizabeth Spriggs, Jake Grossman, and Al Kovaleski. Elizabeth Spriggs, an evolutionary biologist, completed her two-year fellowship focusing on two iconic but threatened genera of North American trees—the chestnuts and ashes (*Castanea* and *Fraxinus*)—to examine genetic diversity and population structure in relation to disease (with an eye towards identifying individuals of conservation value). Jake Grossman, a plant ecophysiologist with a strong interest in forest ecosystems and trees, completed the first year of his fellowship examining drought vulnerability and water use strategies in maples (*Acer*) to analyze the potential effects of climate change on the Arboretum's collections. The year also launched the Putnam Fellowship of Al Kovaleski, a plant physiologist with a guiding interest in understanding how woody plants adapt to freezing stresses during winter. Al's research spotlights the rose family (Rosaceae) in the Arboretum's living collections, investigating cold hardiness, chilling response, and resumption of growth to recalibrate phenological models of budbreak.

After her Putnam fellowship, Beth started as a fellow at Insight Data in Boston to learn large scale data analysis techniques. Jake will begin teaching at Swarthmore College in fall 2020 as a visiting assistant professor of ecology. In spring 2021, Al will join the Department of Horticulture at the University of Wisconsin, Madison as an assistant professor.

Putnam Fellows Jake Grossman (left) and Al Kovaleski in the maple collection.

Jeffrey Blackwell

Darin Butz Foundation Internship Program boosts tomorrow's researchers

Since 2017, the DaRin Butz Foundation Research Internship Program at the Arnold Arboretum has offered undergraduates in the life sciences a unique opportunity to experience research from start to finish while training and networking with scientific colleagues at the Arboretum and across Harvard University. Joining the laboratories of Arnold Arboretum Faculty Fellows, Putnam Fellows, and associated scientists, the DaRin Butz Research Interns develop independent research projects with their advisors, which they develop and share over the course of the ten-week program. Interns participate in additional activities aimed at increasing their knowledge of research methods and careers, including a weekly reading group and field sessions with Arboretum staff.

Jon Hetman

Faye Rosin

DISCOVERIES

2017 Intern Emily Rosa is working as a biologist with the United States Air Force as a civilian employee. "The DaRin Butz Foundation Research Internship allowed me to gain confidence and start viewing myself as a young scientist."

2017 Intern Jessica Leslie is a PhD student in the Molecular and Cell Biology Program at the University of California–Berkeley. "The program allowed me to try research in a different (and great!) environment and solidified my decision to continue studying science. I think the environment at the Arboretum is something I really appreciated, and the community is very friendly—not every research institution is like this! I continue to be grateful for the opportunity to explore my interests in a supportive environment like the Arnold Arboretum."

2018 Intern Matthew Farkatos was awarded the 2019 Undergraduate Research Prize by the American Society of Plant Taxonomists for his work as a DaRin Butz intern. He is currently applying to various graduate schools to study plant ecology. "The DaRin Butz Foundation Internship definitely helped lead me to where I am now. Going into the program, I was not sure daily research in plant biology was for me, but my experiences with the program solidified my drive to attend graduate school. Working collaboratively in a place where everyone is focused on plants really showed me all the possibilities in this field."

2018 Intern Bridget Bickner is currently a PhD student at Harvard University in the Department of Organismic and Evolutionary Biology, with her laboratory advisor in the Internship program—Associate Professor Robin Hopkins—assisting her efforts as faculty advisor. "Through the DaRin-Butz program, I was able to expand my laboratory skill set and benefit from direct interaction and networking with scientists and other emerging plant biologists. It allowed me to explore the research world in greater depth than programs at my undergraduate institution, and the "snapshot" I got from my time at the Arnold Arboretum helped me find a home for my graduate studies for the next six years."

Connecting with the Community

New Signs

share conservation message

Visitors to the Arboretum can learn more about the institution's commitment to global plant conservation and collections of threatened plants through four new interpretive signs installed in the landscape in 2019. Funded by a member of the Arboretum's Sargent-Olmsted Society, the beautifully designed and content-rich signs provide compelling information for serious plant aficionados and casual nature enthusiasts alike. Each sign illuminates broad themes of conservation work practiced at the Arboretum, combining intriguing facts about endangered plant taxa, historical and contemporary images, and firsthand stories from collectors and curators. The new signs are part of a broader initiative to engage visitors about environmental action and bolster opportunities for casual learning in the landscape.

Highlighting the stories of ginkgo (*Ginkgo biloba*), Nantucket shadbush (*Amelanchier nantucketensis*), Franklin tree (*Franklinia alatamaha*), and dawn redwood (*Metasequoia glyptostroboides*), the signs offer intriguing case studies of the Arboretum's significant conservation work since its inception. With one in five plant species threatened with extinction globally, our goal is to educate visitors about how the Arboretum is playing a vital role in worldwide conservation efforts.

These new interpretive signs illustrate how essential cooperation and collaboration are to the Arboretum's approach to conservation. Partnerships with the Center for Plant Conservation (CPC) and the Plant Collections Network (PCN) continue to thrive with eight national collections that are crucial for conservation efforts and cutting-edge research. In addition, through the continued pursuit of the Campaign for the Living Collections, the mission to collect, preserve, and share germplasm with other public gardens remains strong.

Below, new conservation signage highlights some of the threatened plants harbored in the collections. At right, teachers learn how to engage their students in science outside in our annual Summer Institute.

Jeffrey Blackwell

"The shared experience with colleagues along with having access to top scientists made the Institute an invaluable experience. Now I feel supported and confident about teaching science."

Jeffrey Blackwell

Summer Institute

champions the value of learning outside

Since 2016, the Arboretum has increased its professional development outreach to teachers in Boston Public Schools through a week-long Summer Institute. Designed to enhance middle and high school science teaching in the outdoors, this year's Institute—Investigating Ecosystems Through Field Work—focused on data-gathering techniques and addressing issues related to climate change. This is an area of great need in current educational settings and the Arboretum is well positioned to lead the way in outdoor education for Boston schools.

Eighteen educators, representing public schools in Boston and surrounding communities, as well as private and informal education programs in New England and even universities in Spain and China, came together to learn new strategies and content in the area of environmental education. The Institute supports teachers by providing expert guest speakers and opportunities to network with other educators, along with granting transportation to bring students to the Arboretum for field-based activities. Participant Maite Diez explains, "The shared experience with colleagues along with having access to top scientists made the Institute an invaluable experience. Now I feel supported and confident about teaching science."

This confidence has translated into various units of study developed by Institute participants that are changing how students relate to plants. In one school, student teams collected, processed, and analyzed field data from study plots and turned them into reports which were peer reviewed by researchers at the Arnold Arboretum. Another teacher developed a plant transpiration lab that compared water output during the day versus at night as well as between green and senescing leaves of the same plant. Yet another class measured the diameter of local trees to calculate carbon storage in order to understand the important role of trees in mitigating climate change. Participant Sarah Barrington, who brought students back to the Arboretum this winter to conduct fieldwork activities, explained, "Repeatedly taking students out in the field, mixed with instruction and learning from actual scientists on the ground, helps to build students' appreciation and enjoyment of the natural world."

Jeffrey Blackwell

Art at the Arboretum

Artists engage with the Arboretum and its plants through exhibitions that suggest an expansion or heightening of nature and our connection to it. January's *An Artist's Perspective*, with Regina Milan, emphasized this idea with elegant, larger-than-life watercolors of fruits and flowers. This was followed by photographer Chris Morgan's *Transitions: Winter into Spring*, an evocation of nature's transitional qualities. In May, *Drawn to Paint* played on artist Paul Olson's ease with sketching and color-saturated oils to intensify the organic spirit of trees. Workshops by artists furthered the accessibility of visitors to nature and art—*Nature Journal Workshop*, *Exploring the Botany Behind the Art*, and *Making Art in the Landscape*.

Echoes of art in the landscape resounded through June's live production of *Pride and Prejudice*. Actors' Shakespeare Project enhanced the beauty of the Leventritt Shrub and Vine Garden with their creative energy in performing a seminal work by Jane Austen for a 1,500-strong audience, who enjoyed the free performance through the generosity of members Peter and Leslie Ciampi. In July, *Between the Leaves* spotlighted Sarah Cross's ephemeral and unique gum bichromate prints. Also in summer, the Visitor Center showcased a special exhibition by fabric artist Steffanie Schwam, *Art & Science: Fabric, Fiber & Phenology*. Schwam's workshop guided participants to use Arboretum materials in personal ways.

For the fifth year, *Turning Wood: The Art of the Woodturner*, showcased Arboretum wood art and demonstrations on the lathe by local woodturning groups. The year in art ended with the infrared photography of Betsey Henkels, *The Light You Can Not See*. Indeed, exhibitions and art-focused events in 2019 captured many things in nature not immediately apparent, offering visitors the gift of new sight through our artists' eyes.

Actors' Shakespeare Project brought a modern telling of Jane Austen's *Pride and Prejudice* to the Leventritt Garden in June. At right, students from Boston Public Schools learn about plants and ecology in our Field Study Programs.

Jeffrey Blackwell

Connecting to the **Community** through learning programs

Learning opportunities at the Arnold Arboretum draw from the breadth of our resources, the expertise we offer as a premier garden of woody plants, and the wide-ranging audiences we engage. In 2019, the Arboretum's Field Study Experiences offered outdoor lessons in elementary biology and ecology to more than 2,250 children, nearly ninety percent from Boston Public Schools. With nature-focused programs and bus transportation provided by the Arboretum for free to all participating BPS classrooms, our field lessons are carefully tailored to align with the science and engineering standards of the Commonwealth of Massachusetts. Students enjoy learning outdoors through hands-on activities with our plants, experimentation and documentation, and small group interactions guided by Arboretum volunteers—a dedicated group who together contributed nearly 1,900 hours to children's education in 2019.

The Arboretum contributed to community education through an assortment of practical classes, from sustainable and eco-friendly garden planting and design workshops to our first smartphone landscape photography classes. Symposia illuminated the contributions of women to New England horticulture and garden design and the decline and potential rebirth of the American chestnut (*Castenea dentata*). Our Director's Lecture Series included a panel discussion by Director William (Ned) Friedman with award-winning authors Robin Wall Kimmerer and Richard Powers on the majesty and meaning of trees, and a galvanizing talk on the future of environmental protection by former EPA chief Gina McCarthy. Ten Tree Mobs connected scientists and horticulturists with our visitors on topics from box elders to viburnums, earthworms to tree swallows, and even the plants that grow beneath our solar arrays at Weld Hill.

Additional programming for visitors of all ages also highlighted natural and ecological themes, including finding wilderness in urban areas and examining the problem of light pollution globally. Participants were delighted by a nighttime "Moth Meet" with Sam Jaffe and the Caterpillar Lab, featuring illuminated stations by the Hunnewell Building and on Willow Path to observe and identify resident moths of the Arboretum. The Arboretum also developed and shared programs for personal well-being and restoration in nature, including "forest bathing" excursions, yoga and Tai Chi sessions, and wellness programs directed at seniors during Active Aging Week in October. Collections Up Close opportunities illuminated our national collection of ginkgos in spring, and the fruits that abound in the Bradley Rosaceous Collection each autumn.

Jeffrey Blackwell

Thank You for Your Support

Janetta Stringfellow, Director of Institutional Advancement

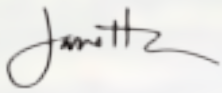
As I write to thank you for your donations in 2019, I'm sitting firmly in 2020 where I'm overwhelmed by and so grateful for the outpouring of support and the deep connections you feel for the Arnold Arboretum.

While we were celebrating so many wonderful advancements—the installation of solar panels with Harvard's President Larry Bacow and dignitaries from the City of Boston; delighting in the Actors' Shakespeare Project production of *Pride and Prejudice* in the Levintritt Shrub and Vine Garden; touring the maple collection with Keeper of the Living Collections Michael Dosmann and members the Sargent-Olmsted Society—we had no idea what the future held.

The Arboretum—in any year—is a place you can rely on for beauty, solace, rejuvenation, science, education, or even just a shady place to sit. Because of the support you and generations of enthusiasts have provided, everyone can enjoy our landscape for free 365 days a year.

Many of our 17,000 accessioned trees have seen more than a century of change, and for nearly 150 years, we have depended on the generosity of our community to fulfill our mission to grow and share one of the world's most comprehensive and best-documented collections of temperate woody plants.

We wouldn't be here without you. Thank you.

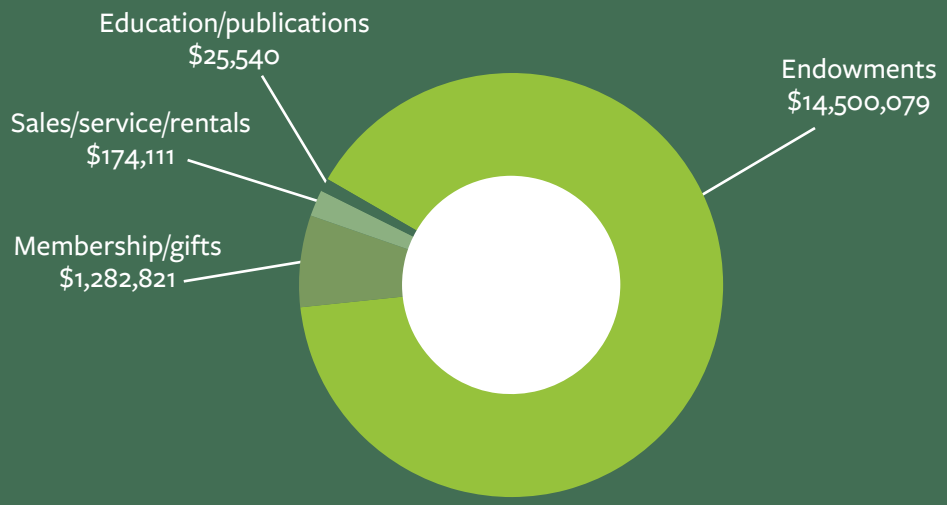


Andrew Gapinski

Statement of Activities

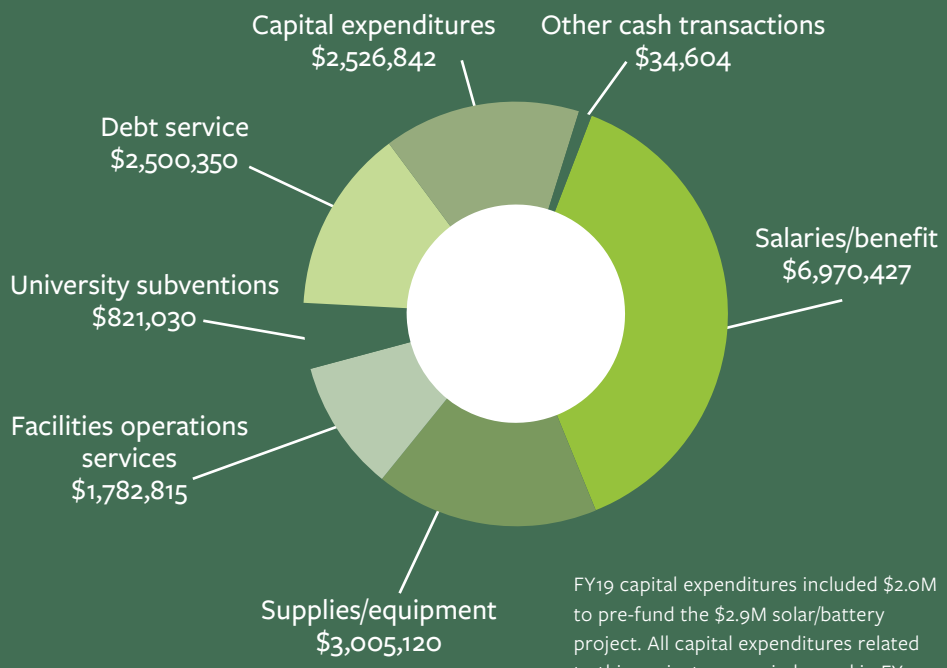
The Arnold Arboretum of Harvard University relies almost exclusively on income derived from the past and present philanthropy of friends and members, who have given generously to support the institution for nearly 150 years. The information provided below reflects the financial activities of the Arboretum in the 2019 fiscal year (July 1, 2018–June 30, 2019).

INCOME: $15,982,551



EXPENSES: $17,641,188

NET CHANGE IN CASH $(1,658,637)



FY19 capital expenditures included $2.0M to pre-fund the $2.9M solar/battery project. All capital expenditures related to this project were reimbursed in FY20 through the Harvard Green Loan program. Exclusive of this project pre-funding, the net in change in cash was $391,363.

Andrew Gapinski

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Plant Collections in 2019

As of December 31, 2019, the Arnold Arboretum living collections (including nursery holdings) comprised:

2,184 **species** • 3,850 **taxa**
11,052 **accessions** • 17,123 **individual plants**

628 **accessioned** plants were added to the permanent collections, while 311 were **deaccessioned.**

The Arnold Arboretum herbarium contains some 1.5 MILLION **specimens.**

The Arboretum's herbarium of cultivated plants contains 121,592 **specimens**

$20,000–$49,999

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Ned Friedman

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Toby Ritterhof
Linda Roistacher
Deder Sidner-Kelly
Marie Sintim
Norma Steinberg
Bethan Steward
Ursula Stone
Pat Suhrcke
Lindsey Toomey
Dorothy Torda
Dede Tower
Carol Waldvogel
Joanna Watson
Martha Watson
Penny Wells
Tori Zissman

NEST WATCH VOLUNTEERS

Justine Hanson
Suzanne Mrozak
Anne Rutter
Cristina Squeff

Ned Friedman

Mitchell Stokes
Donna Sullivan
Karla Naboa

TREE SPOTTERS

84 volunteers participated in our Tree Spotters citizen science program in 2019, logging 77,956 phenological observations of Arboretum plants for use in climate change research through the National Phenology Network. The program is moderated by Catherine Chamberlain, Suzanne Mrozak, and Danny Schissler.

Research Publications

■ **Arnold Arboretum Staff**

■ **Visiting Scholars, Fellows, and Associates**

Award Recipient **Putnam Fellow**

Aguirre-Gutiérrez J, Oliveras I, Rifai S, Fauset S, Adu-Bredu S, Affum-Baffoe K, Baker TR, Feldpausch TR, Gvozdevaite A, Hubau W, Kraft NJB, Lewis SL, Moore S, Niinemets Ü, Peprah T, Phillips OL, **Ziemińska K**, Enquist B, Malhi Y. 2019. Drier tropical forests are susceptible to functional changes in response to a long-term drought. *Ecology Letters* 22: 855-865.

Chamberlain CJ, Cook BI, Garcia de Cortazar-Atauri I, **Wolkovich EM**. 2019. Rethinking False Spring Risk. *Global Change Biology* 25: 2209-2220.

Ettinger AK, **Chuine I**, Cook BI, Dukes JS, Ellison AM, Johnston MR, Panetta AM, Rollinson CR, Vitasse Y, **Wolkovich EM**. 2019. How do climate change experiments alter plot-scale climate? *Ecology Letters* 22: 748-763.

Grossman JJ, Cavender-Bares J. 2019. Consequences of biodiversity shift across phylogenetic scales for aspen and willow growth, survival, and herbivory. *Journal of Vegetation Science* 30: 301– 311.

Grossman JJ, Cavender-Bares J, Reich PB, Montgomery RA, Hobbie SE. 2019. Neighborhood diversity simultaneously increased and decreased susceptibility to contrasting herbivores in an early stage forest diversity experiment. *Journal of Ecology* 107: 1492– 1505.

Joly S, **Flynn DFB, Wolkovich EM.** 2019. On the importance of accounting for intraspecific genomic relatedness in multi-species studies. *Methods in Ecology and Evolution* 10:994-1001.

Li J-H, **Tredici PD**, Lemmon AR, Lemmon EM, Zhao Y, Fu C. 2019. Allopatric speciation in Asia contributed to the diversity anomaly between Eastern Asia and Eastern North America: Evidence from anchored phylogenomics of *Stewartia* (*Theaceae*). *International Journal of Plant Sciences* 180: 768-777.

Losada JM, Blanco-Moure N, Leslie AB. 2019. Not all 'pine cones' flex: functional trade-offs and the evolution of seed release mechanisms. *New Phytologist* 222: 396-407.

Losada JM, Holbrook NM. 2019. Scaling of phloem hydraulic resistance in stems and leaves of the understory angiosperm shrub *Illicium parviflorum*. *American Journal of Botany* 106: 244-259.

Min Y, Bunn JI, Kramer EM. 2019. Homologs of the *STYLISH* gene family control nectary development in *Aquilegia*. *New Phytologist* 221: 1090-1100.

Molina-Henao Y, Hopkins R. 2019. Autopolyploid lineage shows climatic niche expansion but not divergence in *Arabidopsis arenosa*. *American Journal of Botany* 106: 61– 70.

Prior N, Little SA, Boyes I, Griffith P, Husby C, **Pirone-Davies C**, Stevenson DW, Tomlinson PB, von Aderkas P. 2019. Complex reproductive secretions occur in all extant gymnosperm lineages: a proteomic survey of gymnosperm pollination drops. *Plant Reproduction* 32: 153-166.

Roda F, Hopkins R. 2019. Correlated evolution of self and interspecific incompatibility across the range of a Texas wildflower. *New Phytologist* 221: 553-564.

Roddy AB, Jiang G-F, Cao K, Simonin KA, Brodersen CR. 2019. Hydraulic traits are more diverse in flowers than in leaves. *New Phytologist* 223: 193-203.

Savage JA. 2019. A temporal shift in resource allocation facilitates flowering before leaf out and spring vessel maturation in precocious species. *American Journal of Botany* 106: 113-122.

Smith L, Primack RB, Zipf L, Pardo S, Gallinat AS, Panchen ZA. 2019. Leaf longevity in temperate evergreen species is related to phylogeny and leaf size. *Oecologia*.

Spriggs EL, Schlutius C, Eaton DA, Park B, Sweeney PW, Edwards EJ, Donoghue MJ. 2019. Differences in flowering time maintain species boundaries in a continental radiation of Viburnum. *American Journal of Botany* 106: 833-849.

Switzer CM,Russell AL, Papaj DR, Combes SA, **Hopkins R.** 2019. Sonicating bees demonstrate flexible pollen extraction without instrumental learning. *Current Zoology*: zoz013.

Thammina C, Conrad KP, Pooler MR. 2019. Genetic diversity of the U.S. collection of Chinese hemlock *Tsuga chinensis* (Franch.) E. Pritz. based on simple sequence repeat markers. *Genetic Resources and Crop Evolution* 65: 1059.

Jeffrey Blackwell

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Arnold Arboretum—Funded Research Fellowships and Awards

ASHTON AWARD FOR STUDENT RESEARCH

Harikrishnan V. N. Radhamoni, PhD Candidate, Yale University
The diversity and distribution of herbaceous plants along a rainfall gradient in the seasonally dry tropical forests of the Western Ghats, India

Aidan Short, PhD Student, Guangxi University, China
Differences in adaptive evolution between tropical and subtropical mangrove species

CUNIN/SIGAL RESEARCH AWARD

Jedaidah Chilufya, PhD Student, University of Massachusetts, Amherst
Comparative analysis of symbiotic effectiveness of Arboretum woody legume bacteria on soybean production

DELAND AWARD FOR STUDENT RESEARCH

Steven Gougherty, PhD Student, Boston University
Comparing reproductive nutrient use efficiency across samara producing tree species

JEWETT PRIZE

Wendy Clement, Associate Professor, The College of New Jersey
Floral and scent evolution in honeysuckles: a trait-driven approach to detecting evolutionary shifts in pollination strategies in *Lonicera* (Caprifoliaceae)

KATHARINE H. PUTNAM FELLOWSHIP IN PLANT SCIENCE

Alisson Pacheco Kovaleski, PhD, Cornell University
Leveraging woody perennial winter physiology to refine phenological models

SARGENT AWARD FOR VISITING SCHOLARS

Kathryn Mauz, Independent Scholar
Using museum archives to reconstruct provenience for nineteenth century log specimens in the Jesup Collection of North American Woods, toward supporting their use in studies of climate history

SHUI-YING HU STUDENT/POSTDOCTORAL EXCHANGE AWARD

Wenbin Zhou, PhD Student, North Carolina State University
Investigating leaf endophytes in eastern Asian-eastern North American disjunct lineages

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The ARNOLD ARBORETUM of HARVARD UNIVERSITY

Jeffrey Blackwell

Design: Jeanne Abboud