

The Plant Press



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Botany Profile

Machine Learning in a Natural World

By Alex White

For many biologists, a core joy of our work is observing the natural world, formulating questions about our observations, and testing our ideas using clever experiments. Days are spent exploring museum cabinets or mountain valleys – few of us dream up romantic visions of deskwork at the computer. Computational research, however, is no doubt on the rise in biology, fueled by shrinking infrastructure costs, rapid computational advances, and a growing literacy among biologists in the relevant programming tools.

Two rapidly growing fields of ecology and evolution – (phylo)genomics and niche modeling – have already revealed the utility of computational tools when applied to biological questions, with far reaching implications for both basic research and conservation planning, particularly for plants. Yet the well of computational resources has just barely been tapped. For one, genomics and niche modeling take advantage of stereotypical data sources for studying ecology and evolution – sequence data and presence-absence data – but there are many non-traditional sources of data that computers are now poised to ingest and analyze with astonishing speed. These include complex data that machines are well suited to organize for analysis, such as continuous signals (light, audio, chemical, etc.), meshes from 3D scans, and images, whether microscopic, satellite, or traditional. And speed? Consider the latest collaboration between Berkeley National Laboratory, Oak Ridge National Laboratory, and NVIDIA (Kurth et al.

2018, arXiv:1810.01993), in which Kurth et al. showcased a machine learning model operating at 1.13 exaflops (10^{18} calculations per second). Their model was trained in under 3 hours to detect the pixel-level presence of tropical storms in exceptionally large (3.5 TB) atmospheric datasets. Such “deep learning” models hold promise for studying biological questions, but their development in the context of ecology and evolution is still in its early days.

Deep learning defines a class of computational models that are characterized by linking together a hierarchical chain of data transformations and calculations (i.e., fairly simple matrix algebra) to probabilistically “learn” features of a given dataset. Often, these models are used to supply predictions for a related dataset based on common features (this is called supervised learning and is the most common deep learning approach). One can easily visualize the steps involved in a simple deep learning model using Excel – indeed the most complex component is the learning process, where “known” datasets are passed through the model and thousands of randomly initialized parameters are updated iteratively to improve the model predictions. Primary layers of the models learn rough scale representations of the data where deeper layers learn fine scale differences between the features of interest.

One of the most common applications of deep learning is for object detection in images, where a labeled dataset of images is used to train a model that subsequently is used to predict the labels of unknown images. In 2012, the state-of-the-art image

model was able to detect the differences between images containing dogs and those containing cats with an accuracy of approximately 80%. With the proper know-how, one can now build and train a dogs vs. cats model with near perfect accuracy in a matter of minutes.

With these rapid advances in mind, the goal of my postdoctoral research is to develop these methods for use in ecology and evolution and apply them to better understand patterns of biodiversity hidden within complex and noisy datasets. For example, colleagues and I at the University of Chicago recently developed a machine-learning model to evaluate ecological assemblages and their (phylogenetic, functional, and taxonomic) structure. Using this model, we can integrate local community surveys, phylogenetic trees, and biogeographic scale data to quantitatively characterize the regional distribution of biotas and their contributions to individual local assemblages. Unlike the examples I provided above, this model is unsupervised (meaning there are no known labels) and makes use of biogeographic data as images to learn the spatial relationships between species in order to generate characteristic biotas. We are currently using this approach to examine the relationship between bird and plant communities across the forest patches in the Himalayas, and we are finding strong concomitance between the structural patterns in both groups. While we are now working to examine the biological basis

Continued on page 13

Pedro Acevedo traveled to San Juan, Puerto Rico (8/17 – 8/23) to present a talk at the University of Puerto Rico on the botanical legacy of Agustin Stahl; and to Rio de Janeiro, Brazil (9/7 – 10/14) to teach a course Neotropical lianas at the Federal University of Rio de Janeiro and to conduct research.

Barrett Brooks traveled to Belize (8/15 – 8/30) to lead a diving activity for Smithsonian volunteers conducting an annual monitoring for the Caribbean Coastal Marine Productivity project at the Carrie Bow Cay field station.

Manuela Dal Forno traveled to San Juan, Puerto Rico (7/11 – 7/22) to present a talk, “Microbiome of basidiolichens of the *Dictyonema* clade (Hygrophoraceae, Agaricales),” at the 11th International Mycological Congress, where she organized a symposium along with Robert Lücking on the evolution and diversity of lichenization in the Basidiomycota.

Stuart Davies traveled to Singapore (6/30 – 7/2) to attend the annual meeting of the Association of Tropical Biology and Conservation (ATBC); and to Borneo, Malaysia (7/3 – 7/8) to meet with the local

field team and co-principal investigators to discuss the re-census progress in the ForestGEO Lambir plot.

Ashley Egan and **Matthew Haynsen** traveled to Rochester, Minnesota (7/22 – 7/25) to present a talk at the Botany 2018 conference.

Karen Golinski traveled to Haida Gwaii, Canada (6/19 – 6/26) to organize a Schofield Bryophyte and Lichen Foray, to co-organize and attend the annual meeting of Botany BC, to lead public bryophyte walks in Masset and Skidegate for Parks Canada & Council of the Haida Nation, and to present an invited lecture, “Bryophytes of Haida Gwaii,” in the Gwaii Haanas Speaker Series.

Morgan Gostel traveled to Rochester, Minnesota (7/23 – 7/26) to present a talk at the Botany 2018 conference.

Carol Kelloff traveled to Dunedin, New Zealand (8/22 – 9/7) to attend the 2018 joint meeting of the Society for the Preservation of Natural History Collections (SPNHC) and Biodiversity Information Standards (TDWG); and to McBee, South Carolina (9/17 – 9/29) with **Mark Strong** to collect vouchers and genomic quality DNA samples of rare and endemic plants species from the longleaf pine ecosystems of South Carolina as part of the Global Genome Initiative (GGI).

David Kenfack traveled to Nairobi, Kenya (8/26 – 9/5) to assess the re-census progress with co-principal investigators in the ForestGEO Mpala plot.

W. John Kress traveled to Singapore (7/20 – 7/26) to deliver a keynote talk at the 8th International Zingiberales Symposium and to chair the International Scientific Committee for the meeting; and to Reykjavik, Iceland (7/26 – 8/2) to participate as a biodiversity specialist on a panel addressing psychoanalysis and the environment at the conference Psychoanalysis on Ice.

Gary Krupnick traveled to Toronto, Canada (7/22 – 7/27) to present a talk, “Evaluating our knowledge of North American orchid-pollinator interactions as it pertains to conservation,” at the 2018 North American Congress for Conservation Biology.

Erika Gardner traveled to Dunedin, New Zealand (8/22 – 9/7) to present a talk at the 2018 joint meeting of the Society for the Preservation of Natural History

Collections (SPNHC) and Biodiversity Information Standards (TDWG).

Mauro Lepore traveled to Buenos Aires, Argentina (9/3 – 9/5) for the LatinR Conference, a meeting about the use of R in research and development.

Sylvia Orli traveled to Rochester, Minnesota (7/23 – 7/26) to present a talk at the Botany 2018 conference.

Marcelo Pace traveled to Rochester, Minnesota (7/23 – 7/26) to present a talk at the Botany 2018 conference.

Eric Schuettelpelz traveled to Rochester, Minnesota (7/20 – 7/29) to attend the Botany 2018 conference, including the American Fern Society council meeting as current president, and the American Society of Plant Taxonomists council meeting as current finance committee chair.

Peter Schafran traveled from Virginia to Florida (8/14 – 8/26) to collect *Isoetes*.

Laurence Skog traveled to Rochester, Minnesota (7/21 – 7/26) to attend the Botany 2018 conference.

Robert Soreng traveled to Far East Russia (Primorsky, Sakhalin Island, Kamchatka Peninsula, and Magadan regions) (6/18 – 8/24) with Marina Olonova (TK) to collect grasses (ca. 700 numbers, ca. 400 of *Poa*) and to visit Nina Probatova and the VLA herbarium for several days; specimen sets are at US, TK, VLA (partial), and destined for CAN and elsewhere.

Meghann Toner traveled to Dunedin, New Zealand (8/22 – 9/7) to present a talk at the 2018 joint meeting of the Society for the Preservation of Natural History Collections (SPNHC) and Biodiversity Information Standards (TDWG).

Warren Wagner traveled to Rochester, Minnesota (7/22 – 7/26) to attend the Botany 2018 conference.

Jun Wen traveled to Rochester, Minnesota (7/21 – 7/26) to present a talk at the Botany 2018 conference and to conduct fieldwork in the area.

Elizabeth Zimmer traveled to Rochester, Minnesota (7/22 – 7/26) to attend the Botany 2018 conference where graduate student **Peter Schafran**, former intern **Jacob Suissa** and Research Associate **Carl Taylor** all presented talks at a colloquium in honor of Taylor; and to Montpellier, France (8/17 – 8/23) to present a poster, “Polyploidy in eastern North American quillworts (*Isoetes* L.),” at the Evolution 2018 meeting.



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Chair of Botany

Laurence J. Dorr
(dorr1@si.edu)

EDITORIAL STAFF

Editor

Gary Krupnick
(krupnickg@si.edu)

Copy Editors

Robin Everly, Bernadette Gibbons, and
Rose Gullledge

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If you would like to be added to the hard-copy mailing list, please contact Dr. Gary Krupnick at: Department of Botany, Smithsonian Institution, PO Box 37012, NMNH MRC-166, Washington, DC 20013-7012, or by E-mail: krupnickg@si.edu.

Web site: <http://botany.si.edu/>

Fire Destroys the National Museum of Brazil

Editor's Note

On 2 September 2018, a devastating fire destroyed the 200-year-old National Museum of Brazil (Museu Nacional) in Rio de Janeiro. The National Museum of Natural History (NMNH) has a long history of collaboration with Brazilian scientists and many of them are presently working at the Smithsonian. Reprinted below is a public statement that Kirk Johnson, Sant Director of NMNH, released in partnership with the directors of 11 other large natural museums. An effort is underway to collect digital documentation of the Museum's collections and the galleries (images, 3D models, digital records). Researchers and visitors can send their information to any of the following email addresses: thg.museo@gmail.com, lusantosmuseo@gmail.com, and isabelas-freitas@gmail.com.

Standing in solidarity with the National Museum of Brazil

On Sunday evening, a massive fire devastated the National Museum of Brazil. Founded 200 years ago, the museum is Brazil's oldest scientific institution and one of the largest and most renowned museums in Latin America, with a collection of 20 million artifacts and specimens.

It is with a profound sense of loss that our museums share our condolences with our colleagues in Brazil and the public they serve. The importance of the collections lost during this tragic event cannot be overstated. The National Museum is home to priceless artifacts and specimens that hold incalculable value to science—from major pieces of Brazil's scientific and cultural heritage, to the historic building itself, this is a loss not only for Brazil but for the world.

Times like these are a sobering reminder that natural history matters. Natural history museums document, protect, and celebrate the natural world. Our collections are an invaluable library of moments of life on Earth—each artifact and specimen is a crucial record of how the world became what it is today and a clue into how we can protect it in the future.

While we can't change the events of this weekend, we as natural history museums remain committed to working together to use our collections and collective scientific knowledge to generate and safeguard information that can be used by the worldwide community. As our colleagues in Brazil look to the future, we commit to supporting them in the coming weeks, months, and years.

Ellen V. Futter
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American Museum of Natural History

George Sparks
President & CEO
Denver Museum of Nature & Science

Richard W. Lariviere
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Naturalis Biodiversity Center

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Natural History Museum of Denmark

Sir Michael Dixon
Director
Natural History Museum London

Em solidariedade ao Museu Nacional do Brasil

No domingo à noite, um enorme incêndio devastou o Museu Nacional do Brasil. Fundado há 200 anos, o museu é a instituição científica mais antiga do Brasil e um dos maiores e mais renomados museus da América Latina, com uma coleção de 20 milhões de artefatos e espécimes. É com um profundo sentimento de perda que compartilhamos nossas condolências com nossos colegas no Brasil e com o público brasileiro em geral. A importância das coleções perdidas durante este evento trágico é incomensurável. O Museu Nacional abrigava artefatos inestimáveis e espécimes que têm valor incalculável para a ciência. Desde artefatos de suma importância para o patrimônio científico e cultural do Brasil até o prédio histórico em si, essa é uma grande perda não só para o Brasil mas para o patrimônio mundial.

Eventos como esse são um alerta para a importância da história natural e cultural do planeta. Museus como os nossos documentam, protegem e celebram o mundo natural. Nossas coleções são uma inestimável biblioteca de momentos da vida na Terra. Cada artefato e espécime é um registro crucial que nos mostra como o mundo se tornou o que é hoje e também uma pista fundamental que nos guia para respostas sobre como podemos protegê-lo no futuro.

Embora não possamos mudar os eventos deste fim de semana, nós, como museus de história natural, continuamos comprometidos em trabalhar juntos para usar nossas coleções e o poder científico coletivo para gerar e proteger informações que podem ser usadas pela comunidade mundial. No momento em que nossos colegas no Brasil olham para o futuro, nos comprometemos a apoiá-los nas próximas semanas, meses e anos.

Lori Bettison-Varga
President & Director
Natural History Museum of Los Angeles County

Camille Pisani
Director
Royal Belgian Institute of Natural Sciences

Josh Basseches
Director & CEO
Royal Ontario Museum

Kirk R. Johnson
Sant Director
Smithsonian National Museum of Natural History

Staff Research & Activities

Stuart Davies, David Kenfack, Lauren Krizel, Mauro Lepore, and Gabriel Arellano traveled to Nové Hrad, Czechia for the 8th Annual ForestGEO Analytical Workshop from 19 July to 3 August. The workshop provided an opportunity to bring global participants together to foster research and scientific collaborations. Participants also embarked on two field-site visits to the ForestGEO Zofin plot located in the Novohradské Mountains.

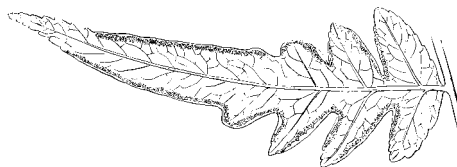
On 28 September, **Gary Krupnick** participated in a panel discussion after the showing of the film, *Seed: The Untold Story*, during a “film-talkback” series of the Rappahannock Association for Arts and Community (RAAC). In partnership with the Smithsonian Conservation Biology Institute and the American Conservation Film Festival, RAAC hosted a special Farm Tour Edition of the talkback series featuring farming-related films over two nights. *Seed: The Untold Story* follows passionate seed keepers protecting a 12,000 year-old food legacy. In the last century, 94 percent of our seed varieties have disappeared. As biotech chemical companies control the majority of our seeds, farmers, scientists, lawyers, and indigenous seed keepers fight a David and Goliath battle to defend the future of our food. The film showing and discussion took place at the Little Washington Theater in Washington, Virginia.

Alice Tangerini served as one of the committee organizers and as a participant in the Guild of Natural Science Illustrators 2018 conference held in Washington, DC from 14-21 July. The conference marked the 50th anniversary of the formation of the Guild, which began at NMNH with a core group of local and NMNH staff illustrators. This year’s conference was held mainly at American University with a day at the NMNH featuring behind-the-scene tours of the research departments, workshops led by Guild members in the Q?rius education center, and talks in Baird Auditorium. Tangerini and volunteer **Mary Monsma** chaired the Committees on signage and way-finding and catering.

Tours of the Botany Department were led by **Leslie Brothers** and **Meghann Toner**, with Tangerini providing a final stop at her office. An exhibit of Guild work was displayed at the AAAS Building, for which Tangerni provided a selection of historic artworks from the Botanical Art Collection.

New Faces

Alex White is a post-doctoral fellow with a joint appointment in the Department of Botany at the National Museum of Natural History (NMNH) and the Data Science Lab in the Smithsonian Office of Information. White is working with **Laurence Dorr** and **Eric Schuettpelz** at NMNH and **Rebecca Dikow** in the Data Science Lab on developing machine learning models for evaluating global scale patterns of trait diversity in digitized herbarium collections. White recently completed his Ph.D. at the University of Chicago where he studied the ecological and evolutionary drivers of Himalayan bird diversity gradients with a particular focus on biogeography. His research broadly concerns developing computational methods for combining local community data with macroscale data to evaluate contemporary and historical limits on diversity.



Awards & Grants

Marcelo Pace and **Andrew Rozefelds** received an award in recognition of their recent paper describing the discovery of the first wood fossil of Vitaceae in the Southern Hemisphere. The *Journal of Systematics and Evolution* presents awards annually to recognize the papers published in JSE with important impact in systematics and evolution. The paper “The first record of fossil Vitaceae wood from the Southern Hemisphere, a new combination for *Vitaceoxylon ramunculiformis*, and reappraisal of the fossil record of the grape family (Vitaceae) from the Cenozoic of Australia” <<http://dx.doi.org/10.1111/jse.12300>> has won the JSE Outstanding Papers award.

Herbarium is Destination for Summer Schools

The US National Herbarium typically attracts visiting research scientists interested in examining specimens in their field of study. The herbarium also serves as a destination in education. Undergraduate and graduate students interested in botany, ecology, evolution, molecular biology, and conservation biology have visited the herbarium to understand the importance of museum collections and how the specimens are used in research. This past summer several groups visited the herbarium. Here are two examples.

The second Oak Spring eFLOWER Summer School took place at the Oak Spring Foundation in Upperville, Virginia on September 18–27. The main goal of this Summer School was to provide high-quality training in modern comparative methods used to study macroevolution. The organizers, **Hervé Sauquet**, **Susana Magallón**, **Jürg Schönenberger**, and **Peter Crane**, hoped that this Summer School would further promote the rapidly evolving field of macroevolution in plant sciences while also conveying their experience in building high-quality morphological datasets. They also sought to inspire the participants to take part in the quest to understand the evolution of angiosperms and their flowers. Using the program PROTEUS, the School included lectures and hands on experience in floral trait data, ancestral state reconstruction, characteristics of early floral diversification, fossil calibration data entry, molecular dating and fossil data entry.

As part of the Summer School the 15 participants and three of their instructors traveled into Washington, DC, on September 23 and spent a day at the Smithsonian’s National Museum of Natural History (NMNH). During part of that time, they spent several hours touring the herbarium and having an open discussion about relevant topics such as the importance of biological collections, best practices in collecting samples, and the future of systematics. Participants attended from Australia, Brazil, Canada, France, Mexico, UK, and the USA (Illinois, Michigan, New York, Pennsylvania, Wisconsin). Invited speakers included **Else Marie Friis**, **Laura**



Vicki Funk (center) with participating students of the Oak Spring eFLOWER Summer School. (photo by Hervé Sauquet)

Lagomarsion, and Stacey Smith, and from the US National Herbarium, **Vicki Funk**.

Each summer, the Blandy Experimental Farm of the University of Virginia hosts a Research Experiences for Undergraduates (REU) program, a residential, 11-week summer program supported by the National Science Foundation. The primary goal of the program is to teach students to formulate testable hypotheses about important ecological and evolutionary questions. The format of the program encourages students to develop skills in experimental design, data collection, analysis, and critical reading of primary scientific literature. Students also learn to prepare and communicate scientific information to other scientists and the general public.

A feature of the Blandy program is to visit the NMNH to understand the importance of biological collections and how it might relate to their research. On July 13, nine participants and one of their instructors, Mary McKenna (Howard University), had the opportunity to visit the Departments of Botany and Vertebrate Zoology. **Gary Krupnick** gave a presentation and discussion on how botanical specimens are used in conservation research followed by a tour of the herbarium.

Visitors

Jie Yu, Southwest University, China; Plant DNA Barcoding (1/22/18-1/4/19).

Hannah Ranft, Johns Hopkins University; Pteridophytes internship (5/29-8/3).

Deborah Ballem, Smith College; DNA barcoding internship (6/4-7/31).

Jared Margulies, University of Sheffield, United Kingdom; Illegal wildlife trade (6/27-7/12).

Liz Matthews, National Park Service; Rosaceae (7/5-7/6).

Andrew Henderson, New York Botanical Garden; Arecaceae (7/9-7/11).

Mary McKenna and nine students, University of Virginia Blandy Field Station; Plant conservation and herbarium tour (7/13).

Jun Lim, University of California at Berkeley; Hawaiian *Peperomia* (Piperaceae) (7/16-7/20).

Joo-Hwan Kim, Gachon University, South Korea, and **Chang Young Yoon**, Shingyeong University, South Korea; Taxonomy of invasive species (7/17-7/20).

Jeronimo Moises Mendoza Flores, Universidade de Brasilia, Brazil; *Manihot* (Euphorbiaceae) (7/23-7/30).

Michael Nee, Missouri Botanical Garden; *Solanum* tribe Iochromineae (Solanaceae) (7/23-7/30).

Ana Maria Planchuelo, Universidad Nacional de Córdoba; *Crotalaria* and *Lupinus* (Fabaceae) (7/23-7/25).

Paul Henry Gonzales Arce, Museo de Historia Natural de la Universidad Nacional Mayor de San Marcos, Peru; Andean *Nototriche* (Malvaceae), *Viola* (Violaceae),

Xenophyllum (Asteraceae), *Werneria* (Asteraceae), and *Senecio* (Asteraceae) (7/24-7/25).

YaLi Wang, Kunming University, China; *Alpinia* (Zingiberaceae) (7/25-11/30).

Stephanie Arredondo, Allan Hancock College, **Tiffany Love**, Santa Barbara City College, and **Crystal Mares**, East Los Angeles College; UCSB-SI Mentoring Program for 2018 ERES (Early Research Experiences for Students) Summer Program (8/14-8/16).

Josh Neely, Lindenwood University; *Stenospermation* (Araceae) (8/24).

Melinda Barnadas, Magpie Studio, Maryland; *Bouteloua* and *Piptochaetium* (Poaceae) (8/28).

Suhyun Kim, Kangwon National University, South Korea; Plant anatomy and taxonomy (8/30-8/31).

Lorena Antunes, University of Brasília, Brazil; American *Aeschynomene* sect. *Aeschynomene* (Fabaceae) (9/10-9/14).

Vivian Oliveira Amorim, Universidade Estadual de Feira de Santana, Brazil; Brazilian Compositae (9/10-9/28).

Alessandro Souza, Universidade de Brasília, Brazil; *Chamaecrista* (Fabaceae) (9/10-9/14).

Annelise Nunes, Universidade de São Paulo, Brazil; Bignoniaceae (9/17-9/23).

Elizabeth Joyce, Australian Tropical Herbarium and James Cook University, Australia; *Aglaia elaeagnoidea* (Meliaceae) (9/17-10/5).

Caroline Pannell, University of Oxford, United Kingdom; *Aglaia elaeagnoidea* (Meliaceae) (9/17-9/23).

Qin Tin, Jiajin Wu, and Tingshuang Yi, Kunming Institute of Botany, China; Nitrogen-fixation clades (9/20-9/29).

Stephen Weller, University of California at Irvine; *Schiedea* (Caryophyllaceae) (9/20).

Jose Saenz, Universidad de Los Andes, Colombia; *Erythroxylum coca* and *E. novogranatense* (Erythroxylaceae) (9/24-9/25).

Gisele Gomes Nogueira Alves, Universidade de São Paulo, Brazil; Simaroubaceae (9/28).

Thomas H. Hollowell

(2 Sept 1954 – 25 Sept 2018)

In 1995 the Biological Diversity of the Guiana Shield (BDG) Program was in need of a new database manager. Judy Skog, then a Professor at George Mason University, recommended one of her students, Tom Hollowell, as a smart and capable person to take on the job. We hired him and we were quite surprised. Not only was he smart and talented at working with databases, he was also funny and optimistic; he loved music, environmental conservation, political activism, riding his bicycle to work, and of course, his family and friends.

Tom was the BDG data manager from 1996 to 2005, responsible for a database of over 150,000 records, producing labels for incoming collections and exchange, and updating the database as identifications arrived. He also coordinated students and volunteers working with the BDG Program databasing and barcoding plant specimens at the U.S. National Herbarium that had been collected in the Guiana Shield region. Tom had a strong sense of teamwork and was always there to help find solutions to any problems. He

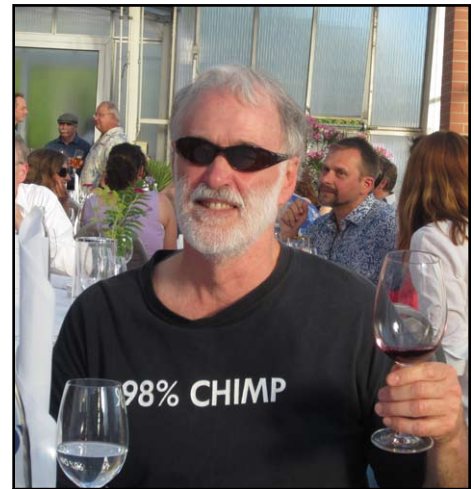
never shied away from assisting staff and researchers with data inquiries or with troubleshooting programs such as Arc-Map, Access, or EMu.

As the Program expanded to include the animals of the Guiana Shield, Tom was instrumental in coordinating researchers from different disciplines and departments to produce the various BDG publications and projects. While working full-time Tom went back to college at night to pursue a Doctoral degree in Environmental Science and Public Policy at George Mason University, receiving his PhD in 2005. As part of his dissertation research Tom studied fire-disturbed mangrove ecosystems in the Shell Beach area of Guyana.

During his time with the Program Tom co-authored many of the BDG publications. We would have kept him forever, but he left for a good cause: becoming a key player in NMNH's Office of Informatics Technology, helping make the museum's new database systems function. Before he left he trained and mentored his replacement, Sara Alexander (BDG 2006-2012; now with ITIS). Although he moved

up a floor he never lost his connection to Botany, and stopped by frequently... especially when we had food!

Tom continued his connection to Botany by assisting the Botany Digitization team with the import of over 60,000 new specimen records and images created every month by the digitization conveyor belt. He wrote many time-saving SQL scripts that cleaned up the conveyor transcription data and imported the data to EMu. To the IT Department he brought his understanding of how scientists collect data, and ideas of how to better serve the Museum at large by integrating



Tom Hollowell at the annual meeting of the Society for the Preservation of Natural History Collections (SPNHC) meeting in Berlin, Germany (2016) and at Shell Beach, Guyana (2001).

research data and images into EMu. Without his knowledge, his sense of teamwork, his enthusiasm, and his cheerful attitude toward the many challenges that he faced working with all the people associated with the BDG Program, we could not have accomplished all that has been done.

Tragically, Tom was killed by a hit and run driver as he bicycled to work (see *Ghost Ride*, left). Until then we never realized that Tom had the same special relationship that he had with BDG and Botany with just about every department in the Museum. No one has cleared his workspace, put away or packed up anything... we all hope he will come walking in the door again to share the latest tunes he found or to peek out our windows to check the weather. He will be greatly missed.

*Department of Botany: Vicki Funk,
Carol Kelloff, and Sylvia Orli
ITIS: Sara Alexander*



Ghost Ride: Remembering Tom Hollowell Fight for Bike Safety. Some 300 friends of Tom Hollowell and others concerned about bike safety rallied, in white shirts, at Farragut Square in Washington, DC on 4 October 2018. After a few words from Hollowell's widow and organizers, the bikers and walkers headed down separate routes to 12th St and Constitution Ave NW for a silent vigil in the middle of the intersection where a red-light running driver struck Hollowell. DC Police guided the ride and held up traffic for about 20 minutes while a white "ghost bike" was chained to a lamppost by the crosswalk where Hollowell was struck. (photo by Rob Soreng)

Funk Receives the 2018 Asa Gray Award

Adapted from ASPT News Blog

The American Society of Plant Taxonomists (ASPT) has selected **Vicki Funk** as its 2018 Asa Gray Award recipient. The prestigious award—named after arguably the most influential North American Botanist of the 19th century—recognizes lifetime achievement in plant systematics.

Funk was selected for the award following nominations and supporting letters submitted from 18 botanical and systematic experts. The primary nominators—Dennis Stevenson, Chelsea Specht, and Warren Wagner—indicate that “Dr. Funk epitomizes the most meritorious type of scientist for the Asa Gray award: an indefatigable and innovative evolutionary biologist, a field and herbarium botanist, a pure taxonomist, and an enthusiastic mentor.” In support of Funk, they continue, “Her career hallmarks include prolific and transformative research, innovations to the ways we do systematic botany ... significant contributions to plant taxonomy rules and regulations, mentoring of a continuous stream of young botanists, and contributing to the excellence of [ASPT] and its mission in promoting plant systematics and plant taxonomy.”

Indeed, the hallmarks of Funk’s career are noteworthy, including more than 200 peer-reviewed papers and as an editor/

author on nine collaborative books. One of these, *Systematics, Evolution, and Biogeography of Compositae* (2009), is a prominent tome that brought together virtually all the researchers of the world’s largest plant family. The book was the winner of the prestigious Stebbins Medal, demonstrating its high international praise. Funk has also produced many seminal papers on topics such as phylogenetic patterns and hybridization (1985), the highly regarded how-to book *The Compleat Cladist* (1991), systematic data in biodiversity studies (2002), and the first book using modern phylogenetic approaches in a standardized way to address biogeography on oceanic islands (*Hawaiian Biogeography*, 1995). For all of the nominators, it is clear that Funk’s name is not only synonymous with Island Biogeography, but her momentous work has also systematically built the foundations on which many plant researcher’s careers have flourished.

Funk’s humility is mentioned time and time again in her letters of support. Her tireless dedication and passion to the field is clearly evident. Her outstanding accomplishments, which are pertinent to the goals of ASPT, are indisputable. Throughout her career, Funk has mentored over 40 undergraduate, graduate, and post-doctoral students and has served as an un-official mentor to countless other interns, students, and postdocs. Funk has an outstanding track of service work serving as president of four major biological societies [Society for Systematic Biolo-



Asa Gray awardee Vicki Funk with previous awardees Harold Robinson and Warren Wagner. (photo by Carol Kelloff)

gists (1998-1999), International Biogeography Society, Founding Member and President (2007-2009), American Society of Plant Taxonomists (2006-2007), and International Association of Plant Taxonomists (2011-2017)] and has completed major service contributions at the Smithsonian. Additionally, she has made other significant editorial contributions, served on numerous review panels (including NSF, to which she herself cannot apply for funding), is a frequent and avid speaker at workshops and conferences, has collected in excess of 13,000 herbarium specimens, and has organized a large number of symposia and other events.

A native of Kentucky, Funk received her B.S. in Biology and History (1969) and then a M.Sc. in Biology (1975) at Murray State University. Funk then completed a Ph.D. in 1980 at Ohio State University where she researched the systematics of *Montanoa* (Compositae) followed by a postdoctoral position at the New York Botanical Garden from 1980-1981. From 1981 to present, Funk has been a research scientist and curator at the U.S. National Herbarium, Department of Botany, National Museum of Natural History, Smithsonian Institution.

Previous recipients of the award from the Smithsonian Institution include **Harold E. Robinson** (2010) and **Warren Wagner** (2015).



Vicki Funk, 2018 Asa Gray awardee with American Society of Plant Taxonomists president Chelsea Specht (left) and Dennis Stevenson. (photo by Jason Cantley)

Botanical Workshop Brings in High School Students

On 1 August, **Liz Zimmer, W. Carl Taylor, Peter Schafran, Destiny Waag, Shruti Dube, Erika Gardner, Steven Canty, Julia Steier, and Fiona Miller** worked with **Gabriel Johnson** to lead an introductory botany class to a group of 21 local high school students. To learn how to take proper field notes and collect plant specimens, each group of 3-4 students was paired with a botanist mentor and they searched the gardens surrounding the National Museum of Natural History to find plants in the family Lamiaceae. Each group brought their specimen back to the Q?rius lab where they learned how to use a dichotomous key to determine the name of the particular lamiaceous plant they found.

Each group made pressings in a plant press, and then received pre-pressed specimens of their plants to mount. They got hands-on experience to appreciate the science and art of plant mounting and how to prepare a proper specimen label. They observed fresh specimens of their plants under stereoscopes to learn about glandular trichomes and to get an appreciation of the diversity of minute insect fauna that are inadvertently collected with the plants.

Juan Pablo Hurtado Padilla showed the students pre-prepared SEM stubs of the same species they collected to see the unique epidermal feature of their plants in high resolution. Hurtado Padilla also presented the students with electron micrographs of the trichomes photographed in 3-D and could be observed with red and blue 3-D glasses. While this was transpiring, the students enjoyed comparing their plants to the other mint family plants collected by the other groups to get a good understanding of the morphological feature that define this family.

In a great cloud of water vapor, a large mortar of *Scutellaria ovata* leaves was flash frozen in liquid nitrogen and ground to a fine powder. The students then scooped samples of this powder into tubes of lysis buffer to see how plant tissue is processed in a molecular lab. After centrifuging the tubes of “green goo,” the students learned to differentiate a supernatant from a pellet and they carefully transferred

their supernatants into a vial of precipitation buffer. With plenty of “ooohs” and “ahhs,” they saw the “webbing” formed by the DNA molecules isolated in this solution.

The students also spoke with Department of Botany fellows and staff about their careers and current research projects.

Cuatrecasas Travel Award Recipient Examines Nyctaginaceae Anatomy

Israel Lopes da Cunha Neto, a doctoral student from the University of São Paulo, Brazil, is a recipient of a 2018 Jose Cuatrecasas Travel Award. He visited the US National Herbarium in August to work on his project, “Diversity and evolution of the vascular system in Nyctaginaceae.” His research aims at integrating data on the ontogeny of the vascular system of Nyctaginaceae stems within a phylogenetic context in order to understand its development, diversity, distribution, and evolution. By carrying out standard methods in plant anatomy, he aims to delimit anatomical characters and to establish the origin and type of the vascular cambial variants, which will then be mapped onto a well-supported phylogeny for the family.

During Cunha Neto’s visit, he examined, sampled, and carried out anatomical analysis of wood specimens from the

Nyctaginaceae family obtained from the Wood Collection of the Smithsonian’s National Museum of Natural History stored in the Museum Support Center (MSC) in Suitland, Maryland. He selected 46 of the 130 Nyctaginaceae specimens to sample. While working in the Plant Anatomy Lab under the supervision of **Stanley Yankowski**, he sectioned, stained, and mounted slides of the samples. He processed 12 specimens that are now part of the slide collection. Cunha Neto also processed four species recently collected in natural populations by **Marcelo Pace** in Costa Rica. At the University of São Paulo, Cunha Neto will continue to work on the remaining specimens that he did not process during his visit, and he will send duplicate slides back to NMNH.

Another objective of Cunha Neto’s visit was to study the Nyctaginaceae collection of pressed specimens to familiarize himself with plants he had not collected, enrich his database, update and determine species, and select localities for his forthcoming field trips to collect fresh material for anatomical studies. With proper authorization, he sampled stem portions from 14 voucher specimens.

Cunha Neto is grateful for his visit and remarks that his research experience abroad “added immense benefits to [his] dreamed career as a botanist, and to [his] aspiration of becoming a distinguished researcher in the field of Botany.” He feels that this opportunity has contributed to the knowledge of the Nyctaginaceae flora both anatomically and phylogenetically.



Israel Lopes da Cunha Neto at work in the Plant Anatomy Lab studying Nyctaginaceae anatomy. (photo by Stanley Yankowski)

A Summer Internship Focused on Women in Science

Department of Botany intern **Fiona Miller** from Smith College worked with **Vicki Funk** during the summer of 2018. During her 10 weeks at NMNH she contributed to the *Smithsonian Women in Science* project (part of the Smithsonian's American Women's History Initiative <https://womenshistory.si.edu/>). Before she arrived some of the curators in the Smithsonian science bureaus (NMNH, SERC, STRI) along with Pam Henson and Effie Kapsalis (Smithsonian Archives) had created a spreadsheet with the names and available information for all the women who had worked as curators in the various units. Miller had two main goals, 1) complete the spreadsheet (depending on available information) and 2) select a subset of the women to develop or improve existing Wikipedia pages.

Miller gathered information using a variety of resources including Smithsonian Archives and Smithsonian Libraries and, of course, she used internet searches. She also conducted interviews with some of the women and some of the older retired curators.

The goal of the Wiki pages is to make women in science at the Smithsonian more visible to the public. Miller felt that while some women such as **Mary Agnes Chase** (NMNH Botanist & Suffragette) had received attention, many other women at the Smithsonian had not been as recognized for their work as their male colleagues. She was glad to make a few more of the women known.

Miller found that women in the early 1900s were not always hired as scientists but as aids and secretaries for male colleagues. She found it interesting to see the different career tracks these women took to navigate the scientific world to find jobs and opportunities. She wrote, rewrote, and edited over 15 Wikipedia pages for women in the museum, some whom are currently employed, but she also used the Archives to locate information on a few that were at NMNH about a hundred years ago. In addition, she started the beginning stages of about 60 more women's Wiki pages.

A Mystery Solved: The Shifty Shifters are Discovered

For some time plant specimens in the U.S. National Herbarium have been mysteriously moving from one case to another. Sometimes the event would happen early in the morning, other times it would happen over the weekend. Whole plant families would simply appear in a new position in the herbarium.

On a recent weekend, early on a Sunday morning, the mystery was solved. **Mark Strong** and **Carol Kelloff** have been shifting during their "off" hours to help make way for the rearrangement of

the herbarium into a modified APG-IV (Angiosperm Phylogeny Group) format. Evidently, the two of them can shift 35 cases in four hours working at top speed. The latest impediment to implementing the new system was the Lauraceae, and it is now in its "forever home." Space is now ready for the next family to move.

Congratulations to both of them and thanks are extended for the extra effort. But one wonders, where will these shifty shifters strike next?

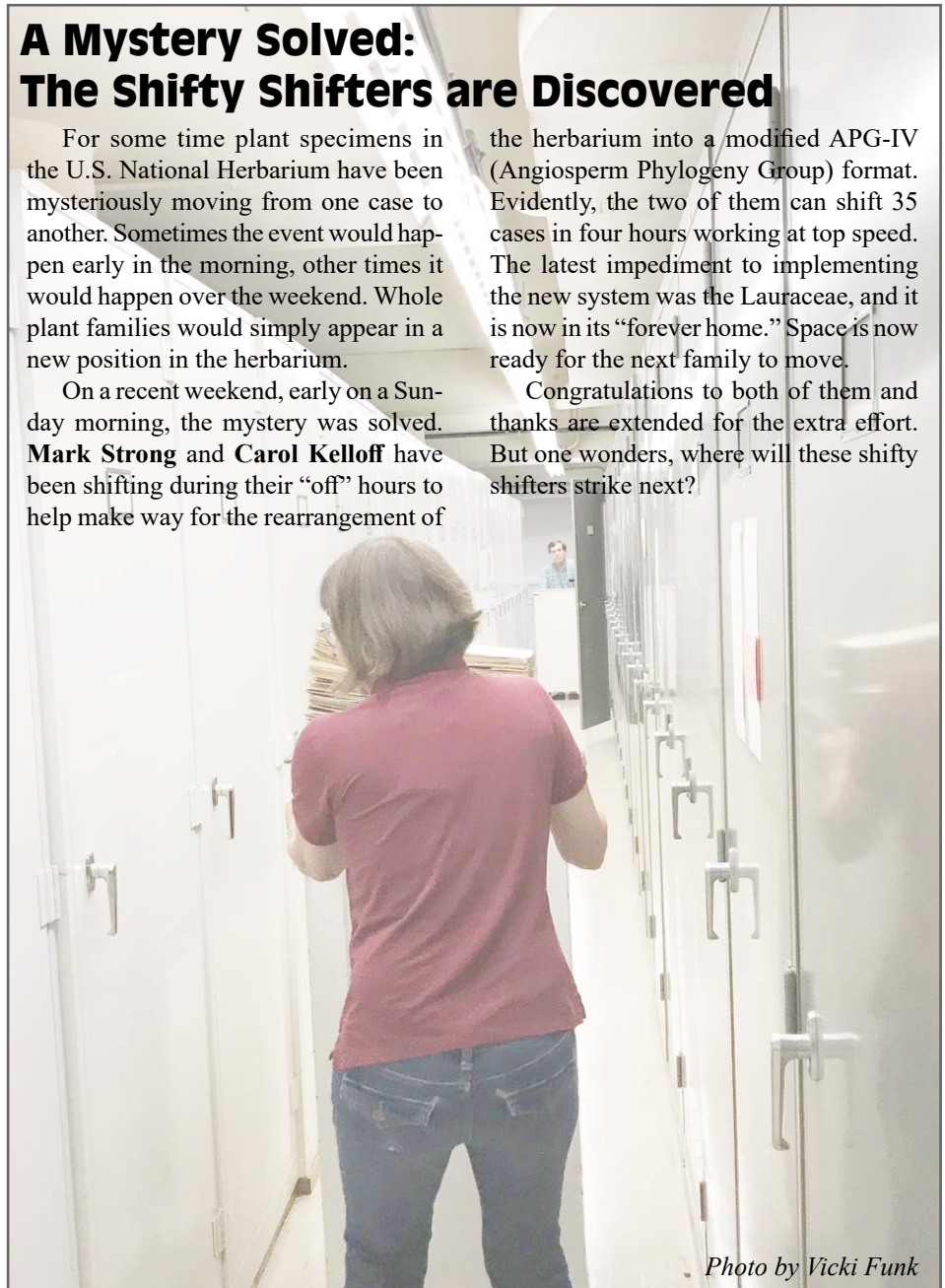


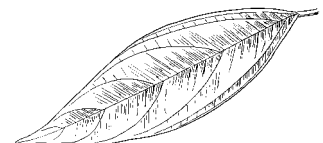
Photo by Vicki Funk

Miller is just starting her junior year at Smith College majoring in Italian with a minor in Archive Studies. She is headed to Florence, Italy, for a year of study and will return to Smith for her senior year.

NMNH staff that were highlighted by Miller and now have new or updated Wiki pages include the following: Carole Baldwin (SI-NMNH-Vertebrate Zoology), Pearl Lee Boone (SI-NMNH-Invertebrate Zoology), Mercedes S. Foster (Fish & Wildlife-NMNH-Vertebrate Zoology), **Vicki Funk** (SI-NMNH-Botany), Karen Osborn (SI-NMNH-Invertebrate Zoology), Valerie Paul (SI-NMNH-Invertebrate Zoology), Marilyn 'Marian' H. Pettibone (SI-NMNH-Invertebrate Zoology), Anna

Phillips (SI-NMNH-Invertebrate Zoology), Mary E. Rice (SI-NMNH-Invertebrate Zoology), Harriet Richardson (SI-NMNH-Invertebrate Zoology), Sally Kuhn Sennert (SI-NMNH-Mineral Sciences), Beryl B. Simpson (SI-NMNH-Botany), Ellen Strong (SI-NMNH-Invertebrate Zoology), **Jun Wen** (SI-NMNH-Botany), Mildred Stratton Wilson (SI-NMNH-Invertebrate Zoology).

Consider becoming a Wikipedian and helping edit, finish, or create new Wikipedia pages for scientists at the Smithsonian.



Artwork of Emily Dickinson Plants to Be Displayed outside Chair's Office

A selection of metalpoint drawings by local artist Kandy Vermeer Phillips will be on display beginning October 10 outside the Department of Botany Chair's office on the fourth floor of the West Wing, National Museum of Natural History in Washington, DC. These illustrations are the culmination of Phillips' yearlong project to illustrate the plants associated with Emily Dickinson's poetry. All of Phillips' artwork represents specimens from the US National Herbarium collections with attention to choosing those in the area and time of Dickinson's poetry.

Phillips' work was supported by an Educational Grant from the American Society of Botanical Artists. The drawings are a generous donation by Phillips to the Botanical Art Collection in the Department of Botany.



A metalpoint drawing of *Rosa carolina* by Kandy Phillips. The drawing was inspired by the poems of Emily Dickinson.

Observing the 100th Anniversary of Armistice Day: the Common Poppy

November 11, 2018, is Veteran's Day and the 100th anniversary of Armistice Day. Armistice Day is commemorated to mark the armistice signed between the Allies of World War I and Germany for the end of fighting on the Western Front of World War I. The armistice took effect in 1918 at eleven o'clock in the morning—the "eleventh hour of the eleventh day of the eleventh month." Veteran's Day, the official United States public holiday to honor military veterans, coincides with Armistice Day and Remembrance Day (also known as Poppy Day), a memorial day observed by the British Commonwealth of Nations member states to remember the members of the armed forces who have died in the line of duty.

The common poppy, *Papaver rhoeas*, is worn in many countries on Armistice Day in order to commemorate those who lost their lives during warfare. The poppy

became the symbol of remembrance soon after the publication of “In Flanders Fields,” a war poem written by Canadian Lieutenant Colonel John McCrae. The poem gives reference to the red poppies that grew over the graves of fallen soldiers:

Take up our quarrel with the foe:
To you from failing hands we throw
The torch; be yours to hold it high.
If ye break faith with us who die
We shall not sleep, though poppies grow
In Flanders fields.

Papaver rhoeas, an annual herbaceous species in the Papaveraceae, has a long-lived soil seed bank that readily germinates in disturbed soils. The plant was readily observed blooming on the battlefields during the war. The species is believed to be native to southern Europe, North Africa, and temperate Asia, but has become naturalized outside of this range.

The U.S. National Herbarium has data-based nine specimens of *Papaver rhoeas* from its collections. These specimens range from Lebanon and Iraq to Spain and the Canary Islands, and they date from the

1890s to the 1970s. The specimen shown here was collected on 19 May 1910 by American botanist Herman Knoche in Montpellier, France.



**A specimen of *Papaver rhoeas* collected
in 1910 by Herman Knoche in
Montpellier, France.**

Smithsonian Botanists Chiefly Edit Scientific Journals

The curators of the Department of Botany have many responsibilities, primarily independent research on plant taxonomy and systematics and the responsible care and interpretation of specimens within the collection of the U.S. National Herbarium. Often, curators take on additional roles. Currently three curators in Botany serve as editors of prominent scientific journals in plant sciences.

Jun Wen and **Song Ge** (Chinese Academy of Sciences) serve as the Editors-in-Chief of *Journal of Systematics and Evolution* (JSE, since 2008; formerly *Acta Phytotaxonomica Sinica*). JSE is a plant-based international journal dedicated to the description and understanding of biological diversity. It covers the description of new taxa, monographic revision, phylogenetics, molecular and genome evolution, evolutionary developmental biology, evolutionary ecology, population biology, conservation biology, biogeography, paleobiology, evolutionary theories, and related subjects. Wen took on the position of Editor-in-Chief in 2014.

JSE has been growing in prominence over the past few years. The journal has a 2017 impact factor of 3.657, an increase on the 2016 impact factor of 2.050. The journal ranks 26 among 222 journals in the Plant Sciences category of the Science Citation Index (SCI), an increase from the 2016 ranking of 68 among 211 journals in the same category. The rise is largely due to Wen and Ge's guidance and vision. Many scientists in the Department of Botany at the Smithsonian have contributed to JSE's growth.

W. John Kress has been serving as

the Editor-in-Chief of *PhytoKeys* since its inaugural issue in 2010. The journal is a peer-reviewed, open-access, rapidly disseminated journal that was launched to accelerate research and to facilitate information exchange in taxonomy, phylogeny, biogeography, and evolution of plants. *PhytoKeys* publishes papers in systematic botany, including taxonomy, phylogeny, ethnobotany, and floristics, on any taxon of any geological age from any part of the world. The journal provides immediate

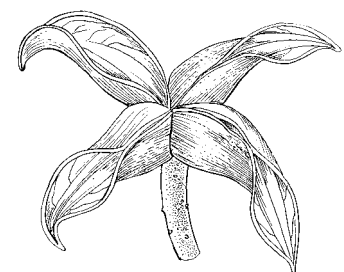
in the popularization of plants and botany through media campaigns on special articles appearing in the journal. Since its start, *PhytoKeys* has published 532 articles including 12,569 pages, and recently published its 100th issue.

In September 2018, **Liz Zimmer** became the Editor-in-Chief of *Molecular Phylogenetics and Evolution* (MPE). She had been an Associate Editor at MPE since its inception in 1992, and was promoted to Deputy Editor starting in 2013. The

journal provides a forum for molecular studies that advance our understanding of phylogeny and evolution, further the development of phylogenetically more accurate taxonomic classifications, and ultimately bring a unified classification for all the ramifying lines of life. MPE encourages articles that are multidisciplinary, especially in areas such as bioinformatics, computational biology, molecular biology, and organismic biology, which are of interest to the

community of systematic and evolutionary biologists.

Articles published in MPE, written by members across the NMNH community, regularly appear in the weekly list of publications compiled by the Smithsonian Libraries staff. Together with the previous Editor-in-Chief, Derek Wildman, Zimmer solicited manuscripts and served as Guest Editors for the 25th Anniversary issue of MPE. From an impact factor less than 3.0 in 1995, MPE now has an impact factor of 4.4.



open access to its content on the principle that making research freely available to the public and scientists everywhere supports a greater global exchange of knowledge.

Launched less than a decade ago in 2010, the main objective of *PhytoKeys* was to implement the latest technology and innovative workflows in publication to speed-up taxonomic data exchange. As a result, *PhytoKeys* was the first botanical journal to introduce a XML-based publishing workflow, pre-publication registration of new taxa with the International Plant Name Index (IPNI), semantic markup and tagging of taxonomic treatments and taxonomic names, and extensive data publishing modalities. In 2015, *PhytoKeys* was granted its first impact factor of 0.68, and it has gradually increased in the subsequent two years and reached 1.11 in 2017. One of *PhytoKeys* strengths is that the publisher Pensoft continues to invest

Untangling Indian Hemp

By Nora Frankel

Plants have always been an integral part of human material history. This may be no surprise to a botanist, but for me, it is sometimes still a revelation. As a conservator, it is my job to understand the material as well as the intangible properties of cultural heritage items so that I can ensure their preservation. Plants became my focus while completing a two-year postgraduate Andrew W. Mellon Fellowship in Textile Conservation at the Smithsonian Institution National Museum of the American Indian (NMAI) Cultural Resources Center (CRC) in Suitland, Maryland. Working with textile conservator Susan Heald (NMAI), physical scientist Thomas Lam (Museum Conservation Institute), and **Marcelo R. Pace** (National Museum of Natural History's Department of Botany), I have been studying identification of certain plants used for fibers throughout North America's northeast woodlands. This region encompasses the Great Lakes, New England, and southern Ontario and Quebec, and has been home to a diversity of culture groups including the Anishinaabe, Haudenosaunee (Iroquois), Abenaki, and Lenape.

While several types of plant fibers are used in the woodlands, I focused on fibers



Nora Frankel in the Botany Plant Anatomy Laboratory microtoming embedded plant fibers. (photo by Stanley Yankowski)

extracted from the primary phloem (pericyclic fibers) of herbaceous plants and secondary phloem of the inner bark of certain tree species. In textile terminology, these are referred to as “bast” fibers, and include the more familiar linen from flax (*Linum usitatissimum* L.), as well as hemp (*Cannabis sativa* L.), ramie (*Boehmeria nivea* L. Gaudich.), and jute (*Corchorus* spp.). Although many different species have

been used for textiles in North America, identification is difficult, and fibers are sometimes grouped under the misnomer “Indian hemp.” This is a common name for several species from the Apocynaceae family, but has also been used to describe any plant fiber from North America. Being neither *Cannabis* nor from India, this terminology can be confusing, and was part of the impetus for this study.

Following a consultation at the CRC with Native American fiber artists Michael Galban (Washoe/Paiute), Wasson (also known as Renee Dillard; Little Traverse Bay Band Odawa), Carla Osawamick (Little Traverse Bay Band Odawa), and Crystal Migwans (Wikwemikong), I selected six species to include in this study. The consultants generously gave samples of basswood (*Tilia americana* L.) and slippery elm (*Ulmus rubra* Muhl.), and I harvested common milkweed (*Asclepias syriaca* L.), swamp milkweed (*Asclepias incarnata* L.), stinging nettle (*Urtica dioica* L.), and dogbane (*Apocynum cannabinum* L.) from across the eastern United States. I learned several methods for processing the raw plant material into usable textile fibers, and created a macroscopic and microscopic reference collection to aid in species identification of bast fiber textiles from the northeast woodlands.

While it is easy to identify a textile fiber as bast using microscopy, it is notori-

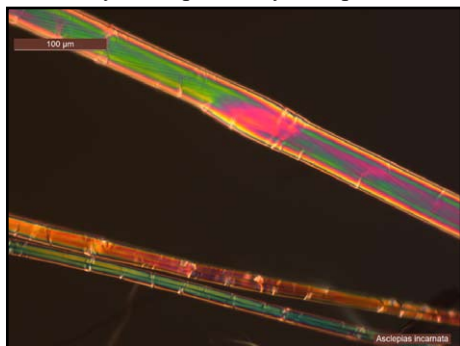


Twined Potawatomi bag with indigenous bast fibers, dyed commercial wool fibers, and hide (NMAI 2/7533).

ously difficult to determine the exact species. In transmitted light microscopy, cells have almost no distinguishing features, and appear smooth, straight, and similarly sized. With crossed polars, “nodes” become visible, which are cellular cross markings that are highly characteristic of bast fibers. With a few exceptions, these features appear very similar across species used for textiles. It was my goal to establish what microscopic characteristics could be used to help identification, and drawing from research in European archaeology, I focused on three areas: microfibrillar orientation, presence and type of crystals, and cross-section characteristics.

To achieve this, I worked with Marcelo Pace in the Botany Plant Anatomy Laboratory, supervised by **Stanley Yankowski**. Pace shared his expertise in cross sectioning bark, and modified his techniques to section samples of softer plant material in blocks of polyethylene glycol to mount on permanent slides for the fiber reference collection. He also helped me prepare slides of whole mounted fibers for examination of surface features and crystals, and guided my interpretation of structures. While I have some experience with microscopy from my conservation training, working with Pace helped me to better understand plant anatomy and to produce permanent slides with methods that were new to me. I was then able to work with Thomas Lam, who used the sections for SEM-EDS (Scanning Electron Microscopy / Energy Dispersive X-Ray Spectroscopy) analysis, providing interesting data on the distribution and elemental makeup of the crystals, which proved to be a useful diagnostic tool for species identification.

Understanding the materials with which an object is made is important to its conservation, as the physical properties may be impacted by the species



***Urtica dioica* fiber samples in crossed polars.**

and fiber processing method. Perhaps more importantly, it adds to the overall understanding of the object, which not only effects the conservation approach, but can help with interpretation, and to provide a richer context for Native and non-Native viewers. Consultants Wasson, Migwans, and Galban each expressed how they have used museum collections, viewed as ancestors by many cultures, for cultural revitalization. Many people are now learning traditional techniques from ancestors in museum collections when they lack a living human instructor within the community. It therefore becomes increasingly imperative to be accurate in our understanding of how these objects are produced, and the species used. Species identification can also be a starting point for re-associating objects with Native languages. A Seneca burden strap made with *Tilia americana* fibers can be linked with the word *O:osas*, adding further richness to the object as a teacher.

Results of this research will be available through the online conservation materials resource CAMEO <http://cameo.mfa.org/wiki/Category:FRIL:_Plant_Fibers> and in *The Textile Specialty Group Post-prints*, American Institute for Conservation of Historic and Artistic Works, 46th Annual Meeting, Houston, Texas, May-June 2018.

Nora Frankel is an Andrew W. Mellon Fellow in Textile Conservation at Smithsonian's National Museum of the American Indian, Cultural Resources Center.

Profile

Continued from page 1

of this association with more fieldwork, it was the model itself that was the primary heuristic we used to detect this pattern (the methods are available as an R package called *ecostructure*).

Building off of these advances, as part of a collaboration between the National Museum of Natural History's Department of Botany and the Smithsonian Data Science Lab, I am currently building deep learning models to more efficiently access the trove of data contained in our digitized herbarium. With millions of images now available, after years of heroic efforts by the herbarium digitization group, we can make use of herbarium labels and known metadata to train deep learning models to

By The Numbers

Digitization Edition

As the Department of Botany approaches digitizing its 2 millionth specimen later this year, it's worth noting some important numbers and figures in its effort to digitize the United States National Herbarium's collection of nearly 5 million specimens.

9

The number of full time staff at work on the rapid digitization project, which began in October 2015.

120

The number of plant families digitized. The list of inventoried plant groups is available online at <<http://botany.si.edu/colls/inventoriedgroups.htm>>.

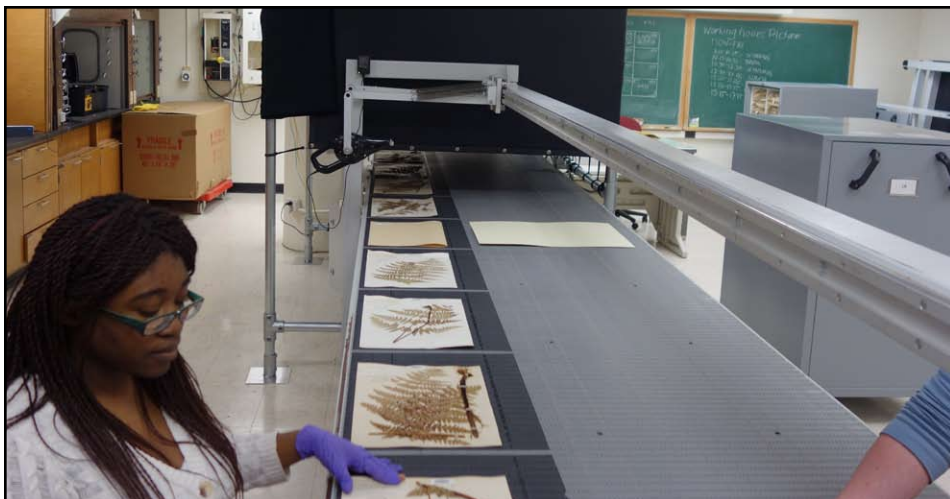
225,000

The number of specimen folders completed. The botany collections can be searched at <<https://collections.nmnh.si.edu/search/botany/?ti=2>>.

detect a number of different features of the specimens in our herbarium.

For example, we have already made quick headway on building a model for taxonomic identification of ferns. Using 140,000 images of individual herbarium specimens (and validating our model using another 35,000 images), we trained a deep learning model to identify the genus of the specimen on the herbarium sheet with an average of 90.5% accuracy across 86 genera in the dataset. Rare genera were not included (we only included genera with more than 500 specimens in the herbarium), and for many genera accuracy was well above 90% (100%, 99%, 99% are the top three). Moreover, we are finding biologically compelling errors in the model – mismatches between the predicted genus and the true genus are often between closely related genera, many of which have been recently split based on microscopic characters. This gives us confidence

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With more and more specimens being digitized, deep learning models can one day ask questions about quantitative traits such as leaf shape. (photo courtesy of NMNH)

Profile

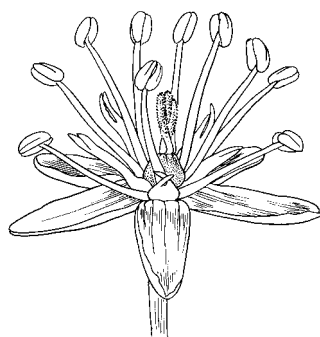
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that it is the shapes of the specimens themselves that the model is cued in on.

Moving forward, there are a number of different avenues for further development of this model. I am particularly interested in how traits are distributed in space, and we hope to use this deep learning approach to extract quantitative traits, with a particular focus on leaf shape. Many have used leaf shape as a proxy for climate, and we would like to evaluate those hypotheses by examining leaf shape across geographic space within a large taxonomic subset of the herbarium. This will require development of a deep learning-based pipeline that can extract leaves from images and quantify their shape, while also maintaining enough generality to be applicable to examining specimens from thousands of taxa.

Machine learning is indeed the antithesis of expert opinion – for this reason, many biologists question the ability of such models to generate useful output. Yet it is critical to consider these models as a tool rather than a statistical test – as with any tool, they are mainly useful for specific tasks and it is entirely up to the practitioner to choose the right tool for the job. As computational methods become more complex, there is no doubt a danger in their opacity, and without the proper understanding of their assumptions and tendencies, one might be led astray by their application. However, such unbiased models are also powerful in their ability to identify patterns without any precon-

ception about the outcome. In this way, they balance our human tendency to see the data as we would like to and help us discover patterns that we would otherwise never be able to observe. There are no doubt more advances on the horizon in machine learning, and biologists should be poised to harness those tools to tackle our pressing concerns.



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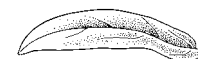
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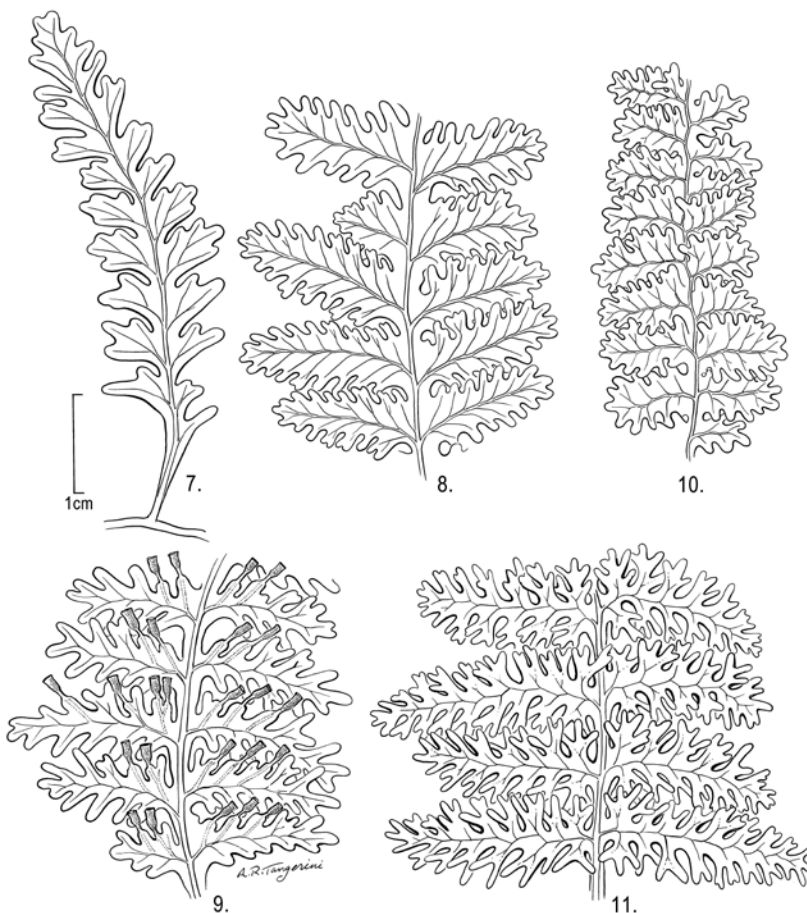


***Trichomanes pedicellatum* Desv.**

Smithsonian botanists have trained a deep learning model to identify fern genera of specimens on herbarium sheets with an average of 90.5 percent accuracy (see cover story in this issue of *The Plant Press*).

For the genus *Trichomanes*, the model is 92 percent accurate. *Trichomanes pedicellatum* is a South American fern found in eastern Venezuela, Guyana, Suriname, and French Guiana.

Alice Tangerini drew this illustration for a 1991 paper by David Lellinger (*Amer. Fern J.* 81(1): 24–36) to highlight the great diversity in frond and pinnae form within *T. pedicellatum*.



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National Museum of Natural History

Department of Botany
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Washington DC 20013-7012

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