Department of Botany & the U.S. National Herbarium

The Plant Press

Smithsonian
National Museum of Natural History

New Series - Vol. 18 - No. 3 July-September 2015

Special Symposium Issue continues on page 12

Botany Profile

Seed-Free and Loving It: Symposium Celebrates Pteridology

By Gary A. Krupnick

Fern and lycophyte biology was the focus of the 13th Smithsonian Botanical Symposium, held 1–4 June 2015 at the National Museum of Natural History (NMNH) and United States Botanic Garden (USBG) in Washington, DC. Also marking the 12th Symposium of the International Organization of Plant Biosystematists, and titled, "Next Generation Pteridology: An International Conference on Lycophyte & Fern Research," the meeting featured a plenary session on 1 June, plus three additional days of focused scientific talks, workshops, a poster session, a reception, a dinner, and a field trip. The conference brought together the world's pteridologists to celebrate the progress of fern and lycophyte biology to date and to forecast developments still on the horizon.

The Symposium began with opening remarks by Warren Wagner (Chair of Botany, NMNH), Kirk Johnson (Sant Director, NMNH), and Ari Novy (Executive Director, USBG). Eric Schuettpelz (Curator of Ferns, NMNH) served as convener. Noting that the last international conference on lycophyte and fern research took place 11 years ago at the Royal Botanic Garden Edinburgh, Schuettpelz expressed excitement as this year's conference of 97 talks and 30 posters, including the 10 invited plenary speakers, was to focus on discussing new and revitalized methods for pteridological research.

After the opening remarks, Laurence Dorr (Curator and Cuatrecasas Committee Chair, NMNH) presented the 13th José Cuatrecasas Medal in Tropical Botany to Paulo Günter Windisch (see related story on page 12). This prestigious award is presented annually to a scholar who has contributed significantly to advancing the field of tropical botany. Windisch, a retired professor from the Universidade Federal do Rio Grande do Sul, was commended for his extensive contributions to the systematics, biogeography, and evolution of neotropical pteridophytes. In his acceptance speech, Windisch expressed his appreciation and gratitude to the Smithsonian Institution and the selection committee. He said that receiving the medal rekindles his inner spirit, and remarked that "translating nature into science is an art."

The first day of the Symposium included a plenary session that was open to the general public. With 10 invited talks, the audience was treated to an overview of fern and lycophyte evolution, genomics, physiology, ecology, horticulture, and conservation. The opening keynote speaker was Robbin C. Moran from the New York Botanical Garden, and his talk, "An Overview of Ferns and Lycophytes," provided an exciting introduction into the world of pteridology. Starting with the life cycle of pteridophytes, Moran discussed the unique, independently living sporophyte and gametophyte generations of this plant group.

Moran also spoke about the differences between pteridophytes and seed plants in aspects of biogeography (ferns comprise a higher percentage of the total vascular flora on islands compared to continents), hybridization and polyploidy (ferns have higher rates), and anatomy (some ferns have tree-like growth using root mantle or have internal reinforcement by sclerenchyma instead of lateral meristem). Moran also provided a historical overview of pteridophytes in the Silurian to Early Devonian (at which time leaves originated); in the Carboniferous (pteridophyte swamps from that time were the precursor of today's fossil fuel); at the Cretaceous-Tertiary Boundary (a spike in fern diversity can be seen soon after the asteroid impact); and in the Early Tertiary (warm weather produced thick carpets of *Azolla* in the Arctic Ocean leading to a sharp reduction in atomospheric CO_2 reducing the greenhouse effect and lowering the Earth's temperature). Moran concluded his talk with a discussion of iridescence in ferns, the diversity of sporangia, and the explosive sporangial dehiscence of the clubmoss *Lycopodium clavatum*. He explained how the spores of this plant, which are highly flammable because of their high fat content, were used as a

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Travel

Walter Adey traveled to Maine (6/17 – 7/24) to complete annual field research in conjunction with the NOAA Marine Sanctuary Program.

Robin Everly traveled to Decorah, Iowa (6/15 – 6/20) to attend the 47th Annual Meeting of the Council on Botanical and Horticultural Libraries (CBHL) at Seed Savers Exchange.

Vicki Funk traveled to Copenhagen, Denmark (5/16 – 5/22) to conduct research.

Gabriel Johnson traveled to India (4/2 – 4/24) to visit the laboratory of Vinita Gowda at the Indian Institute of Science Education and Research and to train laboratory technicians in methods used to generate DNA sequence data.

Sylvia Orli traveled to Gainesville, Florida (5/18 – 5/22) to attend the Society for the Preservation of Natural History Collections conference.

Melinda Peters traveled to Gainesville, Florida (5/18 – 5/22) to deliver a talk on mercuric chloride contaminated herbarium cases at the Society for the Preservation of Natural History Collections conference.

Rusty Russell traveled to Gainesville, Florida (5/18 – 5/22) to speak at the Society for the Preservation of Natural History Collections conference, representing herbarium programs, digitization plans, and the Field Book Project, and convening and moderating two sessions of computer demonstrations.

Eric Schuettpelz traveled to Manhattan, New York (5/5 – 5/6) to give a talk in the 2015 lecture series of the Torrey Botanical Society.

Robert Soreng traveled to Turkey (4/17 – 5/23) to collect grasses for revision of *Poa* in Turkey and annotate specimens at Gazi University, Ankara (GAZI).

Meghann Toner traveled to Gainesville, Florida (5/18 – 5/22) to present a poster on shifting collections at the Society for the Preservation of Natural History Collections conference.

Alain Touwaide and **Emanuela Appetiti** traveled to Iowa City (4/23 – 4/25) to attend the annual banquet of the University of Iowa's History of Medicine Society; to Los Angeles and San Marino, California (4/26 – 5/7) to meet with colleagues, present lectures and do research at the University of California Los Angeles and at the Huntington Library and Botanic Gardens; and to Athens, Greece (6/1 – 6/30) to do research at the National Library of Greece and to deliver classes and lectures at local institutions.

Elizabeth Zimmer traveled to Vienna, Austria (6/21 – 6/25) to speak at the Plant Molecular Ecology and Evolution's International Conference.

The Plant Press

New Series - Vol. 18 - No. 3

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Visitors

Ning Zhang, National Museum of Natural History Buck Fellow; Vitaceae (1/7/13-6/30/15).

Eduardo Pasini, Universidade Federal do Rio Grande do Sul, Brazil; Compositae (8/18/14-4/30/15).

Craig Costion, University of Adelaide, Australia; DNA barcoding (11/3/14 -10/31/15).

Yeni Rahayu, Bogor Agricultural University, Indonesia; Sumatran *Tetrastigma* (Vitaceae) (2/2-4/17).

Monica Carlsen, Missouri Botanical Garden; Araceae and Zingiberales (2/17/15-2/16/17).

Bo Pan, Xishuangbanna Tropical Botanical Garden, China; *Pueraria* (Fabaceae) and related genera (2/20-4/29).

Kenia Velasco, Sociedad para el Estudio de los Recursos Bióticos de Oaxaca, Mexico; Traditional ecological knowledge of the Dixaza-speaking Community (4/4-7/31).

Young Eun Chang, International School, Belgium; Chinese medicinal plants and traditional medicine (4/6-4/17).

José Nascimento, Jr., Campinas State University, Brazil; *Clusia* (Clusiaceae) (4/14-4/19).

Jan Vandersmissen, Université de Liège, Belgium; History of botany (4/22).

Catherine Phillips, Huntington Botanical Garden; Cactaceae and Crassulaceae (4/27).

Tom Lovejoy and 14 students, George Mason University; Plant conservation and herbarium tour (5/4).

Peter Schafran, Old Dominion University; Southeastern U.S. *Isoetes* (Isoetaceae) (5/5-7/31).

Bruce Stein, National Wildlife Federation; *Centropogon* (Campanulaceae) (5/7).

Erin Walch, Smith College; Flora of San Jacinto internship (5/11-6/26).

Chang-Tzu Wang, Patuxent Research Refuge; Collections management (5/11-5/15).

Christine Clancy, Australian and New Zealand Society for the History of Medicine; Mediterranean medicinal plants (5/14).

Mamiyil Sabu, University of Calicut Department of Botany, India; Zingiberaceae (5/15).

Emily Warschefsky, Florida International

Visiting Scientists Have a Sight for Sori

This year's Smithsonian Botanical Symposium was unique in its focus on a particular taxonomic group (pteridophytes), as well as in its duration (spanning an entire week). "Next Generation Pteridology" (see profile on the cover) focused entirely on the biology of ferns and lycophytes. The first day was filled with a broad spectrum of accessible presentations typical of our annual Smithsonian Botanical Symposium and the remainder of the week featured a series of focused colloquia, contributed talks, and workshops. In all, the scientific program included 127 presentations and brought together well over 200 individuals representing 29 countries. But the event had effects well beyond the communication of science. Without a doubt, "Next Generation Pteridology" had a profound influence in building connections to the Smithsonian and strengthening collaborations within the pteridological community. Additionally, the presence of so many of the world's experts under one roof had a significant impact on our collection.

In the days leading up to and following "Next Generation Pteridology," and during the event itself, the pteridophyte herbarium saw nearly 50 visitors (see list of visitors beginning on page 2). Many of these visitors spent several days conducting research in the collection, and the great influx of experts resulted in some extensive curation of our specimens. In all, more than 500 specimens were annotated and about a dozen types were uncovered and moved to the type herbarium. Perhaps most notable was the discovery (by Barbara Parris, from the Fern Research Foundation, New Zealand) of an isotype of *Xiphopteris exilis* Parris, a species that at the time of its publication was known only from the type collection. It was truly wonderful to see so many researchers working in the pteridophyte herbarium advancing their own projects, while simultaneously improving the value of our specimens and helping us to fine tune our collection for the upcoming digitization.

-Eric Schuettpelz and Warren L. Wagner

Visiting botanists overtake the pteridophyte herbarium at the National Museum of Natural History, where they conducted research, annotated specimens, and uncovered types, leading to tremendous benefits to the collections. (photo by Eric Schuettpelz)

Chair With A View — Warren L. Wagner

University and Fairchild Tropical Botanic Garden; *Mangifera* and *Bouea* (Anacardiaceae) (5/19-5/20).

Roger Troutman, Independent researcher, Ohio; *Liatris* (Asteraceae) (5/20-5/21).

Sarah Morris, University of California Los Angeles; History of Mediterranean botany (5/21).

Caitlin Redak, Kenyon College; Historical expeditions and herbarium curation internship (5/25-8/15).

Roy Moger-Reischer, University of Rochester; *Pueraria montana* var. *lobate* (Fabaceae) internship (5/26-7/31).

Jovani Pereira, Ruhr-Universität Bochum, Germany; Pteridophytes (5/26-5/29).

Cheng Wei Chen, Taiwan Tsing Hua University, Taiwan; Pteridophytes (5/27-5/29).

Chloe Siegel, University of Illinois; DNA extraction internship (5/27-8/15).

Florence Stevenson, University of Maryland; DNA extraction internship (5/27-8/20).

Dennise Stefan Bauer, Ruhr-Universität Bochum, Germany; Pteridophytes (5/28-5/29).

Elizabeth Strohbeck, Smith College; Araceae and Zingiberales internship (6/1-8/7).

Sarah White, Wake Forest University; Historical expeditions internship (6/1-8/22).

Nina Derzhavina, Orel State University, Russia; Pteridophytes (6/2).

Patrick Herendeen, Chicago Botanic Garden; Fabaceae (6/2-6/3).

Irina Gureyeva, Tomsk State University, Russia; Pteridophytes (6/2-6/3).

Michelle Nervo, Universidade Federal do Rio Grande do Sul, Brazil; Pteridophytes (6/2).

Germinal Rouhan, National Museum of Natural History, France; Pteridophytes (6/2-6/5).

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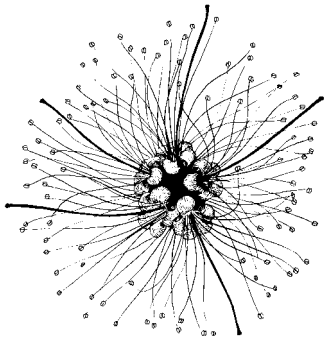
Staff Research & Activities

On 8 April, **W. John Kress** presented the lecture, "Living in the Anthropocene: Yesterday, Today, and Tomorrow." The lecture was a presentation of the National Museum of Natural History's Senate of Scientists and was offered as part of the Museum's *Anthropocene: Life in the Age of Humans* series. The Smithsonian provides a forum to discuss and debate the major issues facing the world, and current research focuses on our changing atmosphere, our changing forests and oceans, and our own responses to these changes. The Smithsonian is also making every effort to preserve our human heritage and the natural heritage of the planet by continuing to build and protect our extensive collections, specimens, and objects. Kress' lecture focused on these challenges and their solutions.

On 27 April, the Smithsonian Center for Learning and Digital Access (SCLDA) held their 9th annual Smithsonian Day for the Council of Chief State School Officers' Teachers of the Year, a group of the top educators in each U.S. state, jurisdiction, and district. The program included behind-the-scenes activities throughout the Smithsonian. Cindy Brown (Smithsonian Gardens) brought a group to the Botany Library as a space for the teachers to write blog posts for the Community of Gardens website. When the group entered the herbarium, however, they began asking questions about the specimens, what the botanists do, and how the gardens and the library work with the botanists.

Fortunately, **Rusty Russell** was on hand to answer their flurry of questions with an impromptu herbarium tour. As the discussion turned to broader botanical research, Russell described the Botany Department's digitization efforts and how herbarium specimens are used. **Robin Everly** described her role in assisting the botanists with their research. At the end of the session, each educator found a creative way to incorporate what they had learned on the tour into their diverse classroom disciplines, showing that the best teachers never stop learning.

Two illustrations, *Hibiscadelphus stellatus* and *Gymnanthemum koekemoerae*, by **Alice Tangerini** were featured in "Botanica 2015: The Art & Science of Plants," an annual juried exhibition of botanical art at Brookside Gardens. The exhibit, which was on display 6 June to 10 July, featured artworks by artists affiliated with the Brookside Gardens School of Botanical Art & Illustration and the Botanical Art Society of the National Capital Region.



New Faces

In early June, **Eduardo Pasini**, a Ph.D student at the Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil, returned home after spending 10 months in the USA, including nine months in the Smithsonian's Department of Botany and the Laboratory of Analytical Biology, and one month at the University of Memphis. While in Washington, D.C., Pasini studied with **Vicki Funk** and focused on his doctoral thesis: Understanding the evolutionary processes that led to the diversification and current distribution of the South American genus of Compositae (Asteraceae), *Trichocline.* This genus has approximately 24 species, distributed mainly in the Andes and Southern Brazil. All of the species are perennial herbs with a monocephalic scape presenting beautiful and conspicuous ray florets, generally yellow, red or white. Several species are endemic and occur in fragile ecosystems, like lowland grasslands or tropical highland grasslands.

Pasini traveled to the Smithsonian with the assistance of a Brazilian scholarship provided by the Coordenação de Aperfeiçoamento de Pessoal de Nível Técnico (Capes). He amplified and sequenced nuclear and plastid markers of the species of *Trichocline* that he had been collecting for almost four years as well as a number of outgroup samples stored in freezers at the US National Herbarium. After the lab work he was able to analyze the data in order to generate a molecular phylogeny of the genus. He also revised the material of *Trichocline* deposited in the herbarium. Pasini was able to get a one-month extension to stay long enough to travel to the University of Memphis where he studied Next Generation Sequencing techniques with Dr. Jennifer Mandell paid for by a Smithsonian grant awarded to Funk.

Caroline Puente joined the Department of Botany in April 2015 under **W. John Kress**. She completed her Ph.D. at James Cook University, Cairns, Australia, in collaboration with the Australian Tropical Herbarium, where she worked as an assistant curator. Her doctoral dissertation focused on the systematics and biogeography of the Australian Ericaceae (Epacrids). At the Smithsonian she is managing the Plant DNA Barcode Project, and is involved in several studies that use DNA barcodes to identify plant species, estimate phylogenetic biodiversity, and study the impacts of climate change at the community level.

Eduardo Pasini (top) and Caroline Puente.

Awards & Grants

At the Washington Academy of Sciences' annual awards banquet, **Paul Peterson** received the 2015 award for Outstanding Scientist in Biological Sciences in the greater Washington D.C. area. The certificate reads, "In recognition of being a tireless and prolific taxonomist, collector, and publisher, who has extensively revised the classification of the large grass subfamily Chloridoideae and its genera, and for leading the effort to prepare a DNA database for the grasses of North America and noxious weeds for the Bar Code of Life."

The Award for Outstanding Scientist in Biological Sciences was presented to Paul Peterson by Chris Puttock (right). (photo by Al Teich)

Visitors

Continued from page 3

Augusto Santiago, Federal University of Pernambuco, Brazil; Pteridophytes (6/2-6/5).

James Beck, Wichita State University; Pteridophytes (6/3-6/4).

Michel Boudrie, Independent researcher, France; Pteridophytes (6/3-6/5).

Sam Champine-Tocher, Lyon Arboretum; Pteridophytes (6/3).

Michael Kessler, University of Zurich, Switzerland; Pteridophytes (6/3).

Samuli Lehtonen, University of Turku, Finland; Pteridophytes (6/3).

Melanie Link-Perez, Armstrong State University; Pteridophytes (6/3).

Yeachen Liu, National Chiayi University, Taiwan; Pteridophytes (6/3-6/4).

Ngan Thi Lu, Vietnam National Museum of Nature, Vietnam; Pteridophytes (6/3-6/4).

Claudine Mynssen, Jardim Botânico do Rio Janeiro, Brazil; Pteridophytes (6/3).

Barbara Parris, Fern Research Foundation, New Zealand; Pteridophytes (6/3-6/5).

Lana Sylvestre, Universidade Federal do Rio de Janeiro, Brazil; Pteridophytes (6/3).

Mark Tebbitt, California University of Pennsylvania; Andean *Begonia* (Begoniaceae) (6/3-6/4).

Leticia Pacheco, Universidad Autonoma Metropolitana-Iztapalapa, Mexico; Pteridophytes (6/4-6/5).

A. Edward Salgado, Christian Brothers University; Pteridophytes (6/4).

Victor Amoroso, Central Mindanao University, Philippines; Pteridophytes (6/5).

Naomi Arcand, University of Colorado, Boulder; Pteridophytes (6/5).

Anthony Baniaga and **Stacy Jorgensen**, University of Arizona; Pteridophytes (6/5).

Dave Barrington, **Michael Sundue**, and **Weston Testo**, Pringle Herbarium; Pteridophytes (6/5).

Julio Cortes-Molina and **Luz Triana-Moreno**, Universidad de Caldas, Colombia; Pteridophytes (6/5).

Joshua Der, California State University Fullerton; Pteridophytes (6/5).

Joe Scott Graham, Natural Resources, Alexandria, Virginia; Herbarium tour (6/5).

Marcelo Guerra, Universidade do Estado do Rio de Janeiro, Brazil; Pteridophytes (6/5).

Cameron Heyder, T.C. Williams High School; Herbarium tour (6/5).

Li-Yuang Kuo, National Taiwan University, Taiwan; Pteridophytes (6/5).

Marcus Lehnert, Nees Institute for Plant Biodiversity, Germany; Pteridophytes (6/5).

Fernando Matos, New York Botanical Garden; Pteridophytes (6/5).

Alison Paul, Natural History Museum, United Kingdom; Pteridophytes (6/5).

Yarely Pérez-Atilano, Universidad Autónoma del Estado de Hidalgo, Mexico; Pteridophytes (6/5).

Jefferson Prado, Instituto de Botânica, Brazil; Pteridophytes (6/5).

Alexandre Salino, Universidade Federal of Pernambuco, Brazil; Pteridophytes (6/5).

Pedro Bond Schwartsburd, Federal University of Vicosa, Brazil; Pteridophytes (6/5).

Esteban Meza Torres, Instituto de Botánica del Nordeste, Argentina; Pteridophytes (6/5).

Alejandra Vasco, Universidad Nacional Autónoma de México; Pteridophytes (6/5).

Keir Wefferling, University of Wisconsin, Milwaukee; Pteridophytes, *Caltha* (Ranunclulaceae) (6/5).

Liang Zhang, Missouri Botanical Garden; Pteridophytes (6/5).

Glenda Cárdenas and **Hanna Tuomisto** University of Turku, Finland; Pteridophytes (6/8-6/12).

Elizabeth Jacobsen, Williams College; Plant Press scientific writing internship (6/08-7/31).

Sarah Jones, Safety Harbor; Herbarium curation internship (6/8-7/2).

Jinmei Lu, Chinese Academy of Sciences, China; Pteridophytes (6/8-6/12).

Anna Raffeld, Brown University; Listed species project internship (6/8-8/22).

Viacheslav Shalisko, University of Guadalajara, Mexico; Pteridophytes (6/8-6/12).

Joel Nitta, Harvard University; Pteridophytes (6/10-6/12).

Stephen Talbot, U.S. Fish and Natural Resources Services, Alaska; Aleutian Island mosses (6/25).

Sara Pineda, Universidad Nacional Autónoma de México; Herbarium curation internship (6/29-7/24).

Preserving Plant Genomic Diversity

By Vicki Funk
-Adapted from Natural History Unearthed

Did you know that half of the families of flowering plants, conifers, and ferns can be found in the Washington D.C., area? Did you know that you can see plants that are from an African desert environment, the hardened surface of a cooled Hawaiian lava flow, and a tropical rain forest, all within a few feet of each other in the nation's capital?

It's true and it is all free for you to enjoy right now at the U.S. Botanic Garden. We're working with our partners at the Botanic Garden to gather a diverse array of plants. This summer marks the beginning of a collecting program called *Global Genome Initiative-Gardens*. It is part of the National Museum of Natural History's *Global Genome Initiative*. The goal of this new collecting program is to sample the global genomic diversity of plants for preservation in the world's biorepositories. Through partnerships with Smithsonian Gardens, the U.S. Botanic Garden and the U.S. National Arboretum, we will preserve samples of half the families of living plants around the world by the end of summer 2015.

Over the next two years, through growing partnerships with other botanical gardens, we hope to preserve samples of half the genera of living plants!

Each day, our team travels to one of the partner gardens or their production facilities and collects 20-30 plants in three ways: a pressed specimen to serve as a permanent voucher that will be stored in the museum's U.S. National Herbarium; tissue dried in silica gel; and liquid nitrogen preserved at the Smithsonian's biorepository at the Museum Support Center (MSC) in Suitland, Maryland.

Vicki Funk (right) leads a team of collectors, including two Smithsonian undergraduate interns from the University of Delaware, Kristen Van Neste (second from left) and Sarah Gabler, for the Global Genome Initiative-Gardens project. (photo by U.S. Botanic Garden)

Some recent collections from the U.S. Botanic Garden include:

Sida fallax Walp. ('Ilima) from the hibiscus family is known only from Hawaii. This plant grows on volcanic rock and is an important colonizer, meaning that it helps establish an environment for other plants and life forms to thrive in. Its flowers are so beautiful that they are used to make Hawaiian leis and have been said to have been favored by Queen Emma.

Aloe rauhii Reynolds (snowflake aloe) is a rare succulent from Madagascar. It is a beautiful desert plant with striped leaves and coral colored flowers, and is important in the horticultural industry where it has been used to make many cultivated plants. This species—and the diverse plant life of Madagascar, more generally—is under threat and becoming increasingly hard to find.

Theobroma cacao L. (chocolate or cacao) is a small tree native to Central and South America. While pollinated in the wild by tiny flies, the tree in the Botanic Garden is pollinated by hand. This tropical plant was long used by indigenous people throughout its range and was later exported to Europe by the Spaniards. Chocolate is now one of our favorite foods! Because of its economic importance, the whole genome of this species has been sequenced, but a voucher sample to pair with that sequence was never saved. Vouchers are important because they document what the sequenced genome actually did in life on Earth at one point in time. Genomes may be the "blueprint of Life," but if you only save the blueprint but not the "Life," you are clearly missing part of the story.

Sabatia kennedyuana Fernald (Plymouth rose gentian), is a bog plant that is

Vicki Funk preparing the pressed specimen of *Aloe rauhii* Reynolds (snowflake aloe) at the U.S. Botanic Garden. (photo by Hilary-Morgan Watt)

native to the east coast of North America but is only found in two widely separated areas: in the northeast in Massachusetts and Rhode Island and again in the south in North Carolina. In all locations it is endangered, threatened, or of special concern. The northern populations are adapted to bogs that were once under glaciers and the southern population live in fire adapted communities. Some scientists are considering recognizing these as two different species. Here we found the North Carolina population growing with pitcher plants (carnivorous).

Gardens such as this one are excellent places to see rare, beautiful and important plants that have their own story to share. We hope to help preserve part of that story through the preservation of the world's plant genomes in biorepositories worldwide. Stay tuned and follow along with *#SmithsonianGGI.*

Interns Get a Glimpse of the Plant ID Process

In early June, as part of a National Museum of Natural History Intern event with the Office of Academic Services, interns from across the Smithsonian joined Melinda Peters to learn about plant identification using herbarium specimens collected in the western United States. Peters began with a description of the important features to notice about a plant in order to make an identification. She explained leaf structure, how to recognize a compound leaf, and floral shapes and structures. Interns then had the opportunity to identify the mounted specimens in front of them, leafing through stacks of books—what Peters described as the plant equivalent of "Choose your own Adventure" books.

Peters pointed out some of the difficulties in making plant identifications based only on pressed specimens. Collected specimens capture merely a snapshot of the plant's life cycle through the year, and therefore can only give information about a certain time and place. Mounted specimens lose some of their original color, and so may not appear as they do in life. Finally, the pressed specimens cannot capture the three-dimensionality of the plant. Peters described how some specimens, such as orchids, are often preserved in alcohol to overcome this difficulty.

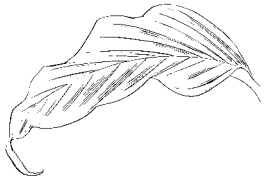
By the end of the session, interns had a much clearer idea of the effort that must go into species identification, and how it feels to work with herbarium specimens.

Interns from throughout the Smithsonian listen as Melinda Peters explains how to use a guide to identify a plant based on a specimen. The interns then had a chance to try out the techniques themselves. (photo by Rusty Russell)

Food for Thought: DNA Metabarcoding Illustrates Dietary Niche Partitioning in Large Herbivores

Herbivores can coexist even in the face of limited resources by consuming different plants than their neighbors. This dietary niche partitioning eases competition between large herbivores that share a geographical space. Previous hypotheses for dietary niche partitioning proposed a "grazer-browser continuum," suggesting a separation of plant types consumed. Additional hypotheses pointed to body size, morphology, digestive strategy (whether a species is ruminant or non-ruminant), or spatiotemporal partitioning to explain the coexistence. In a recent publication for *Proceedings of the National Academy of Sciences,* **David Erickson**, **W. John Kress**, and **Maria Kuzmina** with colleagues from Princeton University and the Mpala Research Center in Kenya used DNA metabarcoding to explore the breadth, composition, and overlap of large mammalian herbivore (LMH) diet at the plant species level.

The group analyzed fecal samples from seven African species ranging from grazers to browsers, including a range of body sizes and digestion types. They found that dietary overlap was greatest in herbivores of similar body size and position on the grazer-browser spectrum, but that actual diet composition differed between all species—grazers were eating similar total amounts of grass but different grass species. These results support previous explanations, but also suggest a greater link between plant diversity and LMH diversity than has been recognized. DNA metabarcoding had not previously been applied to this type of study. Even so, it proved to be more effective than traditional methods of direct observation or microhistology (identifying plant parts visually from feces samples), offering a non-invasive but comprehensive technique to identify and quantify diet.



A Celebration of Pollinators and Plants

National Pollinator Week 2015 was celebrated June 15-21 in an effort to raise awareness of the decline in important pollinator populations. The National Museum of Natural History held a number of events throughout the week, including a Pollination Party in the Butterfly Habitat Garden, "Expert is In!" programs throughout the museum, and a Bumble Bee Blitz in Q?rius to transcribe bumble bee records. Many of the events moved beyond simply raising awareness, giving participants opportunities to contribute towards pollinator protection.

The Pollination Party, held on June 16 in the Butterfly Habitat Garden, brought attention to native bees and butterflies. Partnering with the PollinaTerps from the University of Maryland, university students hosted a variety of activities, including quizzes, crafts, and the chance to take home seeds to start local urban butterfly habitats. The party also offered a history of beekeeping by graduate students from American University, posters featuring fun facts about pollinators, and meet and greet with a tobacco hornworm caterpillar from the Smithsonian Insect Zoo. The PollinaTerps current project focuses on restoring habitat for the imperiled Baltimore checkerspot butterfly, *Euphydryas phaeton*, the official state insect of Maryland.

On June 18, 19, and 21, Smithsonian experts came out to talk about unique pollinators in the museum galleries. Visitors of all ages swarmed their tables to learn about the behavior of plant pollinators. On June 18, **Ida Lopez** illustrated the way male and female hummingbirds of the same species pollinate two different *Heliconia* species because of their unique beak shapes. This separation in form plays a large part in the birds' mating behavior and territoriality. Esther Langan (Department of Vertebrate Zoology) described the role of mammal pollinators such as bats and lemurs, and the kids who were listening were intrigued that a bat's tongue could be as long as its body! In the insect zoo, Sam Droege (U.S. Geological Survey) stood behind a dazzling display of bee specimens from across the world. He reminded visitors that the specificity of native bees is often better for plants than generalist pollinators like the introduced honey bee.

Gary Krupnick and intern Elizabeth Jacobsen speak to the public about carnivorous plants and their pollinators. (photo by Lauren Tuzzolino)

On June 19, two more experts spoke about unique plant-pollinator relationships. **Gary Krupnick** and Botany intern **Elizabeth Jacobsen** told visitors about how carnivorous plants avoid eating their pollinators and displayed specimens of carnivorous plant species from the herbarium. Jonathan Mawdsley (Department of Entomology) spoke about beetle pollinators of the African savannah and how they are linked to large, charismatic herbivores.

On June 21, the focus was on bees. Seán Brady (Department of Entomology) described the importance of bee diversity in food production. At the same time, the Bumble Bee Blitz attracted a number of participants armed with their own laptops to work on transcribing bumble bee specimen records. The events were successful in spreading the word about pollinators and pollinator week to a large number of visitors.

National Pollinator Week follows the May 2015 release of the federal interagency Pollinator Health Task Force's National Strategy to Promote Pollinator Health and the science-based Pollinator Research Action Plan which outlines the needs and priority actions to better understand pollinator losses and improve pollinator health. The reports and plans are in response to the June 2014 Presidential Memorandum directing an interagency Task Force to create a *Strategy to Promote the Health of Honey Bees and Other Pollinators*. The Strategy has three overarching goals: (1) reduce honey bee colony losses to economically sustainable levels; (2) increase monarch butterfly numbers to protect the annual migration; and (3) restore or enhance millions of acres of land for pollinators through combined public and private action.

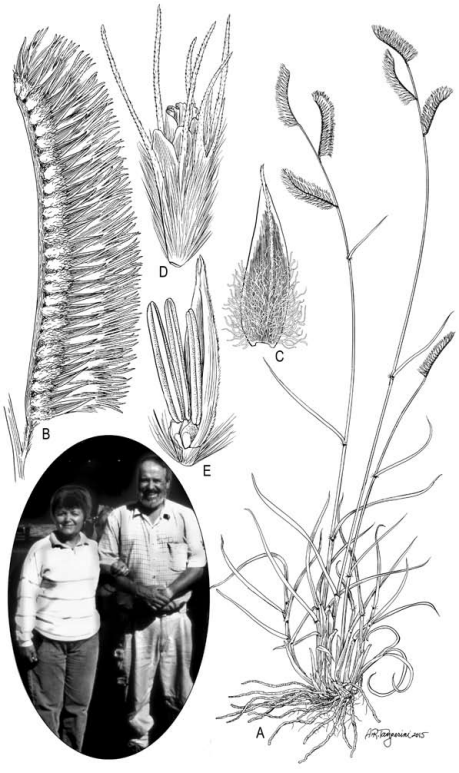
Krupnick, who represented the Smithsonian Institution on the Task Force, says that the Smithsonian is well-represented in the Strategy, in terms of research, education, and landscapes, and the Strategy highlights the efforts at the National Museum of Natural History, Smithsonian Conservation Biology Institute, National Zoological Park, Smithsonian Environmental Research Center, Smithsonian Tropical Research Institute, Smithsonian's Forest Global Earth Observatories, and Smithsonian Gardens.

Smithsonian Gardens volunteer Loretta showing a tobacco hornworm to a visitor. (photo by James Gagliardi)

A Fresh Look at Forage Grasses Reveals New Discoveries

In a recent publication in the *Journal of Systematics and Evolution*, **Paul Peterson**, **Konstantin Romaschenko**, and Yolanda Herrera Arrieta revealed a new phylogenetic tree for *Bouteloua* (Poaceae: Chloridoideae: Cynodonteae; Boutelouinae), a genus of forage grasses found in the Americas. *Bouteloua* is made up of 60 species with a center of diversity in northern Mexico.

The new phylogenetic tree was constructed via genetic analysis of 209 samples, including 59 species (206 individuals) in *Bouteloua*. Using a combination of two plastid spacers and nuclear ITS (ribosomal internal transcribed spacer), the researchers were able to produce a tree that supported a previous phylogeny but is better resolved with strong support for 11 clades. The resultant new subgeneric classification of the species of *Bouteloua* includes 10 sections and two subsections.



Yolanda Herrera Arrieta (photo taken by P.M. Peterson, Oct 2000) and *Bouteloua herrera-arrieta* P.M. Peterson & Romasch. A. Habit. B. Inflorescence branch. C. Upper glume. D. Florets. Drawn by Alice Tangerini.

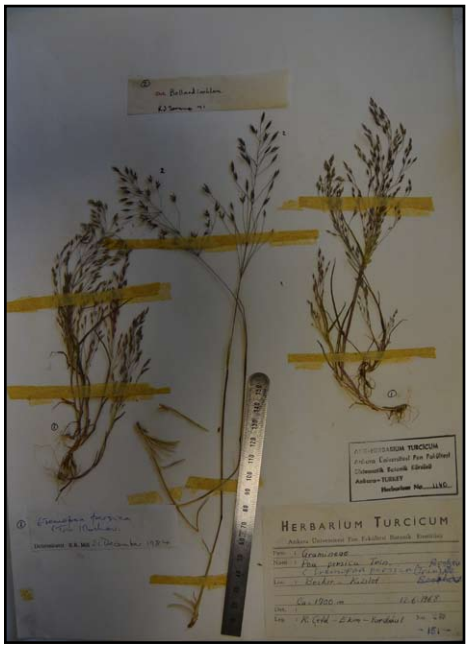
Incongruence between the plastid and nuclear phylogenies suggest at least two ancient hybridizations which will require further study.

Based on the new phylogeny and unique morphological characteristics, Peterson's group described a new species: *Bouteloua herrera-arrietae*. The new species is known only from the Sierra Madre Oriental in Mexico where it occurs on calcareous rocky hills. It is named for Dr. Yolanda Herrera Arrieta, a coauthor who has completed a revision of *Bouteloua* and floristic studies on grasses in Chihuahua, Durango, Mexico, and Zacatecas.

New *Bellardiochloa* Species Discovered in Turkey

A new species of *Bellardiochloa* (Poaceae) was first discovered not on the rocky steppes of Turkey where it grows, but in a forgotten herbarium mount. Before the discovery, *Bellardiochloa* featured four alpine species, all occurring in Turkey, including two endemic species. *Bellardiochloa doganiana*, the newest member of this genus, was first recognized as distinct by **Robert Soreng** on a sheet at Herbarium Turcicum (ANK) at the Ankara University in 1991. The two flowering shoots, mounted along with an *Eremopoa persica* ([Trin.] Roshev. in Komarov 1934: 756) (=*Poa persica* Trin.), was annotated as "*Bellardiochloa*". In 2014, Soreng returned to Turkey, and with Evren Cabi (Namık Kemal University), and Burçin Çingay (Nezahat Gökyiğit Botanic Garden), revisited ANK and established that the specimen was indeed a new species. To support the discovery, they traveled to the Palaz Dağları to collect additional samples to check for variation and collect a suitable type. Ersin Karabacak (Çanakkale Onsekiz Mart University) illustrated the new species.

Bellardiochloa doganiana Cabi & Soreng was named in honor of Prof. Dr. Musa Doğan, a Turkish botanist responsible for extensive contributions to the knowledge of Turkey's flora, especially of grasses. It is endemic to the Palaz Dağları (range) of the Taurus Mountains, in southwestern Turkey, growing on high steppe to low subalpine rocky areas between 2,000 and 2,300 meters. This species differs from all other *Bellardiochloa* species by its short, rigid, sharply tipped basal leafblades, and sparsely flowered panicles. The discovery was published in April in *Phytotaxa* 205(2): 123-128.



Bellardiochloa doganiana

Leafsnap App Adds More Species, Places

A new, updated version of the Leafsnap app was made available beginning in June. The app now has 220 species of common trees of the Northeastern United States and Canada. The app now gives the user location options which include: New York, Washington, DC, Northeast US and Canada.

Leafsnap is an electronic field guide being developed by researchers from the Smithsonian Institution, Columbia University and the University of Maryland. This free app uses visual recognition to identify a species of trees from photographs of its leaves. The Leafsnap app contains beautiful, high-resolution images of leaves, flowers, fruits, petioles, seeds and bark created by the not-for-profit organization, Finding Species.

The Leafsnap webpage <http://leafsnap.com/> has been updated to include all the new species and images.

This updated version is joined in the App Store by Leafsnap UK, the United Kingdom version of Leafsnap with all the same type of beautiful images of British trees. The apps are free and can be found in the Apple App Store.

Botanical Illustrator Returns to Her Ferns

By Elizabeth Jacobsen

Mary Monsma has the eye of an artist. The ink-on-film fern illustrations that she drew 40 years ago look like suncatchers as she moves them from the counter to the scanner, smiling as she points out the similar features, then flipping through the book where they are published to show the finished product. On the computer, she enlarges the scanned images to reveal even greater detail, zooming close enough to see that the stippling dots are not perfectly round. "Those are artifacts of long ago," she says, referring to the imperfections of hand drawing. She could just as easily be referring to the illustrations themselves, which are being scanned to usher in a new age of accessibility.

More than 10 years after she finished a set of 1,178 fern illustrations for **David Lellinger**, Monsma has returned to her drawings as part of a project to digitally archive all illustrations rendered for Smithsonian botanists. A room on the 4th floor was recently designated as a storage room for these drawings, and Monsma is working on archiving the entire collection as a part of the larger herbarium scanning project. Each scanned illustration receives a label that includes the scientific name of the species (as it was designated at the time the drawing was completed), the collector's name, the specimen number, the herbarium name, and the illustrator's name. Once scanned, images may be edited in Photoshop, allowing the artists to easily change the size, refine any issues, rearrange on the plate, or digitally add color or texture—"and that's the joy of Photoshop," Monsma laughed.

Monsma began illustrating as a contractor for Conrad Morton, then started working with Lellinger in 1974 to create the illustrations for *The Ferns and Fern-allies of Costa Rica, Panama, and the Choco (Part 1: Psilotaceae through Dicksoniaceae)*. During a 30-year time period she completed 582 drawings for that publication, and another 596 drawings for the second volume. Part 2 was never published, however, as the classification of ferns had changed too much. She contracted with numerous other Smithsonian botanists throughout that time, including José Cuatrecasas, as well as for other institutions including the U.S. Department of Agriculture, the Peace Corps, Micronesia Historic Preservation Programs, and Barbara Barnsley and Alex George, Commonwealth of Australia. She also was one of three illustrators for Edward Ayensu's *Medicinal Plants of the West Indies*, and has been a part of the Guild of Natural Science Illustrators since the 1980s.

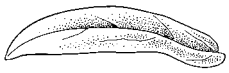
Mary Monsma points out similarities in close-up studies of ferns she illustrated for David Lellinger. She is now scanning these images as part of the herbarium digitization project. (photo by Elizabeth Jacobsen)

"Basically, the illustrator is there at the service of the curator," Monsma remarked. Lellinger requested drawings as enlargements or reductions to emphasize certain details of the ferns. Monsma described that she would first use the camera lucida—a device that allows the artist to trace over a magnified view of the specimen through a scope—to make a rough sketch that captured the proportions and angles of the enlarged plant. She would then refine the drawings, tracing them onto film in ink with dip pens. The drawings on plastic were photographed, cut, and pasted into an arrangement for a plate. Monsma typically drew a particular feature from all the species within a genus to provide a comparison. "It's really fun to go through all of them and see the differences," she says.

Monsma recounted the adventures that could come along with illustrating. "The illustrator's job," she observed, "was to sort through what's not important and show what is important." This job includes the challenge of making pressed, dried plants appear lifelike, drawing out subtle features like veins, and reconstructing incomplete specimens. Sometimes the artist needs some guidance to identify important features. For example, *Frankenia*, a genus found in Australia, accumulates salt crystals in diagnostic ways—a feature that should not be brushed off as dirt! Other times, the artist's close examination of a plant reveals new features the scientist had not noticed. Monsma pointed to the number of ovaries in different plants she had illustrated, describing how she had observed ovary patterns as she dissected different flowers for illustrations.

Since illustrations are designed to clearly delineate the defining features of a plant, scanned images are valuable to have available for botanists to reference. Scanning a collection of illustrations from a particular region, such as Monsma's fern illustrations from Costa Rica, Panama, and the Chocó, may be valuable to the understanding of fern classification. The illustrations are especially significant as a part of the larger herbarium digitization project. Just like the herbarium specimens,

illustrations in the storeroom—including Mary Eaton's illustrations from the early 1900s for *Britton & Rose Cactaceae, Vol. 3*—have both scientific and historic value.



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Windisch Receives 13th Cuatrecasas Medal

The Department of Botany and the United States National Herbarium present this award to a botanist and scholar of international stature who has contributed significantly to advancing the field of tropical botany. The José Cuatrecasas Medal for Excellence in Tropical Botany is named in honor of Dr. José Cuatrecasas, a pioneering botanist and taxonomist, who spent nearly a half-century working in the Smithsonian Institution's Department of Botany. Dr. Cuatrecasas devoted his career to plant exploration in tropical South America and this award serves to keep vibrant the accomplishments and memory of this outstanding scientist.

The winner of this prestigious award is selected by a committee made up of four botanists on the staff of the Department in consultation with other plant scientists outside of the Smithsonian Institution. Nominations for the Medal are accepted from all scientists in the Botany Department. The award consists of a bronze medal bearing an image of José Cuatrecasas on the front with the recipient's name and date of presentation on the back. Highlights from past presentations to the recipients are available at <http://botany.si.edu/cuatrecasas/cuatrecasasMedal.cfm>.

Paulo Günter Windisch is the 13th recipient of the José Cuatrecasas Medal for Excellence in Tropical Botany. Windisch, a retired professor from the Universidade Federal do Rio Grande do Sul, is noted for his extensive contributions to the systematics, biogeography, and evolution of Neotropical pteridophytes. He has published almost 100 research articles—almost all on ferns and fern allies—and a book-length guide to the pteridophytes of São Paulo state in Brazil. In addition, he and his students have presented well over 100 talks in meetings and congresses. This latter statistic speaks to another aspect of Windisch's career that is especially noteworthy and exemplary: his impressive contribution to educating and mentoring university students in Brazil. Windisch has served as principal advisor to 16 Masters-level and eight PhD-level students, as well as serving on the post-graduate committees of another 30 students. Now retired from university teaching, Paulo continues to publish on tropical American ferns.

Laurence Dorr presents Paulo Günter Windisch with the 13th José Cuatrecasas Medal in Tropical Botany. (photo by Ken Wurdack)

Windisch received his bachelor's degree from the Universidade de São Paulo in Brazil in 1971. He then went on to study under Rolla Tryon at Harvard University in Cambridge, Massachusetts, where he received his Ph.D. in 1977 with a dissertation on tropical American ferns. His career has been devoted since then to teaching and research in his native Brazil punctuated with post-doctoral appointments. The first of these was in 1984 when he spent a year studying at the University of Aarhus in Denmark where he worked with Benjamin Ølgaard. The second occurred a decade later when he spent two years here in Washington working in the US National Herbarium, which was then being curated by David Lellinger.

The past recipients of the Cuatrecasas Medal are Rogers McVaugh of the University of North Carolina at Chapel Hill (2001); P. Barry Tomlinson of Harvard University (2002); John Beaman of the Royal Botanic Gardens, Kew (2003); David Mabberley of the University of Leiden, The Netherlands, and the Royal Botanic Gardens, Sydney (2004); Jerzy Rzedowski and Graciela Calderón de Rzedowski of Instituto de Ecología del Bajío, Michoacán, Mexico (2005); Sherwin Carlquist of Rancho Santa Ana Botanic Garden and Pomona College (2006); Mireya D. Correa A. of the University of Panama and Smithsonian Tropical Research Institute (2008); Norris H. Williams of the Florida Museum of Natural History and the University of Florida, Gainesville (2009); Beryl B. Simpson of the University of Texas at Austin (2010); Walter S. Judd of the University of Florida at Gainesville (2012); Ana Maria Giulietti Harley of the Universidade Estadual de Feira de Santana, Brazil (2013); and H. Peter Linder of Zurich University (2014).

Abstracts from the Keynote Speakers at the Smithsonian Botanical Symposium

The 13th Smithsonian Botanical Symposium, "Next Generation Pteridology: An International Conference on Lycophyte & Fern Research," was held 1–4 June 2015. The invited keynote speakers explored a variety of topics, from fern genomics and development to horticulture and conservation. Below are the abstracts from the papers that were presented by the keynote speakers.

Opening keynote speaker Robbin C. Moran, New York Botanical Garden, presenting an overview of ferns and lycophytes. (photo by Ken Wurdack)

Robbin C. Moran
New York Botanical Garden, USA

"An Overview of Ferns and Lycophytes"

During the Renaissance, people believed that ferns reproduced by invisible seeds. It was not until 1794 that it was demonstrated that the "dust" produced on the back of a fern leaf developed into small green "cotyledons." This observation initiated the study of fern and lycophyte life cycles. The importance of understanding this life cycle cannot be overemphasized: it generates and explains much of the distinctive biology of ferns and lycophytes. Worldwide, there are about 13,600 species of ferns and lycophytes. This contrasts with about 450,000 species of angiosperms. Why fewer species of ferns and lycophytes? One idea is that, compared to angiosperms, ferns and lycophytes present fewer barriers to gene flow. Thus, their populations do not become readily isolated genetically, a condition considered a prerequisite for divergent speciation. Compared to angiosperms, ferns and lycophytes are more widely distributed. As a percentage of the total vascular-plant flora on far-flung oceanic islands, ferns and lycophytes are over-represented. This is best explained by the ease with which these plants disperse by tiny dust-like spores. Some species exhibit remarkable adaptations such as iridescent leaves, modified stems harboring ants, and water-absorbing scales that quickly rehydrate dried leaves. Ferns and lycophytes are also used by people: the fiddleheads of some ferns are eaten, and *Azolla* has been used since 1100 AD in the rice paddies of southeastern Asia as a fertilizer. Research on ferns and lycophytes has been transformed over the past 20 years by the introduction of DNA methods. We now have the ability to generate hypotheses of relationships, or "family trees," using DNA and morphological datasets. With these trees, we can analyze such things as character evolution, biogeography, and evolutionary rates. Given recent advances, there has never been a more exciting time to study ferns and lycophytes.

Patricia G. Gensel
University of North Carolina Chapel Hill, USA

"Silurian-Devonian Fossil Plants Provide Some Insights into the Evolutionary History of Ferns and Lycophytes"

Studies of both spores and macrofossils over the past few decades clearly indicate that land plants existed much earlier in time than previously realized (late Ordovician for embryophytes, late Silurian for zosterophylls, lycophytes, cooksonioids), and current work may suggest even earlier. This realization influences our thinking about the timing of both originations and diversification rates of various lineages and of evolutionary innovations. New data are available on the major events in the evolution of both the lycophytes s.l., and those Devonian plants that are generally considered as basal euphyllophytes and pertinent to evolution of ferns. Major phases of diversification can be recognized in the Early and Middle (Givetian) Devonian altering conceptions of vegetation types. While most Early Devonian plants are centimeter-to-decimeters tall and fairly simple, some trimerophyte-grade euphyllophytes were larger (1-2 meters) and more complex, with cryptic variation, in the late Early Devonian. Recently described "forests" (Stein et al. 2012) comprising small to very large cladoxyls or lycopods as dominant plants, some intermixed with either lycopsids or rhizomatous progymnosperms, have been documented in the Middle Devonian. This new information alters our conception of growth architecture and landscapes at that time and whole plant reconstructions may influence character analyses for phylogenetic reconstruction. It remains difficult to trace the phylogenetic relationships of early plants with extant lineages, including horsetails and ferns. Among likely progenitors of ferns and/or horsetails are trimerophyte-grade euphyllophytes, but recent descriptions of several small Psilophyton-like plants exhibiting an early type of wood, suggest some may represent precursors of lignophytes (seed plants). Cladoxyls, iridopterids, rhacophytaleans, groups that have been allied tentatively with early ferns, are now known as sepa-

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rate extinct lineages and undoubted ferns appear later. New data and re-evaluation of existing Devonian euphyllophyte morphology and anatomy may address these phylogenetic questions and demonstrate even greater diversity in that group.

Paul G. Wolf
Utah State University, USA

"Fern Genomics: Progress and Prospects"

Here I review the history, current progress, and hopeful future of studies of fern genomes. The earliest insights came from Irene Manton's (1950) observations of high chromosome numbers in ferns. Later, Klekowski and Baker (1966) noted higher chromosome numbers in homosporous lineages relative to heterosporous ones. The underlying explanation involved polyploidy as an adaptation to the unique patterns of mating in homosporous lineages, which are theoretically capable of gametophytic selfing. Several decades of research testing for polyploid-type inheritance patterns and mating systems refuted these ideas. Meanwhile, plant systematics progressed with DNA sequencing protocols focused on chloroplast genes and complete chloroplast genomes of ferns, both of which revealed phylogenetic relationships among fern lineages. This provided the evolutionary back drop for determining patterns of chromosome number changes in ferns. In 2006, Nakazato published the first nuclear genome map of a homosporous fern, heralding a resurgent interest in comparative nuclear genomics. Using nucleotide sequences of expressed genes (transcriptomes), Barker (2009) demonstrated that homosporous ferns are indeed polyploid, but probably no more so than seed plants. Unlike homosporous lineages, heterosporous plants may be capable of losing extra chromosomes between cycles of polyploidy. This intriguing result suggests that homosporous ferns might indeed have unique patterns of genome evolution compared to the heterosporous seed plants. More recently, the reduced cost of DNA sequencing has enabled the first attempts at assembling ferns genomes. Initial genome scans have revealed possible differences between ferns and seed plants in terms of relative genome content. In addition, two large-scale collaborative projects are underway to assemble the complete nuclear genomes of the heterosporous fern *Azolla* and the homosporous fern *Ceratopteris*. These studies should enable us to make more categorical statements about how the homosporous and heterosporous lineages differ at the genome level. Whether this will explain how the differences evolved remains to be seen.

Alejandra Vasco
Universidad Nacional Autónoma de México, Mexico

"Evolution and Development in Lycophytes and Ferns"

Evolutionary developmental biology (informally evo-devo) is a combination of two disciplines: evolutionary biology and developmental biology. It basically addresses two fundamental questions: how do biological forms develop and what is the basis for their diversity. In vascular plants, most studies in evo-devo have been focused on seed plants. However, lycophytes and ferns are two lineages that occupy key phylogenetic positions within the land plants, and thus provide a fascinating comparison for evolutionary developmental studies. For example, for over a century there has been an intense debate about the origin and evolution of leaves in vascular plants. Leaves have been the center of many evolutionary and developmental studies, because they are the dominant, most conspicuous organs of most plants. Historically, morphologists, anatomists, paleobotanists, and systematists have contributed data to this debate, but have failed to concur on the origin of leaves or even how many times leaves have evolved in vascular plants. More recently, molecular genetic studies have provided insight into leaf evolution and development mainly within angiosperms and, to a lesser extent, lycophytes. Ferns and lycophytes possess a vast amount of leaf diversity, and molecular genetic studies of leaf evo-devo in these taxa are beginning to fill the gap that exists in our understanding of the evolution and origin of leaves. These evo-devo studies, integrated with traditional data, are helping us to develop more robust and broadly hypotheses of leaf evolution and development in vascular plants.

Tony Avent
Juniper Level Botanic Garden & Plant Delights Nursery, USA

"Exploration to Exploitation—the Road from Discovery to Market"

Got ferns? Our mission at Juniper Level Botanic Garden and Plant Delights Nursery is to bring together the worlds of botany, taxonomy, horticulture, and conservation by discovering, documenting, propagating, and then sharing ferns ex-situ with gardeners, collectors, and researchers worldwide. I'll share our travels, discoveries, and successes, and why we all benefit from the sharing of germplasm.

Tony Avent, Plant Delights Nursery, discussing the latest in fern horticulture. (photo by Ken Wurdack)

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- United States Botanic Garden

Hanna Tuomisto
University of Turku, Finland

"How Ferns Help to Unravel the Mysteries of Amazonian Biodiversity"

Amazonian rain forests are famous for their spectacularly high species diversity. Most of the species are difficult to identify or even completely unknown to science. Together with the sheer size of the wilderness area, this makes it challenging to figure out how Amazonian biodiversity is structured. We have approached this problem by focusing on just a small part of the flora. Ferns and lycophytes form a nice group for this purpose: they are easy to spot among the greenery, they are relatively common in the forest understory, and the number of species is manageable (about 600 in lowland Amazonia, compared to perhaps 20,000 tree species). Extensive field sampling in different parts of Amazonia is revealing intriguing patterns. It is now clear that ferns are good habitat indicators, so they can be used to predict both soil properties and general floristic patterns in the forest. There is considerable floristic variation in Amazonia, and sometimes the species composition of the forest changes almost completely within a few meters. Often such changes are not obvious unless one recognizes some indicator species, because the forests can look structurally similar on both sides of the boundary. Local species diversity in Amazonia can also vary considerably, and we have found ferns to be most diverse on the most nutrient-rich soils. Such observations help to interpret biodiversity patterns both locally and at the continental scale.

Masamitsu Wada
Kyushu University, Japan & Tokyo Metropolitan University, Japan

"Photomorphogenesis of *Adiantum capillus-veneris* Gametophytes"

Developmental processes of fern gametophytes from spore germination to antheridium formation are controlled by light. For example, phototropic response is mediated by blue light receptor, phototropins, and also by red and blue light receptor, neochrome, which is a chimeric photoreceptor composed of a chromophore-biding domain of phytochrome and a full length of phototropin. In this symposium, I will talk on the light-induced responses such as phototropism, cell division, cell bulging and chloroplast movement in *Adiantum capillus-veneris* gametophyte cells, in view of intracellular photoreceptive sites, signaling of photoreceptors, microtubule and microfilament involvement in these responses. Our techniques employed for the analytical studies will be shown. At the last part of my talk, the merits of fern gametophytes as experimental materials will be discussed.

Marian M. Chau
University of Hawaii at Manoa, USA

"From Endangered to Invasive: the Role of Fern Ecology in Conservation of Hawaiian Ecosystems"

Conservation of endangered plants is critical to maintaining global biodiversity, and management efforts are more likely to be successful if decisions are based on ecological research. *Marsilea villosa* (ʻihiʻihi) is an endangered, endemic Hawaiian fern with only seven remaining populations on two islands, restricted to ephemerally flooding lowlands. We conducted a restoration experiment and a three-year field study to examine ecological factors that influenced ʻihiʻihi growth. Both found that shade and flooding have positive synergistic effects, while the negative effects of non-native species differ by type. In a genetic study, most variation was at the subpopulation level, but there was also structure that showed some differentiation among populations and between islands. This research provides management recommendations that will increase the likelihood of success in conservation of ʻihiʻihi, and a model upon which to base restoration of more resilient endangered species in Hawaiʻi and worldwide. Another important consideration is that invasive species that alter ecosystems are often successful competitors due to their effects on nutrient cycling. *Sphaeropteris cooperi* (Australian tree fern, ATF) has been invading Hawaiian forests for decades, displacing the dominant native tree fern *Cibotium glaucum* (hapuʻu). ATF produces leaves that grow faster, contain more nutrients, and decompose faster than hapuʻu. We tested effects of leaf litter additions from both tree ferns on the growth of four native understory species in two types of soils. Both litter treatments inhibited growth initially, but subsequent responses were species-specific. Several growth measures were higher with ATF than hapuʻu litter, especially in fast-growing species. Our results show that ATF can alter nutrient cycling in Hawaiian plants, sometimes with positive effects on growth. However, under natural conditions, native plants must compete for these additional nutrients with ATF and other invasive species, underscoring the importance of understanding ecology in order to manage conservation.

James E. Watkins Jr.
Colgate University, USA

"Ecology and Ecophysiology of the Fern Life Cycle: Making the Best of a Double Life"

Ferns play important roles in forests across the world. In the temperate northeast, ferns control seedling ecology of overstory trees; in the tropical rainforest canopy, ferns regulate microclimate and nutrient cycling; in secondary tropical forests, ferns can act as important filters that influence both the direction and rate of regeneration. In short, ferns are major players in regional and global ecology, yet our understanding of the ecophysiology of this lineage is limited. Such limitation is partially generated by the complex fern life cycle. Unlike seed plants, ferns rely on a free-living gametophyte that is function-

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Acknowledgements

The success of the Symposium was due to the significant time and efforts of the following people:

Organizers
- Amanda Grusz
- Gary Krupnick
- Greg McKee
- Ari Novy
- Susan Pell
- Eric Schuettpelz
- Erin Sigel
- Judy Skog
- Carl Taylor
- Warren Wagner
- Jun Wen
- Elizabeth Zimmer

Photographer
- Kenneth Wurdack

Support
- Laura Anthony
- Mary Ann Apicelli
- Victor David
- Larry Dorr
- Bernadette Gibbons
- Nancy Khan
- Sue Lutz
- Victoria Meyers
- Ray Mims
- Sylvia Orli
- Melinda Peters
- Rusty Russell
- Ed Schaefer
- Milt Sigel
- Meghann Toner
- Lauren Tuzzolino
- Carol Youmans

Abstracts

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ally different from the fern sporophyte. The marked functional disparities between these life stages sets up a system of dual ecology where selective pressures can act in different strengths and directions on gametophytes and sporophytes. This talk will present the current state of our knowledge of fern ecophysiology from a lifecycle perspective. I will first explore the challenges and unique opportunities that gametophytes present by examination of stress physiology and reproductive ecology. I will then explore sporophyte physiology paying special attention to the role that light and hydraulics play in controlling species establishment and distribution. Finally the talk will examine how the fern life-cycle influences evolution and radiation into novel habitats.

Kathleen M. Pryer
Duke University, USA

"Communicating Science in Social Settings…Yes, It Matters"

Government research funding has flatlined across the globe. Anti-science rhetoric is on the rise. Traditional news infrastructures are eroding, while the social media landscape is exploding, fundamentally altering how we communicate. At the same time, our research on ferns and lycophytes has become increasingly technical and complex. The choice is ours: do we wring our hands over the decline in scientific literacy, or do we improve our ability to communicate through an audience's preferred medium? Good science communication not only empowers citizens, it enriches the lives and careers of scientists. Here, I draw from my own research and teaching experiences focused on ferns (and other plants of the seed-free genre) to show how I have come to embrace the call to communicate one's science more broadly. To effectively get our message across, it is important to understand the existing knowledge base of one's intended audience, and to be versatile with modes of communication. Continued progress in our field will require more creativity to remain competitive for traditional forms of research funding, while simultaneously identifying and targeting new resources.

Robbin C. Moran giving with a quick demonstration of the high fat content of *Lycopodium* spores by lighting them on fire. (photo by Ken Wurdack)

Symposium

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"flash powder" in early magic acts, and he gave with a quick demonstration by lighting the spores on fire and taking everybody in the audience by surprise.

Patricia G. Gensel from the University of North Carolina at Chapel Hill gave a talk entitled "Silurian-Devonian Fossil Plants Provide Some Insights into the Evolutionary History of Ferns and Lycophytes." Gensel began her talk by presenting the fossil candidates for the origin of pteridophytes. The earliest occurrence of trilete spores is found in the Mid-Late Ordovician (450-470 million years ago). These spores are produced by a very few living bryophytes but mostly seed-free vascular plants. The Silurian-Devonian (425-370 million years ago) fossil record shows evidence of the first occurrences of major plant structures: leaves, tracheids, and rooting structures. Several waves of vascular plant diversification occurred during the late Early Devonian: diverse zosterophyllophytes, leaves of early lycophytes, early barinophyte-like plants, and the diversification of basal euphyllophytes.

Gensel explained that the fossil evidence of plants bearing strobili provides confirmation that heterospory arose in lycopsids by the Middle Devonian. Other major events seen in fossils include a clear rooting structure in zosterophylls, leaves in early lycopsids starting in the Silurian, and upright lycopods (roots at one end and branches at the other end) as seen in *Longostachys* from the Middle Devonian. Gensel also discussed branching patterns in the fossil record and how architecture can be used to distinguish among taxa.

Paul G. Wolf from Utah State University spoke on "Fern Genomics: Progress and Prospects." Wolf explained that since ferns are the sister group to seed plants, they can play an important role in comparative genomics. He noted that the mechanisms of gene and genome duplication are well studied, but processes that occur after genome duplication are not so well understood. He said that it remains unknown why homosporous ferns have so many chromosomes—flowering plants have an average base chromosome number of approximately 16 chromosomes whereas homosporous ferns have an average base chromosome number of approximately 57 chromosomes.

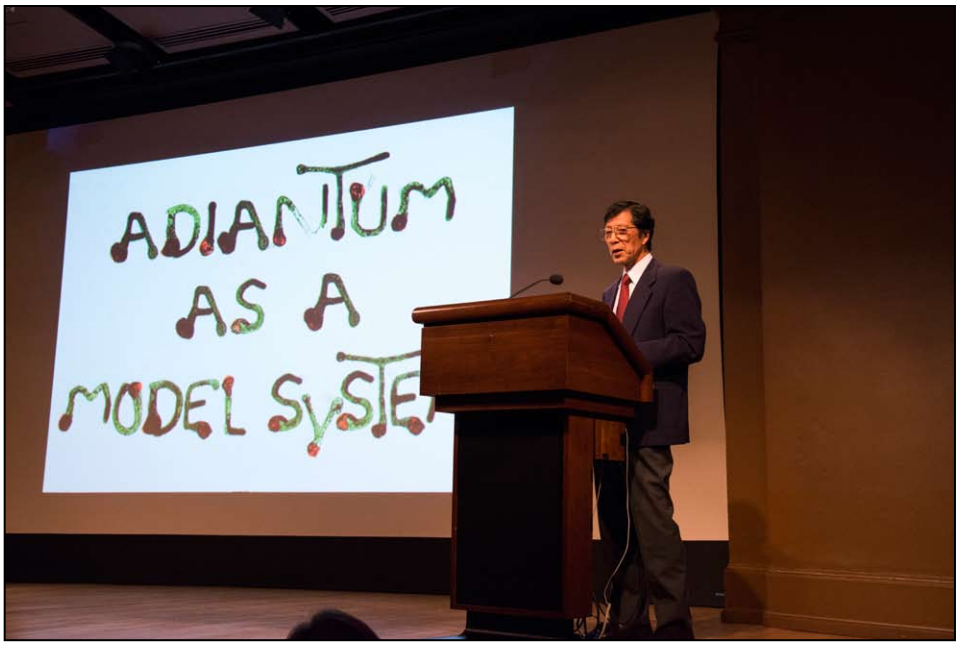
One hypothesis to explain the high chromosome numbers is that homosporous ferns undergo cycles of polyploidy and gene silencing more often than seed plants, but current research reveals that ferns are no more polyploid than seed plants, suggesting that ferns have different genome dynamics. When looking at repetitive DNA of ferns compared to seed plants, a higher proportion of simple repeats can be found in ferns. Wolf concluded his talk by appealing to the research community

to complete the first genome sequence of a fern, suggesting two candidates for this endeavor—*Azolla*, an economically valuable group with a small genome, or *Ceratopteris*, a model experimental system with a large genome.

Alejandra Vasco from the Universidad Nacional Autónoma de México spoke on "Evolution and Development in Lycophytes and Ferns." Lycophytes and ferns occupy key phylogenetic positions within land plants and thus provide a fascinating comparison (to seed plants) for evolutionary developmental studies. Vasco highlighted some innovations in the ancestral vascular plant lineage: naked and dichotomously branched axes, tracheids, terminal sporangia, and homospory. Some lineages of lycophytes and ferns contain other morphological novelties, such as ligules and the rhizophores in lycophytes and the abaxial position of the sporangia in leptosporangiate ferns. Vasco also spoke about the origin of leaves in vascular plants and how many times leaves have evolved. By studying morphology and the fossil record, she showed that the two main types of leaves, microphylls and megaphylls, have different origins. Paleobotanists have hypothesized that megaphylls in ferns and seed plants may be homologous (as lateral branches), but that the processes of flattening into one plane (planation) and the formation of a lamina (webbing) may have developed independently in two lineages. Experimental analyses of fern leaf development show that fern leaf primordia, like those of seed plants, arose from one or a group of cells on the flank of the shoot apical meristem in a distinct phyllotaxy.

Vasco continued by discussing the evidence from systematics and molecular biology of leaf evolution. She argued that dated phylogenies suggest that fern leaves evolved multiple times. Molecular genetics has identified some genes that play key roles in the processes that define a leaf. Various modern techniques such as transgenic tools, gene expression tools, and expression analyses are filling in gaps. She summarized some current findings: ferns and seed plants co-opted the same developmental mechanism for leaf development (deep homology), and the sporangial developmental program was co-opted independently for the development of leaves.

After lunch, Tony Avent from Plant Delights Nursery at Juniper Level Botanic Garden in North Carolina discussed fern horticulture in his talk "Exploration to Exploitation—the Road from Discovery to Market." Avent presented a slideshow of fern species from the wild and in cultivation, which covered his experiences from more than 80 expeditions. The goals of these trips included finding unusual species and varieties, bringing back viable spores, and ultimately bringing the taxa into cultivation. His slideshow included images of ferns from Argentina, Bosnia, China, Crete, Croatia, Korea, Mexico, Slovenia, South Africa, Taiwan, and the United States.



Masamitsu Wada, Kyushu University and Tokyo Metropolitan University, discussing the photomorphogenesis of *Adiantum capillus-veneris* gametophytes. (photo by Ken Wurdack)

In his quest, Avent prefers to find hardy individuals—those growing at high elevation, in deserts, or in the deep shade and standing water of swamps. Sometimes he will find a desired species but is unable to collect spores. Such was the case for *Dipteris conjugata* from Taiwan, what he calls "the coolest fern in the world." In Crete he searched for a heat tolerant species and found *Dryopteris pallida*, "an elegant fern that can have a wonderful place in people's gardens." During his presentation, Avent received some help from the audience—after noting some difficulty identifying a puzzling species from Taiwan, an attending pteridologist shouted out "*Plagiogyria*"! Avent concluded his talk by saying that the fern cultivation potential in modern times is incredible and that we have entered a new Victorian era for ferns.

Hanna Tuomisto from the University of Turku, Finland presented "How Ferns Help to Unravel the Mysteries of Amazonian Biodiversity." Tuomisto's research focuses on species diversity patterns in the state of Amazonas in Brazil, an area under-collected compared to other tropical areas like Ecuador and Costa Rica. High in species richness for hummingbirds and beetles, a 1-hectare plot of forest in Amazonas may have 30 fern species and over 1,000 species of vascular plants. Her fieldwork has shown that geological formations are highly relevant for the ecology of ferns.

In testing the predictability of species composition patterns and environmental gradients in Amazonia, Tuomisto carefully studied the distribution patterns of several fern species: *Lindsaea lancea*, *L. phassa*, *Danaea nigrescens*, and *D. cartilaginea*. She found that soil cation concentration marks a clear separation in the fern flora on different sides of an Amazonian river. Estimating soil properties from fern distribution data can help explain why hunters bring back different amounts of meat from different parts of the rain forest. Extrapolating for the whole area can assist in estimating prey abundance for hunters. Tuomisto explained that species richness shows positive trends with environmental

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variables such as altitude, annual rainfall, and soil cation concentration.

Masamitsu Wada from Kyushu University and Tokyo Metropolitan University, Japan discussed "Photomorphogenesis of *Adiantum capillus-veneris* Gametophytes." Wada began his talk by explaining that *Adiantum* gametophyte cells provide a model system for his studies because cell division is controlled by light. By applying various light treatments, Wada is capable of studying phototropic responses in cell biology. Wada presented his experiments on the timing of cell division and the movement of chloroplasts. Since the timing of cell division is light dependent, Wada demonstrated that blue light induces very fast division by shortening the G1 phase of cell division while red light slows it down.

Wada shared videos of chloroplast movement under different light conditions. If a plant receives light levels higher than those required for photosynthesis, a protective mechanism includes moving chloroplasts from the cell surface to the sides of the cell to reduce photodamage. This chloroplast avoidance movement has been found in algae, mosses, ferns, and many seed plants. Wada obtained *Arabidopsis* cell mutants deficient in this movement to understand the molecular mechanism behind the movement and found that actin filaments are predominantly utilized for chloroplast movement.

Marian M. Chau from the University of Hawaii at Manoa spoke on fern conservation in her talk, "From Endangered to Invasive: the Role of Fern Ecology in Conservation of Hawaiian Ecosystems." For the first half of her talk, Chau discussed the experimental ecology of the endangered ʻihiʻihi fern, *Marsilea villosa*. She conducted vegetation surveys and measured soil characteristics, canopy cover, and flooding levels to determine the best growing conditions and to provide management recommendations for this narrowly endemic species. Based on her results, she recommends that restoration projects occur in areas with consistent flooding and with native tree species, and that non-native grasses should be controlled.

The second half of Chau's talk focused on the effects that an invasive Australian tree fern has on Hawaiian soil and nutrient dynamics. Hawaii has four endemic *Cibotium* tree fern species, called hapuʻu, which act as keystone species by serving as hosts for epiphytes and sequestering more nitrogen and phosphorous than most other native vascular species. One of the worst invaders in Haleakala National Park is the Australian tree fern, *Sphaeropteris cooperi*, which is displacing *Cibotium* with its faster growth rate, higher photosynthetic rate, faster leaf turnover, and higher drought-tolerance. Chau studied how leaf litter of the two taxa affected native angiosperm growth. In an experimental study, she found that invasive leaf litter increased the growth of *Carex* and *Hibiscus* but not the slow-growing, dominant canopy tree *Metrosideros*. She concluded that even though the invasive tree fern's altered nutrient cycling appears to have a positive effect on plant growth, the long-lasting effects may lead to an altered forest structure if it favors fast-growing native species over slow-growing species. She stressed that understanding fern ecology—both native and invasive—is critical to informed conservation practice.

James E. Watkins Jr. from Colgate University, and the current president of the American Fern Society, presented the talk, "Ecology and Ecophysiology of the Fern Life Cycle: Making the Best of a Double Life." Watkins began his presentation with a look at the functional differences between gametophytes and sporophytes: gametophytes are relatively simple, with no vascular tissue or stomata, whereas sporophytes are more complex. Thus the two unique ecologies provide an interesting study system where the selective pressures acting on gametophytes are very different from those on the sporophytes.

Watkins studies fern epiphytism, a trait that has evolved multiple times in the ferns, and he explained how epiphytic ferns function relative to terrestrial species. He spoke about the remarkable variation in gametophyte morphology and explained that epiphytic gametophytes can be longer-lived, have a higher desiccation-tolerance, and are more capable of intragametophytic selfing than their terrestrial counterparts. He also spoke about sporophyte water relations in which epiphytes have smaller tracheid (conduit) diameters and are thus less likely to dry out. Watkins then presented two strategies in fern ecophysiology, in which terrestrial species

Kathleen Pryer, Duke University, who spoke about science communication, posted a selfie of herself with the audience on Twitter during her presentation. (photo by Kathleen Pryer)

are fast growing with simple morphology, and epiphytes are slow-growing with more complex morphology. He concluded that our understanding of fern physiology will provide informative knowledge as ferns respond to climate change and allow for predictive models in the management of endangered fern species.

The closing keynote presentation was by Kathleen M. Pryer from Duke University who presented "Communicating Science in Social Settings…Yes, It Matters." Speaking on the powers of social media for science, Pryer began her talk by taking a selfie of herself with the audience and immediately posting it on Twitter. She argued that a current anti-science rhetoric is on the rise and that disbelief of evolution is too common in the US. She praised the advances in fern science—from understandings of the fossil record to technological breakthroughs in DNA sequencing. Yet fern biology has fierce competition when it comes to funding, especially when ferns are considered "lower plants." Thinking of seed-free plants as "lower" is an old way of thinking. This has hampered her ability to fund her research on *Azolla*, a group of ferns with "massive green potential." Bucking tradition, she crowdfunded an *Azolla* genome sequencing project. Crowdfunding not only raised enough seed money for the exploratory research, but also allowed the public to

participate, support, and witness advancements in science.

Pryer also spoke about the public response when her research team named a new genus of ferns *Gaga*. The name honors the pop music star Lady Gaga, and was chosen because many fern gametophytes have a striking resemblance to one of Gaga's famous costumes, they have a somewhat fluid definition of gender, they bear a distinct DNA sequence synapomorphy spelling GAGA, and the sporophytic fiddleheads look like her fans' "claw greeting." Not intended as a publicity stunt, Pryer said that the result of the naming episode allowed her to connect with a part of society she normally does not encounter. She enjoys making science connections with individuals who do not normally visit natural history museums or watch nature programs. She stated, "When scientists communicate effectively, science thrives." She urges the scientific community to share their passion and to make science more accessible to a variety of communities.

Monday concluded with an evening poster session at the Conservatory of the United States Botanic Garden. An international group of 30 presenters displayed their posters and spoke about their research on ferns and lycophytes ranging in topics from taxonomy and phylogeny to biogeography and physiology.

The next three days featured five colloquia and four contributed presentation sessions. The colloquia were titled (1) Biogeographic patterns and processes of speciation and hybridization in spore-bearing plants; (2) Future challenges of fern and lycophyte ecology: a call for conservation and collaboration in the next generation; (3) Genomics and transcriptomics of ferns and lycophytes; (4) Evolution and development in ferns and lycophytes: case studies and perspectives; and (5) The integration of ecological and phylogenetic approaches in pteridology.

The International Conference on Lycophyte & Fern Research included a field trip to Great Falls Park and Scott's Run Nature Preserve to see native ferns growing in the DC region. The participants are gathered here at Overlook #3 on the Virginia side of Great Falls Park. (photo credit unknown)

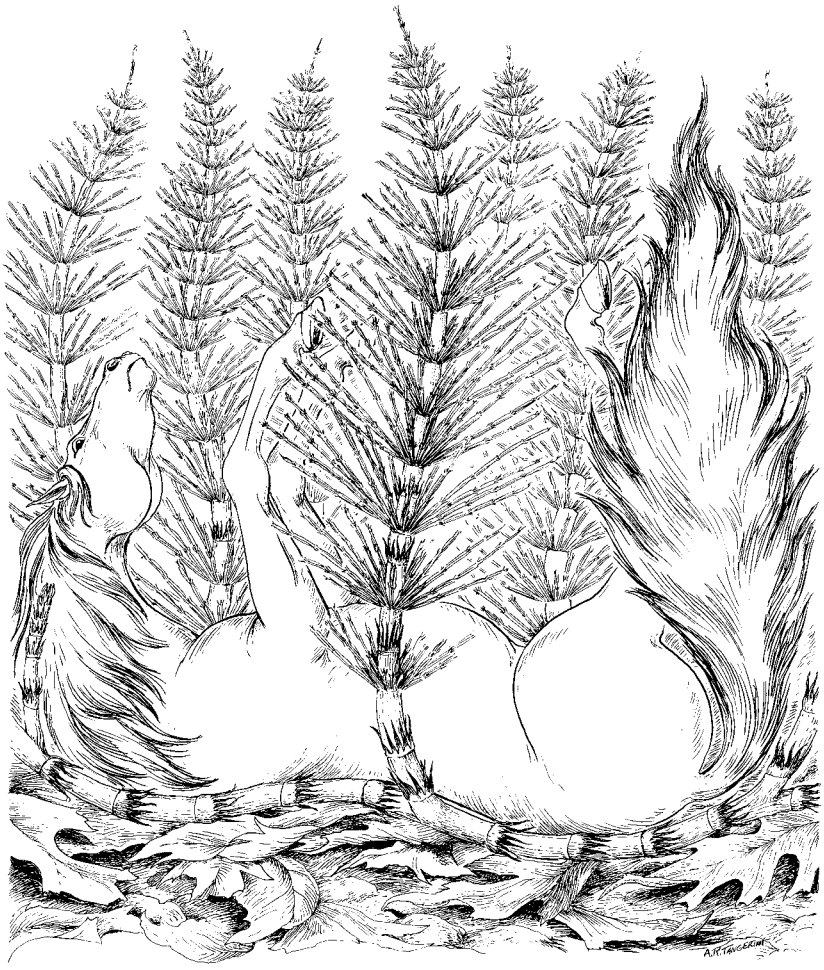
Guests gather in the Rotunda of the National Museum of Natural History for the closing dinner of the International Conference on Lycophyte & Fern Research. (photo by Ken Wurdack)

Thursday night featured a reception and symposium dinner in the Rotunda of NMNH. On Friday, three concurrent workshops were presented: (1) An introduction to next-generation sequencing and bioinformatics; (2) Digital species identification tools; and (3) Field ecology of ferns: a call for new standard methods and opportunities for collaboration among pteridologists. The final event of the conference was a field trip to Great Falls Park and Scott's Run Nature Preserve, where guests were treated to seeing native ferns growing in the DC region. Participants saw 22 fern species, a highlight among which was *Homalosorus pycnocarpus* (the glade fern), the only member of a monotypic genus and one of only two genera belonging to the otherwise Old World family, Diplaziopsidaceae.

Next year's 14th Smithsonian Botanical Symposium will take place on Friday, May 20, 2016, with a theme still to be determined. Be sure to check the symposium website at <http://botany.si.edu/sbs> for updates.

Art by Alice Tangerini

Equisetum arvense L.



At the 13th Smithsonian Botanical Symposium, "Next Generation Pteridology: An International Conference on Lycophyte & Fern Research," opening speaker Robbin Moran gave an overview of ferns, horsetails, and lycophytes and displayed Alice Tangerini's illustration of the horsetail, *Equisetum arvense*. Tangerini's 1977 drawing originally served as the title page for the chapter, "On Names and Naming," in *Humanistic Botany* by Oswald Tippo and William Louis Stern. Knowing Tangerini's predilection for drawing horses, Stern suggested the theme of the chapter illustration to Tangerini and gave her full rein on how to depict the subject. Tangerini consulted images in the Botany Library's collection and likely some herbarium specimens for the drawing. The caption below the illustration reads, "The bushy form of the horsetail plant (*Equisetum*) has suggested both its English vernacular name and its botanical name." In 2001, Stern donated this drawing and others in the book to the Hunt Institute for Botanical Documentation.

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