Herbarium Explorations

Much more than collections of dead plants and fungi, herbaria are irreplaceable repositories of historical plant information vital to a wide variety of scientific applications. BY MARCIA G. YERMAN

IT'S EASY to be amazed and inspired by the vibrant, living collections of plants at public gardens and universities. But there are 400,000 species of plants and possibly millions of species of fungi on the planet—far more than all the public gardens in the world can display. The job of maintaining historical records of all those plants and fungi goes on largely out of public view, in archives known as herbaria.

"Herbaria serve as an encyclopedia of the Earth's flora," says Vicki Funk, Senior Research Botanist & Curator at the Smithsonian National Museum of Natural History (NMNH) in Washington, D.C. "They are really our only record of what's been on the planet in the past, what's here in the present, and what we predict into the future," she adds. Yet many people don't fully understand why herbaria are important. "There's a misconception that the collections are just a bunch of boring dead plants, and that what we do is not science," Funk says. "In reality, it's not that at all. We collect specific things to answer specific questions."

The specimens in herbaria are irreplaceable sources of information regarding the diversity of species and the habitats they come from. They play a critical role in taxonomy, systematics, anatomy, morphology, ethnobiology, paleobiology, and conservation biology. They can be used to confirm the identity of a newly discovered species, and provide locality data for conservation assessments. Specimens can document the effects of climate change on flowering phenology and provide material for DNA analysis and conservation genetics.

INSIDE A HERBARIUM

According to the *Index Herbariorum,* an online catalog of herbaria maintained by the New York Botanical Garden (see "Resources," page 31), there are 2,885 herbaria

Above: In the U.S. National Herbarium at the Smithsonian's National Museum of Natural History, botany department staff examine pressed and jarred specimens of algae. Opposite: A preserved specimen of *Rosa palustris* from the New York Botanical Garden's herbarium.

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THE PLANT DOCTOR

Carver was born into slavery in Missouri in the 1860s. As a child, he was fascinated with plants and the natural world. Local farmers called him the "Plant Doctor" for his ability to nurture sick plants. Carver grew up to become one of America's greatest scientists and agriculturists.

Carver is best known for his promotion of peanuts in American agriculture. Peanuts still covered in dirt in this Herbarium specimen demonstrate how peanuts grows underground with the plant's roots.

Visitors, below, enjoy browsing preserved specimens during a herbarium exhibit at the New York Botanical Garden earlier this year. The exhibit included a display on the work of American botanist George Washington Carver, left. A specimen, above, collected during Captain James Cook's 18th-century voyage to the South Pacific, is part of the herbarium's collection.

TOP LEFT: MARCIA G. YERMAN. TOP RIGHT AND BOTTOM: COURTESY OF NEW YORK BOTANICAL GARDEN

worldwide containing approximately 375 million specimens. Of these, the William and Lynda Steere Herbarium at the New York Botanical Garden (NYBG) is the second largest herbarium in the world (the largest is at the National Museum of Natural History in Paris, France). It houses the most extensive collection in North America with over 7.8 million preserved plant and fungal specimens, including samples from every continent.

This past summer, the NYBG hosted "What in the World is a Herbarium?" to showcase this lesser known side of its work. I toured the exhibit, which explored different aspects of the Steere Herbarium's mission, from the collection of specimens and the process of preservation, to the history of the research of American botanist and inventor George Washington Carver, a former slave who spent much of his career researching alternative crops to cotton.

The theme of one wall, "Saving the Plants of the World," outlined the efforts of NYBG's staff to collect plant species in geographic areas from Myanmar (formerly Burma) to the Brazilian Amazon. From a diversity standpoint, Myanmar's northern forest is exceptional; of the 6,000 plant species found there, 25 percent don't exist anywhere else in the world. Specimens in the herbarium from places like these may represent the last bit of evidence that a species existed on Earth.

I also went behind the scenes with Matthew Pace, the assistant curator and an expert on orchids of the New World. In the climate-controlled herbarium stacks, I viewed with amazement historic specimens that included a plant collected on Captain James Cook's first voyage, when he led an expedition to the South Seas beginning in 1768; a moss collected and documented by English naturalist Charles Darwin; and plants gathered by artist and explorer John J. Audubon, who used them to ensure the accuracy of the habitats depicted in his paintings of birds.

In addition to the historical significance of specimens like these, Pace stressed their importance to current research. For example, ethnobotanists can consult herbarium collections to examine plant use by societies around the world, and scientists on the ground can apply this knowledge while interacting with local populations to develop sustainable practices.

One of the most important components of herbaria collections is what are known as type specimens. These are the original individual specimens from a population that serve as the reference point for naming a new species, so they are vital for determining the correct application of a botanical name.

"Our whole system of nomenclature is linked to these herbarium specimens," says Funk. "Everything that has a name must have a type specimen as a record of it." The U.S. National Herbarium, for instance, holds more than 120,000 type specimens.

REVELATIONS FROM PRESERVED PLANTS

I left the NYBG's exhibit with a whole new level of appreciation for the scientists who study dead plants. It was particularly encouraging to learn about the work occurring, both in the United States and elsewhere, to protect plant life in the face of climate change and other threats. Unlike the situation with endangered animals—especially the so-called charismatic megafauna such as pandas and elephants—the narrative around threatened plants is often under the radar.

Research on herbarium specimens of goldenrod, such as this one, helped scientists learn about the relationship between levels of atmospheric carbon dioxide and the protein content of bee pollen.

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CREATING A HERBARIUM SPECIMEN

Each week, the New York Botanical Garden (NYBG) receives 1,000 new specimens collected by it research staff to accession into the herbarium. During my visit, I watched Sheranza Alli, who has worked in the mounting room for 25 years, demonstrate how these plant samples become part of the collection. She has created 250,000 mounted specimens during her career, averaging about 50 per day.

Working with an already pressed specimen, Alli used tweezers and gloved hands to carefully arrange the plant parts to her satisfaction on special acid-free paper. Then she drizzled glue on the back surfaces and added weights on top of them to help them dry flat. The specimen was labeled with the name of the plant, the collector, date gathered, as well as key habitat data. Once dry, the new mount would move to the climate-controlled herbarium. The specimen would also get photographed with a barcode and "whole label data" for the digital database.

"The collection represents 350 years of what has been going on in nature," says Nicole Tarnowsky, assistant director of NYBG's herbarium. "This permanent preserving will help botanists hundreds of years from now." —M.G.Y.

Sheranza Alli, left, an aide at the NYBG herbarium, prepares a herbarium specimen. A corpse flower *(Amorphophallus titanum)* that drew huge crowds when it bloomed at the NYBG conservatory, above, was displayed in its dried form during the herbarium exhibition, top.

Herbarium collections can reveal a lot about how climate change affects and will affect plants, explains Dennis Desjardin, director of the Harry D. Thiers Herbarium in San Francisco, California. "The presence or absence of a specific species in an area reflects environmental conditions at the time of collection, hence they can be used to evaluate climate change, competition, and other data pertinent to conservation efforts," he says.

Gary Krupnick, a conservation biologist who is Head of the Smithsonian's Plant Conservation Unit in Washington, D.C., points out that new ways to glean climatic insights from herbarium collections continue to surface. "Today, we're using specimens in ways the original collectors could never have imagined," he says. "For instance, a recent study by a team of scientists examined the protein content of pollen from specimens of Canadian goldenrod dating from 1842 to 1998, that are housed at the U.S. National Herbarium. They found that as atmospheric carbon dioxide levels increased, the protein content of the pollen decreased. Thus, an increase in carbon dioxide emissions over the last several decades has made a key food source for bees less nutritious than in the past."

Desjardin is also particularly excited about what herbarium specimens can tell us on a molecular level. "Each specimen contains DNA that can potentially be sequenced, so they provide genetic information for understanding speciation

LEFT: MARCIA G. YERMAN. RIGHT (2) COURTESY OF NEW YORK BOTANICAL GARDEN

and evolutionary relationships," he says. Genetic sequences for individual plant species are being logged into online databases such as GenBank, so that researchers everywhere can access and analyze the data. This information has widespread applications in fields such as medicine, pharmacology, and bioindustry.

COLLABORATIVE EFFORTS

Along with genetic sequences, technological innovations of the Digital Age have made it possible to digitize herbarium specimens and make them more widely accessible online. This has encouraged herbaria to "become more collaborative," says Funk, who has been working at the U.S. National Herbarium at the Smithsonian for more than 36 years.

Resources

Index Herbariorum: A global directory of public herbaria and associated staff, *http://sweetgum.nybg.org/science/ih.*

The C.V. Starr Virtual Herbarium: Gateway to the digitized specimens of the William and Lynda Steere Herbarium, *http://sweetgum.nybg.org/science/vh.*

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A staffer at the U.S. National Herbarium, above, scans herbarium specimens. Digitization is allowing herbaria to share their collections with researchers around the world.

"It used to be that all the collected specimens went back to major herbaria," she says. "Now the plant collections are shared with the country of origin. Also, many programs are digitizing the specimens and the literature so people in places other than major cities with big herbaria have access to resources they never had before." Digitization also provides a cost-effective alternative to having to borrow a specimen across long distances or send a researcher to view it in person. And now that individual institutions and researchers are no longer the sole holders of specialized regional or plant family collections and data, there is greater participation and higher standards in academic research, Funk adds.

Among the many herbaria moving toward this free flow of information are the ones at NYBG and Smithsonian, which have uploaded their collections to a free searchable database (see "Resources," this page). Full documentation accompanies the high-resolution images. Every month, thousands of records are uploaded. In 2013, the NYBG reached the milestone of its two-millionth specimen for digitization, which turned out to be the purple pitcher plant *(Sarracenia purpurea),* a carnivorous plant native to eastern North America. The U.S. National Herbarium hit the same digitization milestone in 2016.

While new technologies continue to advance our ability to tackle complex conservation issues and expand our scientific knowledge, herbaria provide an essential foundation for this critical work. "Though a third of the world's plant species are in inexorable decline and headed to extinction, we have the skills and ability to save the majority if we work hard to do so," says James S. Miller, Senior Vice President for Science and Conservation at the Missouri Botanical Garden in St. Louis, which holds the second largest collection of plant specimens in North America in its herbarium. "The herbarium is the catalog that we work against. We need the whole list of the world's plant species before we can decide which need attention to ensure their future survival."

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