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I have become fascinated by herbaria, collections of dried plant specimens. Like many new loves, this one began rather suddenly. Yes, I had known about them for years and had even been to a symposium on virtual herbaria, but I hardly ever gave them a thought. Then, as described in my January column (Flannery, 2011), while attending the Botany 2010 meeting last August in Providence, Rhode Island, I had a tour of the herbarium at the Museum of Natural History and Planetarium, Roger Williams Park. I also went to a couple of sessions on the effort to digitize herbarium collections throughout the United States. These experiences got me thinking about herbaria and reading up on them. When, in October, I had a chance to revisit the herbarium in Providence, I was moonstruck. I really wanted to dig into the subject and learn as much about herbaria as I could.

Like many love affairs, this one isn't based on particularly sound judgment. I am not a botanist and know little about plants, although I've gotten interested in drawing them, and I've done some work on Agnes Arber, an early-20th-century plant morphologist (Flannery, 2005). Still, I am definitely light on plant knowledge. But I think this is part of the lure of the subject: a plunge into the unknown, a desire to push my brain. I have begun, just begun, to seriously consider herbaria, and this column is my first attempt to write about them. I have already discovered so much I find interesting that I am hoping this information will interest you as well.

## ○ Visiting Herbaria

When I went back to the Providence herbarium, the curator, Marilyn Massaro, opened up not only the shelves of specimens to me, but also boxes of books with pressed plants. Most of these aren't of much use scientifically, but they are interesting historically. Many of the books contain seaweed collections, for which there was a craze in the late 19th and early 20th centuries. These collections were obviously based on the beauty of the specimens rather than on their scientific value, since in many cases there are no labels. Still, the books are treasures because they document a passion for plants that is rather foreign to us today (Armstrong & de Zegher, 2004). This is one of the values of herbaria: to preserve the history of our interest in plants as well as the plants themselves.

## ○ History of Herbaria

The history of herbaria is indeed rich, and I'll share just a view of the highlights I've learned so far. One of the first botanists to create a collection of dried plants was the Italian Luca Ghini (1490–1556), who founded botanical gardens in Pisa and then Florence. The oldest surviving herbarium was put together by one of his pupils and dates to 1532. Within a couple of decades, herbaria had become quite

common and were usually collections of medicinal plants, because these were the most interesting to botanists of the day. This was also the era when many botanical gardens were established. In a history of the Botanical Garden of Padua, there is quite a bit about its herbarium, where some specimens date from the 18th century and where specially designed book-like cases hold a collection of 1000 types of seeds (Minelli, 1995). The oldest sheets of dried plants are bound in books, but, particularly after the time of Linnaeus, sheets were stored unbound, in folders, to allow for easier movement in case of reclassification. This is the storage method still used today, though metal cases have usually replaced wooden ones. The former aren't nearly as attractive, but they are fireproof.

The herbarium that Linnaeus created is now housed in the Linnean Society of London and has been digitized so everyone can see how the master himself pressed his plants ([http://www.linnean-online.org/view/plants\\_alpha/plants\\_alpha.html](http://www.linnean-online.org/view/plants_alpha/plants_alpha.html)). Another great digitized collection is that of the plants Darwin collected on the *Beagle* voyage. They are at the University of Cambridge Herbarium and were mounted by Darwin's teacher and mentor, John Henslow. Darwin collected over 2700 specimens, which Henslow arranged on 950 sheets (<http://www.darwinsbeagleplants.org/Darwin/Home.aspx>). The advances in labeling protocol are evident when Henslow's sheets are compared with those of Linnaeus – and thanks to digitization, this is easily done.

There are many other herbarium collections tied to exploration, such as the plants amassed by Joseph Banks and his party on Captain Cook's voyage on the *Endeavor*; these are at the Natural History Museum, London (<http://www.nhm.ac.uk/research-curation/collections/departmental-collections/botany-collections/historical-collections/banks-herbarium/index.html>). Closer to home, the plants collected by Meriwether Lewis on his expedition with William Clark are found at the Academy of Natural Sciences in Philadelphia, where Lewis learned how to preserve plants before he set out (<http://www.plantsystematics.org/reveal/pbio/LnC/LnCherbindex.html>). Some of the 239 sheets have Lewis's own labels still attached (Munger, 2003).

One thing I've learned about herbaria is that they are full of surprises. They may be one of the best early examples of social networking. Before digitization, and even with it, sheets were sent from herbaria to botanists and then returned after the botanists' studies were completed. It became standard to lend sheets to a herbarium rather than to an individual, and if the lending institution had multiple sheets for a particular species, it might be willing to give rather than just lend the specimen. The etiquette here is that the receiver sends back a sheet or sheets that are of comparable value. This custom helps herbaria fill out their collections and also means that herbaria are wonderful patchworks of specimens collected by botanists over the centuries and throughout the world.

Before leaving the history of herbaria and tackling their present-day uses, I have to mention one more collector, Jean-Jacques Rousseau, who not only had a personal herbarium, but also prepared specimens for others, including the Duchess of Portland, a famous 18th-century collector of natural-history materials (Cook, 2007). For another patron, Étienne Delessert, he wrote eight letters that amount to an introduction to the study of plants, and the last letter in the series is on how to create a herbarium (Rousseau, 1979). He gives very specific directions about what condition the plants should be in when collected and the procedures for drying and mounting them. Until I came across this information, I only knew Rousseau as a philosopher, not a biologist. It is amazing how a new love can introduce one to a whole new bunch of friends.

## ○ Herbaria Today

When I went to Minneapolis for the NABT meeting last fall, I used the opportunity to visit the herbarium at the University of Minnesota, which is part of the University's Bell Museum of Natural History. It takes up a large portion of one floor of a biology building on the St. Paul Campus. As I have discovered, most herbaria, including this one, don't have just one collection, with all the plants filed together. Rather, the specimens are grouped into several collections. For example, it is usual for all the type specimens in a collection to be stored together, so they can get the best care and attention. A type specimen is the one that formed the basis of the original description of the species; it's the standard against which other specimens are compared. University herbaria also usually have a teaching or synoptic collection, which students use in doing their botanical course work. Needless to say, there are no type specimens there. As at most institutions, the history of the collections at the University of Minnesota can in part be told by the cabinets; the synoptic collection is stored in old metal cabinets, more decorative than those of today. The type specimens are housed in newer storage units.

Except for rare cases, such as the Providence herbarium, which is a static collection – or, as Marilyn Massaro terms it, a “time capsule,” representing collections made in the late 19th and early 20th centuries – herbarium collections grow over time. That means new storage space has to be found, so in a sense the history of the growth of the collection can be seen in its cabinets. Wooden ones with glass doors are really old, and have been replaced in many institutions either partially or completely by metal ones with movable shelves that allow for more compact storage.

Obviously there is a limit to how much can be stored in a room, which those of us who have “spare” rooms know all too well. Just as our belongings often spill over into garages, herbarium cabinets spill into the halls of biology buildings. This is definitely the case at the University of North Carolina's Coker Hall, where the herbarium itself has matching metal cabinets but earlier ones have been relegated to the halls of several floors. They definitely give the building a lived-in feel and are a testament to the long plant-collecting tradition at UNC Chapel Hill (Radford, 1998). The Assistant Curator of the collection, Carol Ann McCormick, filled me in on how an active herbarium functions, on how loans and trades are at the heart of what the herbarium does, in addition to mounting new specimens and supporting taxonomic and other plant-science research. It quickly became clear that running a herbarium is a labor-intensive operation and that the labor is often hard to come by. Yes, student-workers are available and are great at mounting specimens and packaging sheets for mailing. But much of the work requires greater expertise, and because herbaria are undervalued today, getting educational

institutions to commit the necessary funds isn't easy. Kathleen Pryer, the Director of the Duke University Herbarium, has taken to selling prints of herbarium specimens and even coffee mugs to provide not only supplementary funds but also publicity.

I visited both these North Carolina herbaria, which are a 20-minute drive from each other, while on a trip to South Carolina to visit my son and his wife. This is now my strategy: to piggyback trips to herbaria onto other reasons to travel. It may not be the most methodical way to approach my subject, but it does make traveling more fun. My visit to Duke was as wonderful as going to UNC, though their facilities and institutional structures are quite different. (I have to appear as impartial as possible here, but in the interest of full disclosure I must say that my son is a Duke graduate and an avid, if not rabid, Blue Devils basketball fan, which means the initials UNC can't be whispered in his home.) At UNC the herbarium is associated with the botanical garden, and at Duke, it is part of the biology department. Thanks to a recent National Science Foundation grant, the vascular plants at Duke have been moved to a new, state-of-the-art facility with compact shelving and climate control. The latter is important for insect control, a perpetual problem in herbaria: there's so much good stuff for insects to eat. According to the curator of vascular plants at the Duke Herbarium, Michael Windham, the reigning insect there is, not surprisingly, the cigarette beetle.

Beyond all the logistical problems and the housekeeping issues, what came through most clearly during my conversations at both Duke and UNC is that herbaria are vital research hubs for the plant world. Pryer has collected statistics indicating that over a 5-year period, the Duke Herbarium collections have been cited in over 300 scientific publications. Of these, 200 were written by researchers at other institutions, which suggests that there is a great deal of borrowing and lending going on. These loans have supported many different kinds of research, an indication of how varied plant science is today.

One study used herbarium specimens as a source of citrus bacterial canker and was able to access its genetic diversity and even its changes over time (Li et al., 2007). The noted entomologist May Berenbaum and her student, Arthur Zangerl, used herbarium specimens to trace an interesting change in the chemistry of the wild parsnip, *Pastinaca sativa*. It was brought to North America by early colonists who used it for food. The plant quickly became a noxious weed, in part because it was no longer plagued by the parsnip webworm, *Depressaria pastinella*, which dogged it in Europe. However, the webworm finally made its way to America in 1869 and has helped to control the *P. sativa* populations, despite the fact that the plant makes furanocoumarins that are toxic to the webworm. Zangerl and Berenbaum (2005) found that herbarium specimens collected in the United States before the 1870s had much lower levels of furanocoumarins than more recent specimens. Old European specimens made these toxins. Apparently, low selection pressure for the production of the toxin in the parsnips during its early years in North America led to lower levels. However, when the webworm appeared, there was selection for toxin production – a beautiful example of evolutionary change. This is a case of herbaria aiding not only plant research but ecological work as well.

At UNC, I learned about the massive project that went on there in the 1950s and 1960s to produce the *Guide to the Vascular Flora of the Carolinas* (Radford et al., 1964). More recently, DNA from a UNC herbarium specimen had been used to clear up the situation concerning three species of red algae that turned out to all belong to the same species, *Prionitis sternbergii* (McCormick, 2010). In another case,

a specimen of a new species of *Eupatorium* called the bay boneset, *E. paludicola*, has been deposited in the UNC herbarium; this is a rare plant that has been found at seven sites in the Carolinas (LeBlond, 2007). As an example of trading between herbaria, UNC sent several dozen specimens of newly described species from the southeastern United States to the herbarium at the Natural History Museum, London, and the museum reciprocated with 150 specimens amassed by Ferdinand Rugel, a German plant collector who settled in Tennessee (McCormick, 2009). So, by a very circuitous route, these plants came back to their homeland.

## ○ The Politics of Herbaria

Another aspect of herbaria is that there are different collecting philosophies, which influence not only the character of collections but the conduct of botanical research as well. In *Imperial Nature*, a biography of the British botanist Joseph Hooker, Jim Endersby (2008) argues that Hooker's huge herbarium at the Royal Botanic Gardens, Kew, shaped how he classified plants. Specimens from all over the world came into Kew, the hub of British botany, so in most cases he had at his fingertips many specimens within a genus and, often, even within a species. Because of this, he could accept that there was variation within species, while botanists in the British colonies, which in the 19th century were vast, had smaller collections and tended to see small differences as more significant and therefore worthy of classification as different species. In other words, Hooker was a lumper and the colonists were splitters. Endersby argues that one reason for Hooker's strategy was very practical: there was limited space at Kew, so the more species, the more specimens that would be needed, and with specimens coming from all over the world, this could lead to a storage crisis.

However, Hooker used a more intellectual argument for his approach: because of the superiority of his study material, he and his colleagues in Britain should do the classifying and those in the colonies should do the collecting, just sending the specimens on rather than attempting serious taxonomic work themselves. This was done in many cases, so much so that almost 600 duplicate sheets that Joseph Banks and his collaborators collected in Australia were sent from the British Museum to the herbarium at Royal Botanic Gardens, Sydney, in 1905, but only after the gardens' director, Joseph Henry Maiden, had visited the museum (Stacey & Hay, 2004).

The Banks collection was one of the mainstays of the British Museum collection, which is now at the museum's spinoff, the Natural History Museum, London. When the latter was getting its own building in the 1870s, there was a move to divest it of its herbarium, sending all plant material to Kew. There were also counterproposals to make the move in the opposite direction. In the end, neither was done, in part because neither institution wanted to push too hard, for fear of the other winning the whole pot. Also, there were more practical considerations, housekeeping issues that become important when large numbers of specimens are concerned. At Kew, the cabinets had movable shelves, which make shifting specimens during a reclassification easier. If everything went to the museum, there would have been a massive reshuffling job, and it would be a nightmare to try to use both types of cabinets. Also, the two institutions employed different mounting techniques and differently sized sheets. There was a discrepancy of an inch in each dimension: the museum's sheets were larger and so wouldn't fit in Kew's cabinets if the two collections had to be integrated. These seem like trivial considerations, but in this case, they became deal breakers. As an aside, the Kew sheets became the standard size.

On this side of the Atlantic, there were also political issues affecting collecting. These were discussed by Edgar Anderson (1952) in his classic, *Plants, Man and Life*. I was led back to this book, which I had read and loved years ago, by Kim Kleinman's (2003) article on it, in which Kleinman discusses Anderson's views on herbarium management. Anderson was a plant taxonomist working at the Missouri Botanical Garden. He was interested in cultivated plants, including irises, and eventually became fascinated by the puzzle of the wild origins of corn. His book deals with all this, and he is as opinionated about herbaria as Hooker was, but for different reasons. Anderson argues that most herbaria are rich in wild plants and extremely poor in cultivated plants. This is because most curators and researchers associated with herbaria are interested in indigenous plants, for which the location of the plant is important. With cultivated plants, things can get much messier. They can be planted anywhere by humans, and they can have a myriad of different forms, thanks to the work of plant breeders and horticulturists. Again, it comes down to logistics: dealing with too many specimens and trying to find room to store them. So the solution is usually to exclude cultivated plants.

This is not a universal situation – cultivated plants are more welcome in some herbaria, particularly those tied to agricultural schools – but Anderson was painting a rather bleak picture to prepare the reader for the solution he had devised and wanted to promulgate. Since a corn cob can't be pressed between two pieces of paper, and a corn plant is a little large for a 16.5 × 10.5 inch sheet, he uprooted corn plants, set them against a grid to measure height, and photographed them. He also photographed the ears and tassels. He attached these pictures to a standard herbarium sheet, sometimes including kernels in an envelope along with other pertinent information. In other words, he devised a way to get even difficult cultivated plants into a herbarium. I don't yet know enough about herbaria to know if his idea caught on, but it suggests something more fundamental than a storage problem. It suggests a difference of philosophy, and perhaps even of values held by those who study wild and cultivated plants. Another important name in the history of plant biology, Liberty Hyde Bailey, called the herbarium he founded a "hortorium" to emphasize his interest in cultivated plants; it's now housed at Cornell University (Dorf, 1956).

## ○ Herbaria in the Future

Perhaps what I've found most interesting in my exploration of herbaria is that along with their rich history and present-day usefulness in research, there is the prospect of a fascinating future. This is despite the fact that many herbaria are being closed and others amalgamated. First, there is the growing importance of herbaria in the study of global warming. Among the articles Kathleen Pryer shared with me was one on the possible effects of climate change on California's endemic flora (Loarie et al., 2008); it was based on a survey of herbarium specimens tied to geographic data. That's one of the exciting new trends in herbarium work: georeferencing or finding GIS coordinates for specimens. This makes the mapping of plant distributions much easier and so makes herbarium information richer. Georeferencing is often done along with digitizing the data on specimen labels, and in some cases with the creation of high-resolution digital images (Funk, 2010). Digitization is an exciting trend in herbarium work, but it is obviously costly, especially for collections like those of the New York Botanical Garden and Kew that have over 7 million specimens each. It is type specimens that are usually digitized first, and important historical collections such as those of Linnaeus and Darwin that I've already mentioned.

Another study validated the use of herbarium collections as a source of phenological data in climate-change research. Predictions of peak flowering time for the orchid *Ophrys sphegodes* (Robbirt et al., 2010) based on herbarium specimens were found to correlate well with observed peak flowering times in the field. This information suggests still greater value for herbaria in the future; comparing historical and present-day specimens can help track changes in flowering times. If that weren't enough, a recent study done at Kew found that the discovery of new species was much more often based on herbarium specimens than on recently collected material (Bebber et al., 2010). In fact, only 16% of new plant species were described in publications within 5 years of collection, and nearly a quarter waited over 50 years to be identified – in one case, 210 years. The authors of this study argue that plant taxonomists should be concentrating on herbarium studies rather than field work in attempting to identify the estimated 70,000 flowering plants that have yet to be named.

Marie Long, a research librarian at the New York Botanical Garden, brought this paper to my attention the other day, and I think it's a wonderful way to end this article. It celebrates the importance of herbaria and helps to explain why I am in love with them. They are treasure troves of history and biology, and they are full of beautiful plants that are wondrous to behold.

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