

The Herbarium As a Data-Bank

The practice of collecting plant samples to be preserved for one purpose or another is very old indeed. While initially it may have reflected in part man's inherent curiosity about the natural world around him, he must have collected these samples largely because of some real or fancied property important to his survival. Food plants, medicinal herbs, as well as those with magical powers to control the reactions of friends and/or enemies, are examples of the utilitarian thinking that undergirded the earliest plant collections. These along with pretty stones, fossil bones, butterflies, and other objects of nature were gathered in "cabinets of curiosities". Ultimately, of course, these proto-herbaria were recognized as important documentation of the kinds of plants, their distribution geographically and temporally, and their variability and evolutionary history, but in saying this I have omitted a long period of development of plant collections which continues even now.

In spite of the early interest of Greek philosophers in the properties and identities of plants, the first herbaria, as such, were established only about 425 years ago, in 1543 at Pisa by Luca Ghini (Stearn 1971) and at the University of Padua and Florence in 1545. It was almost 200 years more before herbaria were used extensively in the generation of classificatory systems by Linnaeus and others. Now, 200 years after Linnaeus, something like a thousand herbaria of various sizes, distributed over the world, contain upwards of 200 million specimens. We must recognize this as a significant accomplishment, but also as the source of enormous problems of organization, inter-communication, and support in terms of both people and funds. It is appropriate to the times, especially on this centennial of one of America's great botanical centers, to ask whether the herbarium as an entity continues to meet the needs of modern biology. I believe the most objective answer must be, only partially. If that is true, how can it become more responsive to the present, as well as the anticipated future requirements for botanical information?

We are told (Shetler 1969) that herbaria originated and were

organized by and for the use principally of descriptive botanists. This surely is not surprising nor pejorative. There are many other demands, however, which have existed, or are now emerging in most insistent terms, that must be satisfied somehow if the herbarium is to continue to be a viable organizational entity, supported by society because its information content/accessibility is significant to problem-solving. After all, its principal reason for being is that it is the source of diverse botanical data and as long as only taxonomic purposes are served, there is little cause to restructure anything to recover those data in a timely fashion. However, can the urgent needs of systematic and environmental biology be satisfied by modern herbaria without some modifications in structure, attitudes, functional relationships?

I very much doubt that any man-created institution can survive indefinitely without some genuine, major relationship to the context in which it exists and this is so very true of scientific institutions. As an especially poignant example of the truth of this statement, let me mention briefly the forthcoming national symposium on the development and management of the primary systematic resources; that is, collections and libraries.

One response by the National Science Foundation to the report submitted January 1971 by the Conference of Directors of Systematic Collections is recognition that the needs of systematics resource centers are clearly established. A second response, following closely on the heels of the first, is that the needs surpass present and near-future capabilities of the National Science Foundation to meet them and a "national plan" is essential to distribute what resources may become available in ways that will have the greatest benefit for science and the nation. The evolution of a national plan instantaneously is unlikely but the message is unmistakably clear — the systematics centers must find ways in which they can operate more effectively, *together*. That some of our present autonomy is bound to be sacrificed is obvious but some other, perhaps more drastic, changes will doubtless emerge from such planning in the near future too. The alternative is to maintain the *status quo* and perhaps increasingly lose relevance and, as a consequence, also lose support that is already woefully deficient in most collections centers. So a review at this point of the role of the herbaria as it is and has been, as well as its potential, is a worthwhile objective.

Initially, as I indicated earlier, the creation and maintenance

of plant collections was largely motivated by economics and folk uses but one can believe that the first true herbarium developed at a university because of the necessity to transmit existing botanical knowledge to successive generations through the educational system. This is no less urgent today and most of our universities maintain at least teaching collections, although of the five largest herbaria, with the notable exception of Harvard University, all are at non-degree-granting institutions. In fact, in the last decade there was a considerable trend to transfer all except teaching collections to these great centers but this may have slowed with greater realization of the potential value of these materials and with the passing of the molecular biology bandwagon which has found its proper niche in relation to the rest of biology. What we have seen, I think, is the evolution of two kinds of herbaria, teaching collections and research collections, which may be a healthy division of labors. Most academic centers should perhaps concentrate on the development of teaching collections and documentation of their state and local floras. The research herbaria could be expected to develop global representation of plants from all regions, each herbarium with one or more emphases in which it would be responsible for developing great depth in its collections.

The second major role of herbaria has been to provide services, largely identifications, and such division of responsibilities as suggested above would certainly facilitate this function. Because the roles of many herbaria are inexact and also because there are all too few curators to provide these services, an archaeologist, agriculturist, or ecologist may be totally frustrated in the search for systematic botany data. The largest obstacle to providing such data in a timely way is the lack of people, a shortage which has become more serious in direct proportion to the increase in professionalism of the curator. In earlier times he was frequently little more than a highly competent, knowledgeable cataloger-identifier, often with little understanding of or interest in the broader biological, philosophical bases for his work. With each succeeding generation, the level of professional competence has increased and today's curator must be reckoned with as a serious scientist whose researches are as harmful to interrupt for mundane routine services as are those of the more fashionable sub-disciplines of any moment.

One way in which this impasse that arises from needs for services as well as for research can be met is by the recognition in the major centers of the usefulness of three kinds of individuals — the "curator", the researcher, and the professional

technician. The “curator” is similar to the herbarium botanist of yesteryear, who functioned essentially as a source of identifications and of related data. Motivated by a compulsive desire for order, for knowing *what* grows *where*, he was a most useful scientific colleague. As our understanding of processes and principles expanded in the course of advanced education, a new insistent kind of question was added to those of *what* and *where* — *WHY*. Both sets of questions still are, and always will be, valid but the *WHY-kind* of problems attracted a somewhat different breed to systematic biology, with the care of collections, in some instances, taking second priority. Thus, most major collections might meet needs more adequately with a staff consisting of some para-professional “curators” with technicians, aids, or other assistants to organize the data, the documentation, and to provide services generally. The research staff of such centers are then free to develop, singly and collectively, in concert with practitioners of other disciplines at times, the answers to the many “*whys*” and generally to generate the factual data for providing the services required.

As Shetler (1969) points out, the herbarium has served many purposes, especially those which are based on the concept that the collections are an inventory of plant diversity in terms of kinds and distribution. One may identify several use-phases: A descriptive phase, followed by a phytogeographic one, are the earliest stages in the herbarium “life cycle”. In the descriptive phase, the emphasis is on the accumulation of representative materials of as many different taxa as possible from anywhere and everywhere. Some herbaria and their curators never evolve beyond this stage but in most, taxonomy grades into systematics and the growth of the collections has more direction both in terms of taxa and geographic representation.

The next phase of botanical taxonomy, the biosystematic, has its characteristic influences on the development of herbaria too, whatever the term “biosystematics” means to each of you. Population samples of the taxa under study are amassed in great quantities for such studies and while they may threaten to overwhelm the ordinary herbarium, these samples are surely valuable documentation materials, just as much as those in conventional herbaria. Obviously, however, there is neither space, equipment, nor caretaking available for such vast accumulations of what may appear to be “duplicates” in many instances. At the National Herbarium these vouchers for taxon variability are kept in files separate from the “regular” herbarium as a special collection, partly perhaps because no one

is completely certain whether to keep or discard them. Certainly they are not duplicates in the usual sense, one of several whole plants or parts of plants collected under the same collector's number.

The most recent phase in the development of plant taxonomy is what Shetler calls "ecosystematics" or ecosystem taxonomy. If it is not already clear that all these phases continue to coexist in the present, let me emphasize that point now. It is that just now, botanical collections, indeed all those of systematic biology, have the opportunity to serve new purposes in addition to those they have always provided for previously. In meeting the new challenges of ecosystematics, the herbaria have an enormously important opportunity to address many of the problems with which they have been grappling only partially successfully from the beginning. Although the time is ripe for new strategies, we are scarcely prepared to meet the needs that are with us even now. Change is so rapid that only the most innovative thinking will serve to ensure the herbarium the place in science most of us would like, that in which we are not required either to operate without adequate support or to be constantly grubbing-out only survival-level support. Let us look at some of the recently developed and future demands of herbaria resources which, if met, contribute to the effectiveness of plant collections and the people who tend them.

While not novel, strictly speaking, the use of herbaria in the search for new drugs and other economic plants seems almost a reversion to some of the earliest uses of collections. The U.S. Department of Agriculture has for decades carried on field and herbarium studies toward this goal and currently their global search for cash crops that might replace the culture of poppies and other drug plants in countries of the Near and Far East is an especially dramatic example. Herbaria as they are presently constituted are reasonably helpful to such efforts but data needs that cut across the ordinary organizational criteria (phylogeny and geography) of most herbaria are accessible only at great cost or, more often, not available at all.

It is in the field of environmental research that herbaria are excitingly challenged. The use of plants, phanerogams and cryptogams, to detect and monitor environmental change is a genuine prospect, if the associated data resident in the relevant collections can be extracted and organized for recovery. Such a use of collections is not unlike those with which we are somewhat more familiar, as for example the use of plants to indicate soil fertility, the presence of economically important minerals,

the presence of salt or other materials unfavorable to most plants, and the water content of soils. Some very interesting work has been done on the effect of air pollution on flowering plants, as well as some cryptogams, but most collections of phanerogams in herbaria have been made to avoid damaged foliage, so they may be somewhat less useful for tracing environmental degradation. On the other hand, such plants as the aquatic, unicellular, and colonial algae are most useful in that they are differentially affected by water pollution. Thus, the species composition at a particular site now and in the past, as shown by collections, may be highly significant for detecting the onset of water quality loss and tracing its history. Similarly, the distribution of lichens in industrial countries coincides precisely with the distribution of air-borne pollutants. It is reported that if one plots the distribution of lichens in some areas of Western Europe, the pattern of distribution of industrial pollutants is plotted simultaneously.

Still another use of herbarium collections is in a relatively new field, sometimes called landscape planning. Two botanists at Colorado State University, using advanced electronic equipment, have constructed a system for data control that is proving extremely valuable for management of the lands of that state. They collect information on the distribution of plant species and plant communities and plot these data electronically on base maps of the state. Then by superimposing plans for placement of new housing or new agricultural areas on plant distribution maps, it is possible to avoid serious mistakes and to make the best use of the lands for each of several purposes. Because many plants are sensitive to altitude, soil nutrients and water, etc., the potential impact of botanical data on long-range planning for the best utilization of environmental resources is a most important aspect of our botanical future.

One thing is sure, all these new and future uses of botanical information require sophisticated computer equipment and software technology. The major herbaria of the future will have computerized control of selected kinds of data, although not necessarily in each center on an individual, unilateral basis, nor will there need to be developed banks of all the data from all the collections in any herbarium. It is entirely practical and attainable, indeed mandatory, that segments of the total data represented in the principal botanical data centers be made available — for a price in both people-time and money. It is just as certain that not all the three-plus million plant collections in the National Herbarium or the New York Botanical

Garden will be mindlessly cranked into a data-bank, for there are probably at least half of all these that do not have appended data worth incorporating in any data-control system. On the other hand, we could be capturing data regularly from newly arriving materials in all the most actively growing centers. At the same time, these botanical centers should be prepared constantly to respond to the needs for latent data in the collections that can be made available when those who need the information are willing to pay for its extraction from the herbaria. This, like the need for identification and other taxonomic/systematic services, poses no real problems so long as they are budgeted for in advance. No longer can the taxonomic community provide any of these services as if they are not costly, as if they are of secondary importance to other sets of data for which people expect to pay.

The Flora North America Program illustrates very well indeed the kind of data-control system I believe is mandatory for systematic biology generally, if it is to have a vital role in human affairs of the future. Just as present arrangement of data in herbaria is unidirectional, the data presented in conventional floras, monographs, and revisions provide answers to questions that parallel their structure, but just try a question that requires search across the lines of organization of the data presented, questions such as which of the species grows with what others at x-1000 feet altitude and flower in June-July! Another kind of question needs asking — how long does it take to produce a definitive flora of a state, or of a particular phytogeographic province, even if the funds were available? Then at what cost the next edition of such a flora? An example of what I mean by questioning the cost of a second edition is provided by a current entomological project in the National Museum of Natural History. The names, distribution, etc. of the Hymenoptera were compiled in a catalog published by the Department of Agriculture in 1950. Now, after two decades of new research and data accumulation, specialists are no longer able to retrieve their information rapidly and a new edition of the catalog is being prepared using machine methods. Interestingly, the new edition will be produced more economically, but even more important, all the data in the catalog will be on magnetic tape where it can be corrected or added to as required. At any point in the future, the third edition or any part of it can be generated by the computer with minimal human attention at that point. This kind of capability is going to be needed in all areas of systematic biology, I am convinced.

The Flora North America as such a data-bank is an entirely viable concept. Once the existing information on North American plants is collected, collated, edited, and input to the data base, the possibility of answering many existing questions, including floristic treatments of various geographic, altitudinal, or phenological parameters will be semi-automatic. The taxonomist, rather than rearranging the data along still one more set of criteria, can be truly gainfully engaged in collecting new information and refining that existing in the bank. I am not presuming that this transformation will come quickly or inexpensively but it is unquestionable that the rate of publication of new information far exceeds the capacity of any of us to keep abreast of it. Will we use all the tools available to us and maintain our central role in addressing man's needs, or will we use only those that are familiar, those that satisfy the individual taxonomist's needs and the handful of his kind in the world interested enough in his work to request a reprint? The time to act with vision, with dynamic purpose is now. Even if we were concerned only with data from gross morphology and phytogeography, the time is now to find ways for more effective storage and retrieval of the facts. When we add to these, as we certainly must, the anatomical, embryological, cytological, and biochemical knowledge, taxonomists are more likely to be overwhelmed by the wealth of data than assisted in achieving improved understanding of evolutionary sequences and relationships.

These remarks are not intended to be an attack on either traditional publications or on the herbarium as an institution. What I am speaking of is an extension to the usefulness of both by the application of data-processing technology to enhance their information value for the present and future. Clearly, systematists generally must evolve better means to deal with the millions of specimens and to make better decisions about the necessity of collecting additional ones; to control systematic data gleaned from the collections in such a way that they may be rapidly compared with new data; and to make available the data in published form so that the efforts of each generation of systematists will be truly additive, rather than repetitive or of minimal importance. There is too much to be learned of the planet's plants and animals for systematists to waste one day, one word in unproductive investigations and the need to know far exceeds our ability even to accumulate the data. We are already coming to the point in many parts of science where it is simpler to redo a study than to discover whether it has been done adequately!

Lest someone concludes from my remarks that computers are the long-awaited panacea for all our problems, I want to emphasize that the need for good observations, sound judgments, and the other attributes of the human mind is not eliminated by the machine. Rather, the mind of man no longer needs to be cluttered by the inconsequential and it is thus freed for creative accomplishments at new levels. The taxonomist now is able, with this tool, to have access to any number of taxa, to discover new relationships and immediately associate these with those in the multi-dimensional data-base in storage.

The role of the herbarium and those who are its curators has been to bring together samples of the world flora, to arrange and conserve them, to conduct studies of the identities and relationships of the taxa the specimens represent, and to make accumulated botanical wisdom available to those who need it. In spite of dire predictions to the contrary, that most species of organisms will disappear before being known, there is greater need to continue taxonomic/systematic studies than ever before, but with a very clear new attention to those groups with the greatest potential for being important to man's struggle to adapt to new threats. The results may not enable us to be much more definitive about plant phylogeny but we may be able to preserve more of the earth's germ plasm in botanic gardens, arboreta, and other such live collections if we know it exists. Also, we may be able to preserve more of the aesthetic as well as practical aspects of our surroundings if we know them and their properties.

So herbaria and their curators have a well-defined, important role today. With imagination, innovation, and inspiration, herbaria, systematic collections generally, have an expanding, nearly limitless role tomorrow.

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