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Cover: Tangential section of hemlock wood which is infected
with dwarfmistletoe. Photo: L. Srivastava.
Centennial Symposium:
The Potential of Arboreta and Botanical Gardens

[Papers presented during the two concurrent morning sessions of the all day Centennial symposium, May 23, are being reprinted in this issue. In March-April, those of the afternoon sessions will be published, along with the text of the alternate speaker.]
Moderators

HOWARD S. IRWIN, Executive Director of the New York Botanical Garden

R. HENRY NORWEB, Jr., Director of the Holden Arboretum

PETER H. RAVEN, Director of the Missouri Botanical Garden and Professor of Biology, Washington University

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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
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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Bibliography

Ornamental Plant Introduction—
Building On the Past

It is a particular pleasure to participate in the Centennial Celebration of the Arnold Arboretum, not only because of the esteem with which we all hold "The Arnold", but also because of the fact that I have been assigned a subject to which I have devoted the major portion of my career — plant introduction and exploration.

As many of you know, plant introduction is a foundation stone on which a successful arboretum, botanic garden, or like institution, must build. Any one of the special activities that is encompassed by the broad term "plant introduction" can be an exciting program, whether simply exchange of plants and seed, the undertaking of actual field explorations, or the subsequent evaluation of introduced plants. The Arnold Arboretum has been deeply involved in all these pursuits and, because of its role in the introduction of new trees and shrubs and the explorations of E. H. Wilson in Asia, has often been called "America's Greatest Garden".

During the course of the past 100 years, the Arnold Arboretum has introduced more than 2,000 new plants, of which 60-70 are common in American gardens. The Arnold Arboretum is, of course, not alone in such activities, although during the early part of the 20th Century it was the Arnold Arboretum and the U.S. Department of Agriculture that were responsible for the majority of introductions through exploration. Today, many arboretums and botanic gardens are engaged in plant introduction, and there is no longer a single "greatest garden" but, rather, many great gardens share in the efforts to introduce new plants to the American public.

Although the USDA has been engaged in plant explorations since 1897 and has undertaken over 150 explorations, these have been mostly for economic crop plants. Early USDA explorers did not ignore ornamental plants when encountered, but only the Arnold Arboretum sent out collectors whose main objective was to collect ornamental plants. It is fairly safe to say that these two organizations have pre-empted plant ex-
ploration for the United States, while English collectors have been in the same position in Europe. In 1956, however, the USDA, as a result of the cooperative Longwood-ARS program, assumed the leading role in ornamental plant exploration which I will discuss later.

The history of plant exploration since about 1900 is replete with incidents of high adventure, encounters with adversity and tragedy, often in the loss of valuable plants enroute, failures after plants had arrived, and, sadly, in the death of plant collectors in the field—Frank Meyer (1918), Reginald Farrer (1920), and George Forrest (1932)—all of whom met their fate in the China or Burma region. While it is the professional explorer who must receive the plaudits for his contributions to horticulture due to his authoritative role and, in part, to the better documentation of his collections, mention must be made of the missionaries, doctors, foreign service officers, and occasional travelers who accounted for many of our plant introductions. A medical missionary, Ralph Mills, collected the handful of seed of Korean Lespedeza (Lespedeza stipulacea) in 1919 that was the basis of this multi-million dollar crop. A missionary, A. S. Cooper, introduced the lot of seed of Ilex cornuta, P.I. 65860, from which the widely-used clone 'Rotunda' was selected. The USDA inventory states that he collected the seed near Ichang, China, in 1923. Those of you who are familiar with the travels of our Chinese explorers will appreciate that this was the principal starting point on the Yangtse River for journeys into western China. This lot of seed was sent to the McIlhenny Estate, Avery Island, Louisiana, where it was sown and the seedlings planted into a long hedgerow. From this highly variable introduction, nine named selections have been made. Another scarcely-known collector was the departmental pathologist, R. Kent Beattie, who traveled in Japan and Korea from 1927 to 1931 while studying chestnuts, particularly Castanea mollissima and C. crenata, for sources of resistance to chestnut blight. In addition to large shipments of chestnuts, he sent back a number of ornamental plants. But, chiefly, he should be remembered for the collection of some 80 evergreen azaleas that were used by B. Y. Morrison as parents in the development of the Glenn Dale azaleas. When I traveled to Japan in 1955, Beattie's notes on Japanese nurseries and the lists of rare plants he encountered there were most valuable since the nurseries still maintained many of the plants described by Beattie. Today, because of very strict international quarantines, limitations of where most people can travel in foreign countries,
and fewer opportunities to encounter unique plants, the role of the casual collector has all but disappeared.

I should now like to return to the professional plant collectors and comment on some of their journeys. The grand period of ornamental plant exploration began just prior to 1900 and continued up to about 1930. In 1899, E. H. Wilson set off for China on behalf of the English firm, Veitch and Sons. Before starting his field work, Wilson spent some time with the famous British medical officer, Dr. Augustine Henry. Henry was one of the most learned botanical collectors of the 19th Century, with years of experience in China, and was stationed at Ichang from 1882 to 1889. Wilson's two trips for the Veitch nursery in 1899 and 1903 netted a number of important ornamentals of western China, but chiefly his early trips are remembered for the introduction of *Davidia involucrata* and *Meconopsis integrifolia*. On Wilson's return to England, his reputation as a plant collector was established. Here begins one of the more intriguing developments in plant exploration of the early 20th Century.

David Fairchild, champion of plant exploration in the Department of Agriculture, was responsible for many of the Japanese economic and ornamental plants introduced into the United States. He arrived in Japan on April 26, 1902, but, according to his notes, too late to see the flowering cherries he had set out to collect. However, he traveled the length of Japan, sampling the curious edibles with enthusiasm. The margins of his field map are annotated with notes on interesting plant localities. During his journey, he noted the extensive use of *Zoysia japonica* as a lawn grass and sent the first introductions of *Zoysia* (P.I. 9299-300) to the United States, along with a collection of 18 bamboos and 30 varieties of flowering cherries. To David Fairchild we owe recognition not only for his own collections, but also for his sustained encouragement of the Department's plant exploration program in China, resulting in vast numbers of plant introductions that have contributed to American agriculture.

Charles S. Sargent, who had already been to Japan in the fall of 1892, was also determined to develop a leadership role for the Arnold Arboretum in plant exploration in the Orient. While Sargent spent only 10 weeks in Japan, his journey to Mt. Hakkoda was most rewarding. Not only must it have encouraged him to give primary attention to woody plant introductions from the Orient, but he introduced *Rhododendron kaempferi*, *Acer nikoense* in large quantity, and several mag-
nolias into the United States. It was here that he may have been encouraged by James Veitch to emphasize collecting in China. Japan for many years after was not intensively explored for ornamental plants.

Fairchild employed Frank Meyer, a Dutch immigrant, in 1905 to undertake extensive explorations in China. Meanwhile, Sargent was negotiating for the employment of E. H. Wilson, who finally accepted to collect in China for two years and hoped to return to become a member of the Arboretum staff. Meyer arrived in China in 1905 and concentrated on economic plants near Peking during the first winter, then moved down to the Yangtse River in the spring of 1906 and slowly journeyed northward during the summer as far as Manchuria and western Korea, collecting small grain cereals, forage crops, and soybeans. His shipments from northeast China included, as well, fruits with unusual hardiness and a number of shrubs and shade trees.

Wilson arrived in China in 1907 and met with Meyer in Shanghai on an arrangement between Sargent and Fairchild. Meyer explored the Lau-shan mountains and agreed to collect in the Wu-tai mountains, a rather desolate and disappointing region. Nevertheless, Meyer collected more than a thousand seed and plant specimens from North China and returned with a wealth of information on dry-land farming methods and other facts on Chinese agriculture. Wilson, meanwhile, traveled his familiar route up the Yangtse from Ichang and spent the next two years collecting in western Hupeh and Szechuan, from Cheng-tu across the mountains to Tatsien-lu, and covered the triangle formed by the mountains Wa-wu-shan, Wu-shan, and Omei-shan. Keep in mind that, although this was only a journey of less than 100 miles, the terrain was of such a dangerous nature it was indeed a remarkable trip and yielded more than 2,000 packets of seed and 1,400 living plants. Both explorers returned to the United States; Meyer in 1908 and Wilson in 1909. And both soon were back in the field; Meyer in central Asia in 1909 and Wilson again in China in 1910. The accounts of their further journeys are so familiar that I need not go into them here.

From the various letters and comments in books by and about Fairchild and Sargent, there was to continue an obvious amount of professional suspicion throughout their relationship. It is somewhat reflected in the attitude of Wilson and other collectors toward the rather morose Meyer. But I can find no similar attitude of his colleagues in the letters written by Meyer to Fair-
child. Indeed, Meyer’s methods of collecting, with little attention to herbarium specimens and other supporting materials, his patient resolve to remain in the field in winter, and his attitude toward the Chinese customs, seem to have annoyed other collectors in China (see Farrer, R. *On The Eaves Of The World*, Vol. II: 276–282. 1917). Herein Farrer describes, with his vivid flair for over-emphasis, his encounter with Meyer in the village of Siku, Kansu Province in 1914. It is one of the enjoyable insights into the highly complex attitudes that prevailed among these individualistic collectors. It must also be remembered that Purdom, who had followed Meyer on an equally unfruitful journey to Wu-Tai for the Arnold Arboretum in 1909, was now the traveling companion of Farrer during the 1914 expedition to Kansu and may also have influenced Farrer’s opinions.

Despite their keen competition, these two very strong leaders (Fairchild and Sargent) did not permit their feelings to interfere with the sharing of introduced materials between the Arnold Arboretum and the USDA. This cooperation has continued through the century to the general benefit of American horticulture.

The fervor of plant collecting in western China peaked just prior to the First World War. No fewer than six well-known British and American collectors — Farrer, Forrest, Kingdon Ward, Meyer, Purdom, and Wilson — could be found attacking the great snow ranges of western China, up from Burma as seemed to be the route for Forrest and Kingdon Ward, or along the Yangtse River with Ichang as the starting point for Wilson, and the North China route for Meyer, Purdom and Farrer. Following the First World War Joseph Rock began collecting, first for the USDA in 1920 and later for the Arnold Arboretum and the National Geographic Society, until 1934. But now, Meyer and Farrer were both dead and Wilson had left off field work, leaving Forrest and Kingdon Ward to continue collecting. Kingdon Ward was the only one of this group who carried on into contemporary times. His field work exceeded 40 years and the amazing record of 23 expeditions. Few, if any, more recent collectors of note of ornamental plants can be added to this list. Fairchild did, however, continue his travels in the 1920’s and 1930’s to Europe, Africa, and South America, expounding on the importance of plant exploration and encouraging others to collect. The USDA continued in its collecting of economic plants and sent 38 exploration teams into the field between 1930 and World War II, and many of these collectors sent home ornamental species.
Time does not allow for a discussion of the many introductions of plants obtained during the first 40 years of the 20th Century that survived the rigors of climate, war and depression, and horticultural acceptance to become important nursery plants. These are well documented in horticultural literature. As for plant exploration, an era was at end. No longer would explorers roam remote places on trips of several years’ duration and the methods of collecting and shipment would be sharply changed by the advent of plastic films and the airplane. As for China, it was thought that the cream of the species had been collected already and there was little reason to continue interest in that country. But it should be noted that this same opinion was voiced prior to the explorations that began the 20th Century.

The present era of plant introduction opened with a resounding discovery. *Metasequoia glyptostroboides*, previously known only from paleobotanic records, was discovered in China as a living species in 1945. Following this lead, the Arnold Arboretum promptly supported an expedition to the locality on the Szechuan-Hupeh border. As a result, a limited stand of about 1,000 trees was discovered in the Shui-sa-pa valley in Hupeh. Seed from this find was widely distributed by the Arnold Arboretum in 1948 and seedlings became established in almost every suitable locality around the world. I first reported on the rooting of *Metasequoia* from juvenile cuttings in 1948 and the National Arboretum selected and released a clone, ‘National’, in 1963 from P.I. 16188. This came from seedlings growing at the National Arboretum as the result of a shipment of seed sent from the National Central University, Nanking, to the USDA in 1948. I believe no species received as wide and as rapid a distribution around the world as was the case of *Metasequoia*.

The finding of *Metasequoia* in a locality not far from where many early explorers had worked rejected the concept that the enormously rich flora of China had been sampled to the point of diminished returns. The opportunities to find new forms and more useful variants of ornamental plants in China was as promising as at any earlier time.

During the first several years after World War II, arboretums that received scant support prior to World War II, such as the National Arboretum, began to progress markedly. Their interests turned to the evaluation of the many early introductions now reaching maturity in our arboretums, botanic gardens, and other test localities. A broader interest in horticulture resulting from the development of suburbia caused horticulturists...
to look for better and different types of trees and shrubs. Dr. Donald Wyman provided outstanding leadership in this research evaluating hundreds of species and varieties trying to develop lists of those with the best qualities. Others followed this same approach. For example, when Frank Meyer collected seeds of Pyrus calleryana in China, his main purpose was a source of fire-blight resistance. The ornamental possibilities of this species were not even considered. In 1952 I selected a tree from the few specimens of P. calleryana remaining at the U.S. Plant Introduction Station, Glenn Dale, Maryland, grafted it onto P. calleryana seedlings, and established the trees in a nearby subdivision for a street tree study. Over the ensuing years, this selection has become more and more popular and the USDA named it 'Bradford'. Today, the 'Bradford' pear is regarded among the top ten trees for street planting in eastern United States. But it is limited in its cold-hardiness. Perhaps a search of its native Chinese homeland will locate additional germ plasm for evaluation. This species, it is important to note, was first introduced into the United States in 1908 by E. H. Wilson.
Ornamental exploration had yet to fully recover from the War years. Kingdon Ward was back in the field and conducted six explorations in the Assam-Burma area between 1946 and 1957. The Royal Horticultural Society and the Japanese sent teams of explorers to Nepal in the early 1950's. In the United States a new concept of plant collecting resulted from the 1946 Research and Marketing Act. It gave support to foreign and domestic exploration on a sustained basis. Previously there were few Federal funds for explorations, and no mechanism to provide for inputs by States and others in determining priorities for exploration. Under the new Federal/State cooperative program plant explorations became mission-oriented with emphasis on collecting to fill the gaps in our germ plasm base of specific crops. General collecting became a thing of the past. In addition to introduction activities, this program provided for four regional introduction stations — Geneva, New York; Ames, Iowa; Experiment, Georgia; and Pullman, Washington. Later a special inter-regional potato station was established at Sturgeon Bay, Wisconsin, and in 1958 a National Seed Storage Laboratory was established at Fort Collins, Col. to house our genetic resources under optimum conditions for long term storage.

Provisions were also made for domestic explorations, taking advantage of the many experiment stations and their scientific staffs to conduct the field work. Since 1953, 39 such collecting trips have been made, of which 9 have been for native ornamental plants, including rhododendrons, junipers, mountain ash, and ground covers. While the principal objectives of the regional stations were preliminary evaluation, increase, and distribution of plant introductions, some ornamentals were tested on a regional basis and released as named varieties. ‘Cheyenne’ privet, P.I. 107630, collected by Edgar Anderson during an Arnold Arboretum exploration in Yugoslavia in 1934, was introduced into the trade because of its superior hardiness in the northern Great Plains. A sweet basil (Ocimum basilicum) collected in Turkey during a field crop expedition in 1949 was named ‘Dark Opal’ by the Connecticut Agricultural Experiment Station because of the purple coloring of foliage and flowers. It received the bronze medal in the 1960 All-America trials.

Despite the profound effort at organized introduction of economic crop germ plasm, ornamentals did not share in the support. Quarantine laws had been tightened and many of the ornamental trees and shrubs previously imported from Europe
were prohibited. This was unfortunate in that arboretums like the Arnold, Morton, National, and University of Washington were renewing their activity in assembling clonal material from European sources. In order that new material might reach the U.S., the Arnold Arboretum proposed a program to the USDA in 1953 whereby restricted plants already known to be in the U.S. would not be re-introduced. Rather the Arnold Arboretum would act as an “agent” for other gardens, and evidently “new” plants would be shipped from Europe to the Plant Introduction Station at Glenn Dale, Maryland, for quarantine. After the required 2-year quarantine, the plants were then released to the ordering institution and propagated for other gardens. Individual botanic gardens and arboretums also searched European nurseries for non-restricted plants and these have continued to be introduced in order to fully understand the variation in our ornamental species and to locate improvements over current cultivars.

Perhaps the most significant event in modern ornamental exploration was the initiation of the Longwood-ARS program in 1956. Recognizing that current Federal programs did not include ornamental collecting, Dr. Russell Seibert proposed that ARS enter into an agreement with Longwood Gardens to collect ornamentals on a sustained basis. For the first time public and private institutions were joining forces to meet the needs of the gardening public by collecting wild and cultivated plant materials in the fashion of the early explorers. In order not to conflict with other efforts, the Longwood-ARS program concentrated on regions of the world where exchange of plants and seeds could not be easily accomplished; it supported explorations to centers of origin of important ornamentals, and provided for a thorough survey of botanic gardens and nurseries of Europe for improved varieties otherwise not available to American horticulture.

Thirteen explorations have now been completed under this program. Of these, 9 collecting trips have been to Asia, virtually ringing mainland China. The two most recent were the New Guinea exploration by H. Winters and J. Higgins in 1970 and my own journeys to Siberia in 1971. Materials collected on all these explorations are shared with experiment stations, botanic gardens and arboretums, and the nursery trade as rapidly as possible. For example, a large group of Impatiens collected from the 1970 expedition to New Guinea has already been released to growers. These have created considerable excitement by their striking range of flower color and variation in form.
and foliage. This material will be the basis of new cultivars for the commercial trade and, in addition, will provide a wealth of germ plasm for breeding programs.

With this rich history of plant collecting by various institutions and the success achieved in the evaluation of plant introductions, it is now time to look to the future. In relation to economic plants, there is a broad collaborative effort underway under sponsorship of a consortium of international agricultural institutions to develop a global network to collect, evaluate, and conserve genetic diversity around the world. There is evidence that our world's genetic resources of crop plants are being displaced, depleted, and, in the case of some collections, discarded. As a result, priorities for crops and geographical areas have been defined by experts in plant genetic resources for immediate action. Inventories are being developed of the total holdings of collections of crop germ plasm. Despite an inventory of over 2 million items reportedly held by various nations, an FAO survey showed that only 28% are under secure conditions to assure their survival. These are largely in the U.S., USSR, and a few other developed countries. There will be an attempt to place the bulk of our genetic resources into major regional storages before they are lost. The need for immediate action is readily understood.

These programs do not include ornamentals since it is assumed that the various associations devoted to ornamental horticulture will develop their own program. These could very well be along similar lines to those proposed for economic crops. Already the American Horticultural Society is moving forward with its Plant Record Center to document living collections in the U.S. The Longwood program is providing for a long-range plan for exploration and, as discussed earlier, a system has been developed by the Arnold Arboretum to introduce plants normally prohibited from entry. Perhaps our weakest link is lack of a nationally coordinated program for evaluation of new ornamentals and a system of regional testing of superior selections for adaptation. There are some instances of this, but not on a major scale. In the North Central States there is a cooperative regional testing program underway among States and Federal institutions. This began in 1954 and provides for performance trials of selected ornamentals with respect to established criteria: survival, growth, freedom from pests and diseases, pollution resistance, and characteristics of foliage, flowers, and fruit. The results of these trials, reported on a 5-year basis,
provide scientists, nurserymen, and home-owners with reliable information on potentially new ornamentals.

As for plant exploration, we are all aware that the future is on the Chinese mainland just as it was at the turn of the Century. The advent of air travel and access to areas previously unattainable because roads did not exist offer opportunities for collecting beyond what was accomplished by early explorers. In addition, new information gleaned from the ensuing years of evaluation, plant breeding, and taxonomic research provide us with useful priorities for future collecting trips.

The hollies of Eastern Asia, numbering some 120 species, illustrate this point. Although China is especially rich in species of Ilex, we know many of them imperfectly because of the few introductions. A similar situation had existed with the species native to Japan, but it is now somewhat improved. Since 1956 a broad base of variability of the major Japanese species, Ilex crenata, has been introduced under the Longwood program. Over 50 collections of I. crenata representing its total range of distribution in Japan have been introduced and distributed. Seed lots of 14 other species and natural hybrids were introduced for the first time during this period.

One of the very interesting research findings in relation to Chinese species of Ilex is the naming of a new species, Ilex centrochinensis, by Dr. S. Y. Hu of the Arnold Arboretum. Long confused with I. ciliospinosa, this new species was first introduced from China not far from the locality where Metasequoia was discovered. The importance of this species has been its usefulness in crosses with I. cornuta, from which some remarkably fine hybrids have been produced. Since there probably has not been a single wild collection of this particular species introduced under its own name during the last 50 years, it offers a challenge to the future collectors in China. Equally significant information could be developed for other Chinese holly species, i.e., I. cornuta, I. pernyi, I. rotunda, and I. yunnanensis, and for many other plant genera. Just as for economic crop species, ornamentals are threatened with eradication and because of their lower status are usually the first to go when land is diverted to other use. Species diversity, and finally the species themselves, disappear as a result.

As far as future plans for collecting in China are concerned, we might develop various levels of exchange programs such as have been in effect between the U.S. and the USSR since 1959. This initial exchange of seeds and plants on a quid pro quo basis developed into a mutually satisfying arrangement,
leading to four explorations of the USSR since 1963. We know very little about current germ plasm activities in China. It has been estimated that there are over 200,000 accessions of some 50 crops in Chinese collections. This is about the extent of the collections held in the U.S. and in the USSR. Probably a considerable amount of attention has been paid to ornamentals judging from earlier exchanges that took place between Soviet and Chinese botanic gardens. With airports at Cheng-tu, Szechuan, Kun-ming, Yunan, and development of modern roads in Western China, a new and equally rewarding phase of plant collecting in China may become a reality with exchange and exploration initiated simultaneously.

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The Botanist and the Computer

Modern taxonomic botany has changed little from its descriptive origins in the 18th century. With the modern understanding of the plant as a living system and its place in the larger system around it, our descriptive efforts have changed to place the plant in context and not simply consider it as a dried specimen on an isolated herbarium sheet thousands of miles from its origin. In spite of this, however, our science has remained largely a descriptive one, and perhaps it is the pressure of our own needs, plus the pressure from our academic companions in other fields, which has caused us to look to a more mathematical approach to botany. The advent of the computer was a natural beginning to numerical processing of taxonomic data. From initial enthusiasm about ten years ago for numerical taxonomy as the cure-all for taxonomic problems, we have now settled down into a more reasonable and wider use of computers in the field of botany. For many botanists, this early enthusiasm was entered into without a thorough understanding of the tool which made it possible. Today, with 30 years of computer experience behind us and perhaps some ten years of botanical enthusiasm in the same area, we are in a position to look at the equipment available and to evaluate the potential and the pitfalls of the computer as a new tool in the botanist's laboratory. We must, however, recognize that the computer is only a tool and not in itself a solution to the problems of botany. The computer can be used by the botanist only to the extent that he is logical or mathematical in his approach to problem solving. The past literature of botany, which is the data bank of the science, has already grown to such an extent that it is a nearly impossible task to extract from it all the pertinent facts relating to any given taxon. With the number of botanists working today, the situation will continue to worsen unless we start now to logically orient our facts and to place this logical assemblage into a machine-readable form which will allow us to search it and process it as the needs of the individual scientist require.

In recent years there has been an increasing quantity of literature built up relative to the use of computers in the broad field of biology. It is not the purpose of this paper to review the applications of computers to specific problems. This has been done
in part by Crovello and MacDonald in their index of EDP-IR projects in systematics, and also has been covered to a great extent by the papers reported in the *Biological Journal of the Linnean Society* in September 1971. It is the purpose of this paper to present some of the basics of computer operations and the effects they must have upon the approach to botanical problems if proper use is to be made of this new tool. Those persons who have not taken up the new world of computers often continue to shy away from, and in some cases even to fear, the unknown. Many others who have become absorbed in this new technology have often gone to the other extreme and completely masked the products of their efforts in a foreign jargon which has served only to increase the gap between the users and the non-users. This paper is an attempt to both slay the dragons and to bring the prophets back to earth for the greater number of botanists who have remained until now on neutral ground. The central theme of this discussion is that the computer is simply a tool, and in no way is it an end unto itself. The problems to which this modern tool may be applied are not unique to modern thinking, nor does the use of this equipment mean, of necessity, the abandonment of familiar procedures and techniques. On the other hand, a proper comprehension of the potential use of the new tool can lead to entirely new approaches to old problems.

Perhaps it is best to start by looking at what a computer is and what it can do in the abstract. In its most fundamental form, a computer is a machine that can execute simple logical commands. It can be made to compare two sets of data and, based upon the result, can embark upon one or another of a set of previously determined courses of action. In its simplest form, the computer is not a mathematical machine, but it is as a consequence of specific series of logical operations within the machine that various mathematical operations are carried out. Computers in themselves exhibit no intelligence, and it is unfortunate that the anthropomorphic view of these machines has become the popular one. Problems cannot be solved nor questions answered except to the extent that a previously anticipated answer or course of action has been selected as the correct solution based upon a logical and previously determined analysis of the data in hand. In a perhaps over-simplified sense, what computers are best suited to do is to carry out a relatively simple manipulation in a repetitive fashion upon a large body of data. Alternatively, they can also be utilized to process a fairly complex series of operations on a relatively small quantity of data,
but since the operations must all be previously carried out by hand (i.e., programmed), a decision must be made as to whether it is worthwhile to spend the programming effort necessary for a relatively low degree of utilization of the computer.

An early and continuing area of misunderstanding has been the supposed numerical nature of computers. Whereas most computers have been designed for the solution of numerical problems, there is nothing inherent in the nature of the machine which prevents representation within it of alphabetical characters. The concept of numericlature as opposed to nomenclature is both unnecessary and undesirable. The early mechanical limits of fixed field from a punch card origin, and of numericlature as a means to conserve storage space within the computer by codifying otherwise lengthier conventional language statements, have been two facets of the early use of computer techniques which have imposed unnecessary and unfortunate procrustean limits on data processing in botany. These initial difficulties, augmented by an unnecessary jargon and a number of unsuccessful projects initiated primarily in the name of fashion, have led to a slow start in the use of computers within the field of botany.

Before going on to some of the possible advantages of computer utilization in the botanical area of activity, it is perhaps best to digress momentarily in order to discuss a matter which is basic not only to the utilization of computers but in many ways to science itself. Consideration of the broad spectrum of biological problems in light of possible solutions by computer means is, in effect, a consideration of the design of experiments. Perhaps one of the most critical areas in botany in this regard is the general field of taxonomy. Classical taxonomy has, since the time of Linnaeus, been rather in the nature of an art, in spite of all protestations as to its scientific status. The questioning of such status comes not from the end result which has stood the test of time well, but from the manner in which the decision is arrived at. In the physical sciences, an experiment can theoretically be conducted by anyone if the conditions and the equipment involved in the experiment are stated, and if this set of conditions and equipment can be duplicated. Given the same data and the same procedures, the same results should be obtained. What has been lacking in botanical taxonomy and, in fact, in taxonomy in general, has been the specific designation of the parameters involved in any given "experiment". It was precisely the rigidity of such re-
quirements which led to the early misunderstanding, apprehension, and derogatory comment upon the use of computers in botanical taxonomy. It is not, however, the computer which is in question in such circumstances, but the statement of the experiment itself. If the taxonomist is not able to precisely define his terms and with equal precision to define the steps by which he arrives at a given conclusion, then he is unable to describe the experiment. If such parameters cannot be precisely determined and defined, then it is not possible for other individuals to consistently arrive at the same conclusion, given the same starting point. Recent work in the computer construction of identification keys and in random access identification queries in on-line computer systems have shown that the unforgiving taskmaster, the computer, can considerably simplify the task of identification if the logical processes by which a specific identification is reached are rigidly stated.4

The complexity and redundancy of the human mental process, while it is yet to be mechanically duplicated, can be more fully appreciated today than in the recent past. The capability of visualization without apparent quantitization was apparently unique to the human mind. It is now certain, however, that the neuron of the human brain is comparable to the single flip-flop of the computer, but both are meaningless except as they participate in the larger context of the total machine system. The process of learning in the human being is directly comparable, in part, to the building of a data bank in the computer. Furthermore, the learning process consists of considerable reprogramming which, as anyone who has worked with large data banks finds, is also a necessity as one develops the uses of the stored information.

In many fields, such as computer design and chemical engineering, considerable effort has been expended in utilizing the computer both as a design tool and as an automatic means of control. In many cases where the problem has been reduced to a machine-soluble form, it has been the repetitive nature of the task which has lent itself to successful computer application. In other instances, however, the rigid test of logical statement that must be met before the problem can be reduced to computer solution has often times been sufficient in itself. That is to say, that having reduced the problem to a logical statement, it was no longer a problem and could be solved without the use of expensive computer equipment. It is precisely this rigid evaluation of logical processes with which the botanist is now faced, and it is in this context that the problems of botany must
be stated. A careful distinction must be made between the problems and their potential solutions utilizing current technology. Too often the question is asked, "How can I use the computer to solve my problems?", in situations where the problems themselves have not been stated. While it cannot be denied that some of the solutions to botanical problems, particularly those involved in the curating of large collections or extensive literature search, are possible only because of the potential use of computer technology, it should not be presumed a priori that such problems will only have their ultimate solution through the application of computer systems. If the botanist can develop the ability to ask himself what he wants from his data without burdening himself with the seeming limitations of his present technology, the solution can ultimately result in considerably expanded horizons. This has been particularly significant in the statistical handling of biological data. Many of the techniques of such statistical evaluation, some of which have been unfortunately labeled as a sub-science of numerical taxonomy, are really only mathematical manipulations of data which could be done equally well with pencil and paper, but unfortunately could not be carried out in that way on a large data set within a reasonable period of time. The computer as a tool has allowed the statistical technique to expand, but statistics and computers are not synonymous.

Whereas the advent of computers has offered a wider horizon to the botanist for the potential solution of previously unsolvable problems, this potential, in itself, is not the only basis upon which a decision for computerization can be made. A realistic evaluation of the utility of any information retrieval system or statistical evaluation must be made on a basis of the value of the net result without consideration of the means of possible solution. If the end result is justifiable, only then can the means of reaching that end be evaluated. The distinction must be clearly made between the organization of knowledge and the mechanization of that knowledge. In this respect, a realistic evaluation of time and cost for the solution to any given problem must be considered. The high internal operating speeds of modern computers are impressive statistics. The fact that data can be manipulated within the computer in fractions of a second is not a realistic statistic when evaluating the true time from presentation of the data to the availability of the solution to a given problem. The true solution time includes all that time which is involved in the entry of the raw data, all of the delays and waiting periods in submitting the problem to the
computer (and the programmer), and in ultimately receiving the printout or other output from the computer. In a practical sense, what is often spoken of as microseconds of response can, in fact, represent weeks of waiting time for the individual botanist. In a similar manner, costs must also be evaluated. Can the expense of direct communication with a computer data bank be justified for information which is needed for a paper to be presented next month? The identification of an unknown plant by carrying out a question and answer session at a computer console is an impressive application of the computer, and, in fact, the random sequence in which the pertinent characteristics may in some cases be presented to a computer is a considerable improvement over the dichotomous key. The questions which must be realistically asked, however, are, "How much does it cost?" and "Is it worth it?" In small systems operating in small computers, the cost may seem reasonable, but when larger data banks are involved and consequently larger computer systems, the cost can quickly get out of hand. For direct communication with the computer, the data which are being referenced must be kept in a readily accessible storage medium. Even the least expensive of these can cost in the hundreds of dollars per day, while the most sophisticated high speed systems may run into the thousands of dollars per day for a data bank equivalent to the information content of a one-volume printed flora. As one who pays a rather healthy monthly computer bill for the operation of my own research projects, I have strong feelings that an unrealistic approach to botanical problems is presented in instances where major data banks are proposed on a large-scale basis without realistically evaluating the true costs of immediate availability. Realistic operating times and ultimate costs must be evaluated in the context of the true need of the user. This aspect of computer utilization has become most critical in recent times with the introduction of on-line terminals and time-shared computers. Can the individual scientist really justify the true costs of direct communication to a computer data bank as compared to looking up a similar piece of information in a more conventional reference work? This question must be asked each time one goes to a computer for the solution to a problem.

Oftentimes the on-line system is considered justification because of the supposedly random nature of the access need of the user. Critically evaluated, such access is too often not truly random but is limited to a finite number of rearrangements of the data. It must be remembered that the computer has not
only changed the mode of communication in terms of on-line access to stored data banks but has also greatly amplified the communication which is possible with the conventional printed word through the availability of permuted indices. By using computers for the preparation of multiple indices to a given reference work, the same ease of access that is available in an on-line operation can be made available in a printed report. In our own work, the preparation of a complete title index for a file of bibliographical references having more than 25,000 entries took only three minutes of computer running time. Actually, it took closer to a week in terms of response time from conception of the need to ultimate receipt of the print-out. Having once prepared this permutation of the data, however, it is now available on a direct access basis at a speed equal to that of an on-line computer inquiry, and, I might add, at a considerably lower cost of operation. When truly evaluated in terms of the total context of programming and equipment cost versus the time and effort required to manually look up a set of facts in a computer-prepared index to a data set, the justification for the use of on-line computer systems is difficult. The index which we prepared could not have practically been completed by other than computer means, but the off-line mode of operation was sufficient for our needs and continues to be so.

The preparation of multiple indices by computer means brings out still another aspect of the need for proper preparation and analysis of problems before entering into the computer operation. While the computer is particularly well adapted to searching large quantities of data for a particular set of facts, this search is made by comparing the information content of the body of data being searched against a standard which is the item being searched for. Comparison of two items to determine whether or not they are completely alike in every detail is a characteristic ability which is inherent in the computer hardware. Comprehension of the significance of two items which are functionally the same but which are stated in a different manner is not a built-in ability of computers. Such comprehension must be programmed and is one of the most difficult types of logic to program.

Thus, it becomes essential in preparing information for computer analysis that such information be presented in an absolutely consistent form in all cases. Such simple variations as an extra space or an incorrectly placed period are as different to the computer comparison as an entirely different word. If such variations are to be disregarded, the instructions to dis-
regard them must be specifically programmed into the computer. The solution to this problem is a simple one: consistency. This, however, is not an easy thing to achieve, particularly in an endeavor which extends over a long period of time. The preparation of indices requires the searching out and bringing together of all of a like item. Achieving this without programming comprehension into the computer can be done to a great extent by specifically identifying each particular type of information in each record. This "data language" is the responsibility of the individual botanist, and consequently data banks have the disadvantage, unlike museum specimens, that the information which is stored in the computer is already biased upon entry. If, however, the data are entered into the file in a consistent format and adequate recognition is given to the specific information units within the data and the potential extent of any piece of data, then for any given processing of the data the entire record need not be searched. Only that segment of the record which contains the specific information being sought must be processed. In more every-day terms, this simply means that the format in which data are presented to the computer must be rigidly adhered to, and that considerable attention must be given to this format before any data recording is begun. Only in this way will maximum utility of the data bank be possible for future needs.

Another problem facing the individual botanist when using computers is that of compatibility. Actually, this involves three separate and distinct problems in data processing. Machine compatibility is the ability to enter data automatically into the computer file. In its most acceptable form, the data should be able to be entered into the file without the need for human intervention. Recording the shape of the leaf scanned by a computer input device is, for all practicality, still a dream of the future. The more practical entering of numerical data from mark-sensed cards is a direct machine entry procedure. The capability of entering literature files, such as Index Kewensis, by means of direct optical character reading is a rapidly developing technique of the present. For the taxonomic botanist, however, most of the data which he will need in the computer file must be entered manually, and only after this manual data processing will a machine-compatible form of the file exist. The second type of compatibility is that of the data bank itself. While there are various formats for internal storage use in different computer systems, the transition from one format to another is almost always possible by direct computer processing,
and thus the data file compatibility is not a major concern, so long as the specific items of information which are stored in the file are analogous to any other file with which the data are to be utilized. This is not a new problem to botany but one which must be squarely faced if the botanist is to use a computer. Classification systems, based on the shape of leaf in one plant and the color of flower in another, do not lend themselves readily to the impartial comparison of a computer data file. Finally, the last level of compatibility is program compatibility, and this involves not only the operating programs which process the data but also is unfortunately tied closely to the individual hardware systems in use. The plea for compatible programs which can be exchanged between scientists is regrettably somewhat premature, considering the developmental stage of the computer industry. Computers began from a standing start at the end of World War II and now number in excess of 100,000 machines in use. The technology began with operations taking tens of milliseconds, and now has developed into operations described in nanoseconds. The hardware has developed from relatively small computers occupying the entire space of a large building to highly sophisticated computers occupying little more than the volume of an average television set. The development in this industry is not over, and with the rapidity of advance comes inevitable change. For the foreseeable future, true program compatibility is something to be sought but hardly to be achieved. What approach one uses to compatibility of programs depends in large part on which of two basic approaches to programming are utilized by the individual worker. If your computer needs are sufficient to maintain your own programming staff, then one can be relatively independent of changing hardware specifications, since new programs can be written to meet current needs and old programs can be modified as necessary. If, on the other hand, the computing needs are small and one uses the packaged programs which are available with most commercial computers, then one must be careful in this rapidly developing industry to choose a manufacturer who will provide a reasonable degree of stability. As a general rule, the more interchangeable the program, the longer the running time of that program in the machine, but here again, the true costs of using a computer must be evaluated, not in the simple running time of the computer, but in the total concept of the staff and equipment necessary to process the data.

If the botanist is to use the computer well, he must understand the processing of his problem in the computer. He must,
in essence, be able to program his own problems. Significant uses of computer data sets will come only from the individual who himself fully comprehends the abilities of the processing equipment. If the botanist is completely dependent upon another individual to provide programming, then he will be able to derive advantage from the computer only to the extent that he is able to state his problem in terms of the computer's ability. Programming has unfortunately become synonymous with the operation of translating the logical solution to the problem into the specific commands to be given to the computer. In reality, the most important part of programming is the ability to state the process of problem solution in simple logical terms. This is analogous to considering a skilled translator as equivalent to a talented novelist. The knowledge of the words of a language is not the same as the ability to use that language well. The botanist who does his own programming will soon learn to make the distinction between these two facets of the job. Whereas most university programming courses are exactly equivalent to university language courses, the course, Computers in Biological Systematics, which is now offered at Michigan State University, is much more comparable to a course in composition and writing of a foreign language. Both knowledge of the language and fluency are necessary, but ultimately the latter is essential to the successful use of this new tool. A recent paper by Cutbill, on new methods for handling biological information, should become required reading for any botanist involved in computer data processing.

In closing, I should like to say that the computer offers the botanist the means of coming from the 18th century into the present, but in order to do so, a retraining program is required so that the individual botanist may become completely familiar with the abilities of the computer and fluent in its language.

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References

Plant Ailments

Plants, like man and animals, are subject to myriad diseases. Moreover, there is no single kind of plant that is not affected by some disease.

Plant ailments are older than man. We know this because fossils that predate man’s appearance on earth show evidence of such ailments.

As long ago as 700 B.C. man attempted to control plant ailments. The Romans later instituted the feast Robigalia to appease the rust gods with prayers and sacrifice.

In 1660, nearly 200 years before the true nature of wheat rust was known, a law was passed in Rouen, France, requiring the eradication of barberry in order to control rust. At that time some connection between the rust and the shrub had been established but it was not known that barberry was an alternate host of the fungus. Later, in 1726 and 1766 several New England states passed laws to suppress the spread of the common barberry.

Development of the science of plant pathology in the United States in the past 100 years parallels the development of botanical gardens and arboreta.

For some years the federal government maintained a commissioner of agriculture under whose jurisdiction were several divisions, including the Botanical Division. A section of Mycology of this division was established in 1881, and F. Lamson Scribner was appointed as the mycologist, with Erwin F. Smith as his assistant. This represented the first official recognition of the science of phytopathology in the United States, for the work had to do primarily with the diseases in plants.

The early research on plant diseases was conducted largely by federal and state plant pathologists.

In 1881 T. J. Burrill in Illinois demonstrated that the fire blight disease of apples, pears, and other members of the Rosaceae is caused by the bacterium Erwinia amylovora. Ten years later M. B. Waite proved that bees and wasps could spread the causal organism.

In 1912 passage of the Quarantine Act officially prohibited the importation into the United States of certain plants and soils
in a belated attempt to reduce the possibility of introducing pests and diseases from other parts of the world. By this time the white pine blister rust fungus had already been introduced on low-priced pine seedlings from Europe.

Today, more than 35,000 different diseases affect our economic plants — those used as food, feeds, fibers, and lumber. The number of known diseases of wheat in the United States, for example, is conservatively estimated at 100; of apple at 125; and of potato at nearly 100.

Nor are such large numbers of ailments confined to plants producing food, fiber and lumber. Shade and ornamental trees and shrubs as well as flowers are also subject to many diseases.

The average annual loss from plant diseases in the United States is estimated to be between 3 and 4 billion dollars.

**Causes of Plant Ailments**

There are two major causes of plant diseases — nonparasitic and parasitic.

Among the nonparasitic causes are mineral deficiencies, chemical injuries, and unfavorable water relationships.

**Mineral Deficiencies.** All plants need a balanced diet to do well. Those grown in soil which lacks one of the so-called major elements — nitrogen, phosphorus, or potash — or one or more of the essential minor elements, such as iron, boron, or magnesium, will not be normal.

The foliage of rhododendrons, mountain-laurel, and andromeda (*Pieris*) may turn yellow (chlorotic) because of a lack of available iron, which may, in turn, be due to excessive lime. This commonly occurs when these acid-loving plants are planted near a cement wall. Many trees, including pin oaks, cottonwood, boxelder, and sweet gum (*Liquidambar styraciflua*), also become chlorotic because of the unavailability of iron. Incorporating a so-called iron chelate into the soil or spraying it on the leaves helps to overcome such a deficiency.

**Chemical Injuries.** Faulty application of nitrate, of potash, or of acid or alkaline fertilizers often brings on symptoms similar to those caused by parasitic organisms. If an excess of sodium nitrate is supplied during dry weather, for example, the foliage at the tops of the plants becomes brown and appears scorched.

Careless use of weed killers also may result in severe damage or even death of trees and shrubs. Weed-killing materials containing arsenicals or the hormone 2, 4-D should be used with extreme care.

Rock salt (sodium chloride) scattered over sidewalks or along
roadways to melt ice and snow or prevent water from freezing also causes severe damage to plants growing nearby.

Trees and shrubs growing along large bodies of salt water are often injured by wind-blown salt spray. During hurricanes the spray can actually damage foliage 50 miles from salt water. Smoke emanating from chimneys of manufacturing plants, apartment house incinerators, and other instruments of combustion, including automobiles, contains ingredients which are harmful to vegetation.

The three major pollutants released by manufacturing plants are sulfur dioxide, fluorine compounds, and the smog typical of urban areas. Maple and other broad-leaved trees exposed to high concentrations of sulfur dioxide, for instance, show ivory-white markings, mostly between the main veins; whereas Douglas fir and ponderosa pine exhibit a reddish discoloration of the needles followed by a shriveling of the affected tissues.

Unfavorable Water Relationships. A deficiency of moisture in the soil may result in the scorching of leaves. In such cases the leaves wilt when water lost through transpiration cannot be quickly replaced. Winter injury of broad-leaved evergreens occurs, for example, when the leaves lose more water than can be replaced via the roots while the soil is still frozen in late winter or early spring. In summer, the blossom-end rot of tomatoes is caused by a combination of insufficient moisture and a deficiency of calcium in the soil.

An excessive amount of water in the soil is another non-parasitic cause of some plant ailments. Yews (Taxus spp.), for example, are extremely susceptible to an overly wet soil. Research at Rutgers University revealed that yews could be killed by immersing their roots in water-saturated soil for 32 to 64 hours and then drying out the soil.

Parasitic Causes

Fungi, bacteria, nemas (nematodes), and ultramicroscopic entities known as viruses and mycoplasmas are the five parasitic causes of plant ailments. The last, mycoplasmas, are half way in size between viruses and bacteria. Some diseases such as aster yellows and witches' brooms formerly thought to be due to viruses are now known to be caused by mycoplasmas.

Let me briefly review the history and present status of some of the more important diseases of trees that have become widespread in the United States since the founding of the Arnold Arboretum a century ago.
Chestnut Blight

The rapid disappearance of one of our best forest, ornamental, and nut trees, the American chestnut (Castanea dentata), as a result of infection by the fungus Endothia parasitica is too well known to warrant much discussion today. Despite tireless effort and tremendous monetary expenditures, dead and diseased chestnut trees are all that remain of the losing battle man has waged to check this invader.

No one will dispute the statement that the chestnut blight disease has done more than any other single factor in American history to make the public tree-conscious. Within a span of 60 years many persons have witnessed the passing of this irreplaceable tree. Believed to be of minor importance when first reported by the late Herman Merkel, who found a few infected trees in Bronx Park, New York City, in 1904, the disease proceeded to wipe out the chestnut stands in New England forests and along the eastern slope of the Allegheny and Blue Ridge mountains, the principal range of this host. Today some chestnuts still stand in the extreme southern and western parts of this tree's natural range: in Tennessee, Georgia, and South Carolina. It is safe to say, however, that they too will soon suffer the same fate as their northern kin, for blight has been reported in all these states.

Dutch Elm Disease

The second most widely publicized disease in the last 35 years is the Dutch elm disease caused by the fungus Ceratocystis ulmi. The misleading name given the disease merely refers to the Netherlands, where it was first identified in 1919. The disease is believed to have entered the United States in the late 1920's on burled elm logs from Europe. After killing literally thousands of elms in the eastern United States, it has spread to the deep South, the Middle West, and Canada. The disease has been found in at least 33 states, the westernmost being Idaho.

Conditions are ripe, however, for the spread of the disease to California. The principal carrier of the causal fungus, the smaller European elm bark beetle Scolytus multistriatus, has been found in 20 California counties.

Many claims of cures or preventives have been made in recent years. However, as of now not one has been substantiated. I have worked with this disease since 1933 when I was in charge of the eradication campaign on Long Island. I have used many of the materials suggested as cures or preventives but found them all wanting.
Among a number of elm species introduced from Asia, the most resistant (though not immune) are the Siberian elm (*Ulmus pumila*) and the Chinese elm (*U. parvifolia*). Unfortunately they lack the qualities that have made the American elm so great a favorite over the past century, particularly in the New England states.

One of the latest efforts to control the disease on American elm seedlings has been exposure to thermal neutrons or x-rays. Four of 150,000 treated trees showed increased resistance, and one has withstood nine inoculations of the fungus *Ceratocystis ulmi*.

A sex attractant produced by virgin female elm bark beetles is also being investigated. If this substance can be produced synthetically in the laboratory, it may help to lure male bark beetles into traps where they can be killed or sterilized by any one of several methods.

A new approach is to use predators to control the insect vector. A wasp-like insect (*Dendrosoter protuberans*), introduced from Europe, lays its eggs in dead or dying elms infested with the larvae of bark beetles. The young hatching from the predator’s eggs attack and kill the bark beetle larvae. Whether or not this predator can become sufficiently well-established to cause an appreciable reduction in the bark beetle population remains to be seen.

The use of systemic chemicals which are either injected into elm trunks or applied to the soil in the root feeding zone has been tried by several investigators. It was hoped that such chemicals would move up into the branches and twigs in sufficient amounts to kill the bark beetles which spread the causal fungus.

Encouraging results have recently been reported from the use of Benlate. In fact, only a few months ago, the du Pont Company, manufacturers of this fungicide, received clearance from the federal regulatory agencies to permit its use as an aid in the control of Dutch elm disease.

Benlate is applied as a foliar spray or is injected into the trunk of the tree.

As a foliar spray, it is used at the rate of 8 pounds in 100 gallons of water in spring when the leaves are fully formed. This is the time the bark beetles begin to feed.

As a trunk injection, it is used at the rate of 2 pounds per 100 gallons of water. Injector tubes equipped with cups of approximately 2 fluid ounce capacity are inserted into the outer growth rings just deep enough to prevent leaking at the point
of entry. The injector tubes are spaced at 2-inch intervals around the trunk. The cups are filled and left in place for 24 to 48 hours. They are refilled as needed. The injector tubes are removed when the treatment is completed.

The Benlate treatment must be given by a trained arborist. It is to be hoped that this treatment combined with a sanitation and insect control program will be successful in slowing down this highly destructive disease.

Phloem Necrosis

Even more deadly than the fungus-induced Dutch elm disease is phloem necrosis. This disease was once thought to be caused by a virus but it is now known to be caused by a mycoplasma. Thousands of elms in the Middle West along the Ohio River basin have died from its effects in the past 30 years.

Just recently phloem necrosis has appeared in the western and central parts of New York State. It is only a matter of time before it will reach New England to destroy those elms that have thus far escaped the Dutch elm disease.

The phloem necrosis organism can be transmitted experimentally by grafting patches of diseased bark, scions or roots on healthy trees. In nature the infectious principal is transmitted by the elm leafhopper Scaphoideus luteolus. Because of the nature of the causal organism, there is a possibility that control of infected trees can be achieved by using an antibiotic such as tetracycline.

Oak Wilt

Another highly publicized disease, wilt, of oaks, is causing some concern to arborists, nurserymen, tree owners, and lumber interests in the Middle West. The disease has been found in 20 states from Kansas and Nebraska eastward to Pennsylvania, and from Minnesota southward to Texas.

The fungus Ceratocystis fagacearum is known to cause wilt. It is spread by root grafts and by several insects including fruit flies; Nitidulid beetles; the flat-headed borer, Chrysobothris femorata; and two species of oak bark beetles, Pseudopityophthus minutissimus and P. pruinosus. The fungus can also be transmitted on tools used by arborists and foresters.

No effective control of wilt is known. For the present, eradication and burning of infected specimens is being advocated. Because the oak wilt fungus appears to be most infectious early in the growing season when the new spring wood vessels are developing, it is suggested that pruning operations in oaks be delayed until July or later.
Ash Dieback

In the northeastern United States, white ash (Fraxinus americana) has been affected by a branch dieback, and since 1940 occasional death of some of the affected trees has been noted. Dr. Craig Hibben at the Kitchawan Research Laboratory of the Brooklyn Botanic Garden found that a strain of tobacco ringspot virus was associated with leaves exhibiting early symptoms of ash dieback.

In addition, Dr. Hibben was successful in transmitting a mycoplasma-like organism from declining white ash trees showing witches’ broom symptoms to healthy ash trees by means of the parasitic flowering plant known as dodder (Cuscuta sp.).

Although much research still must be done, these discoveries should eventually help to solve some very serious problems on white ash.

(The wood of white ash, by the way, is used to make baseball bats for America’s favorite sport.)

Other important contributions on plant diseases have been made by arboreta and botanical gardens over the years. A brief review of some of these may be in order here.

At the Arnold Arboretum, more than 40 years ago, a forest pathologist, Dr. J. Horace Faull, was first to recognize the occurrence of the Dutch elm disease in the United States and warned of the potential danger of this disease to elms. Unfortunately his many warnings went unheeded. More widely recognized was the herbarium of specimens of diseases of native and cultivated plants prepared by Dr. Faull, his co-workers, and students.

Alfred Fordham, plant propagator at the Arboretum, found that many woody plants which failed to grow in spring died not from so-called winterkill but from the first sharp freeze in autumn. The bark of susceptible plants is ruptured and separates from the wood, resulting in death of the plant.

Donald Wyman, Horticulturist, Emeritus, at the Arnold Arboretum, found that some trees are unusually susceptible to certain pests and diseases and suggested that they should not be planted in areas where they cannot receive adequate care. He recommends, instead, the planting of trees that are unusually pest-free. Included in this group are: Carpinus species, Cercidiphyllum japonicum, Eucommia ulmoides, Franklinia alatamaha, Ginkgo biloba, Gymnocladus dioicus, Koelreuteria paniculata, Liquidambar styraciflua, Phellodendron species, and Sophora japonica.

At the Brooklyn Botanic Garden, classical research on virus
diseases has been conducted since the early 1940's, starting with Dr. L. M. Black and continuing with Doctors Karl Marasco, Myron K. Brakke and Walter Tulecke. Brakke's work on density gradient centrifugation was responsible for a new approach to the separation and identification of viruses. The contributions made more recently by Dr. Craig Hibben have already been noted in my discussion of ash dieback.

At the Cornell University Arboretum, now known as The Cornell Plantations, hundreds of elms are being grown to determine their resistance to the Dutch elm disease fungus.

At the Missouri Botanical Garden, early in this century Dr. B. M. Duggar contributed to the understanding of the future of viruses by measuring the tobacco mosaic particle. The garden also pioneered in the growing of mushrooms from pure culture spawn, transforming mushroom production into a profitable industry. In the 1930's A. P. Beilman made many contributions to the care of shade trees.

At the National Arboretum in Washington, D.C., Frank S. Santamour, Jr., research geneticist, has discovered the first natural hybrid between the tetraploid American elm and the highly resistant diploid Siberian elm. More recently, another triploid elm, a hybrid of *U. pumila* and *U. rubra*, was found through cytological research. According to Dr. Santamour, “It is likely that triploids created by crossing diploids with colchicine-induced tetraploids will be partially fertile and be useful in further breeding for resistance to Dutch elm disease”.

There is one discouraging aspect in the development of plants resistant to fungi and other parasites. It is now well established that a plant resistant to one strain of a fungus may succumb to another strain of the same fungus. This has been shown in the development of varieties of wheat resistant to the rust fungus *Puccinia graminis*. The same situation holds for the fungus *Ceratocystis ulmi*, the cause of the Dutch elm disease. There are strains, particularly one known as the black line strain because it produces a black growth at its perimeter of growth in culture, that are extremely virulent and capable of killing an elm within a year of infection. Other strains are less virulent and may take three or more years to cause death.

Important contributions have also been made by the New York Botanical Garden. Pioneer work on the cytology and genet-

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ics of the fungus *Neurospora sitophila* was done by my predecessor, Dr. B. O. Dodge. This was followed by the work of other geneticists that resulted in the discovery of the chemical affinities of chromosomes and genes. For their part in these researches Doctors G. W. Beadle, J. Lederberg, and E. L. Tatum received the Nobel prize in medicine in 1958.

Other contributions made by the New York Botanical Garden, directly or indirectly related to plant ailments, include the effect of natural gas on trees, and the application of plant nutrients directly to the foliage of trees and shrubs.

The newly established 1800-acre Cary Arboretum of the New York Botanical Garden at Millbrook, N.Y., has among its objectives the finding of a replacement of the fast disappearing American elm, the mass planting of all elm species to assess their relative resistance to the Dutch elm disease, and the testing of blight-resistant clones of the American chestnut.

Thus down through the years, the study of plant ailments and their control continues to progress. Modern research at botanical gardens and arboreta such as the Arnold Arboretum is a far cry from the efforts of the ancient Romans to appease the rust gods with prayers and sacrifice.

**Pascal P. Pirone**  
**Senior Plant Pathologist**  
**New York Botanical Garden**
Cambial Activity in Trees

The major difference between trees on the one hand and herbs on the other is that the trees show lateral growth or growth in thickness, over and beyond the growth in length. The growth in length — called the extension growth — is due to division and elongation of cells at the tip of stem or root (Fig. 1). In trees, the subterminal regions which have ceased elongation undergo another kind of growth, the lateral growth which is due to cambium and which results in an increase in their girth. This is shown easily by a comparison of photographs of the same branch taken at different times (Fig. 2). In the photograph on the left the lowermost internode is about 1 1/2" long, and the one above it is about 2 1/2" long. After 3 weeks of growth (photograph on the right), a few more internodes have been added at the tip, but note that the bottom internode has not elongated. The one above it is now almost 3 1/2" long and also has stopped elongating, soon the one above it will stop elongating, then the one still above and so on. If cross sections of these internodes are stained with phloroglucinol-HCl which imparts a red color to wood (Fig. 3), it can be seen that the cambial activity has begun in the two internodes from the bottom. Henceforth, these internodes will only increase in girth.

The cambium is a layer of cells between wood (xylem) and bark (phloem) ¹ which remains permanently meristematic or capable of division. In temperate climates, the cambial cells are active only in spring and summer, they cut a number of new cells toward the wood, about 1/2 to 1/4 that number toward the bark, and the new cells differentiate, respectively, as new wood and bark cells. With the beginning of autumn, the cam-

¹ Strictly speaking the term wood pertains to secondary xylem or xylem derived from the cambium as opposed to primary xylem which is derived from the procambium. The term bark refers to all tissues outside the cambium and includes besides primary and secondary phloem such tissues as cortex, epidermis, periderm and rhytidome. In older stems of most trees the primary phloem, cortex and epidermis are shed and the bark consists essentially of the secondary phloem, periderm and rhytidome.
Fig. 1 Two types of growth in trees, their location and meristems involved.

<table>
<thead>
<tr>
<th>GROWTH AT TIP OF STEM (OR ROOT)</th>
<th>EXTENSION GROWTH</th>
<th>APICAL MERISTEM</th>
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<tbody>
<tr>
<td>GROWTH BELOW TIP</td>
<td>LATERAL GROWTH</td>
<td>CAMBIIUM</td>
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Fig. 2 Photographs of the same elderberry branch separated by a 3-week interval.

Fig. 3 Cross sections of six internodes from the youngest (1) downwards stained with phloroglucinol/HCl to show beginning of formation of wood (internodes 6 and 5) and hence beginning of cambial activity.
bital cells become dormant, remain in that state through the winter, and are activated again next spring. As a result of this seasonal activity of the cambium, there are growth rings in the wood, which may be considered as a record of cambial activity (Fig. 4). In contrast to the wood, the record of cambial activity is only poorly preserved in the bark (Fig. 4). First, the yearly increments in the bark are usually not distinct as growth rings. Second, they are further obliterated because of stress and distortion in mature bark due to the ever increasing diameter of the wood cylinder. Third, in most trees, the bark does not keep on accumulating from year to year as wood does; instead, the outer parts of bark are periodically cut off as bark scales by another kind of cambium, the cork cambium (Fig. 4). The formation and shedding of bark scales gives the trees their typical rough bark appearance. Some trees such as oak acquire a rough bark very early, at times within the first year; others like fir, poplar, birch, beech, and cherry may retain their smooth bark for several decades.

Wood is an important commercial product and a good deal of research has gone into it. Much less is known about bark, mainly from pharmacological work concerned with extractives; but cambium which produces both wood and bark, very little indeed is known about it. Yet the cambium is a very interesting tissue indeed. Since it produces xylem and phloem, two very different tissues, on its two sides and since each of these two tissues is composed of different types of cells, it is of interest to students of oriented cell divisions, cell differentiation, and pattern formation in plants. Its seasonal activity in temperate climates, likewise, is of extreme interest to students of dormancy and frost resistance. Finally, a feature of cambium that has not been well recognized in the past is that it is a very dynamic tissue — it is the seat of rapid change and response to external and internal environment. In the following pages, I am going to concentrate mainly on cell types in the cambium, concept of the initiating ring, multiplicative divisions in the cambial initials and their role in plasticity of the cambium, and the effect of hormones on cambial activity and production of xylem and phloem.

Some plants such as arborescent monocotyledons, tropical dicotyledons, and lianas show unusual cambial activity in that xylem and phloem are produced on the same side, at times in successive rings, or in different proportions in different radial sectors. Very little is known about the physiological and morphogenetical aspects of these types of cambial activity. They are not considered here.
Fig. 4 Montage of a cross section of a stem of pine. Only two growth rings and part of a third are shown in xylem (X). In contrast several years growth, marked by small bars arranged in a row, is shown in the phloem (P). The approximate position of cambium is denoted by a longer horizontal bar. Note the distortion of tissue in outer bark and separation of outermost bark tissue by periderm (PD). The parts so separated comprise dead bark marked by an asterisk (*) and are periodically shed as bark scales.
1. Cambial layer, fusiform and ray initials: There are theoretical reasons for maintaining that cambium is a single layer of cells (2, 3, 6) between xylem and phloem although it is not easy and often impossible to identify the cambial layer from the neighboring layers. Figures 5 and 6 represent cross sections of stems of white pine (Pinus strobus) sampled in winter and summer, respectively. In the winter collection 3–4 layers of undifferentiated cells intervene between the fully differentiated xylem and phloem cells. In the summer collection, the number
of layers of undifferentiated cells is much larger. Many of these, of course, are differentiating though not yet mature, xylem and phloem cells. With experience and under the higher resolution of an electron microscope it is possible to delimit the cambium both in winter and summer material to either one of 2 or 3 layers of cells. Further delimitation has proven impossible so far and perhaps is of little practical consequence.

The number of undifferentiated cell layers in winter and summer materials of different trees varies widely and in the same tree under different conditions of age, growth, and environment. For instance, in rapidly growing trees the number of undifferentiated and differentiating cell layers is usually much larger than in slow growing trees. Also, in winter collections of some trees, it may be possible to delimit the cambium to a single layer of cells.

These variations aside, the cambium basically has two types of cells (Fig. 7): 1. one type is narrow and elongated along the length of the stem and is called the fusiform initial; 2. the other type is short, isodiametric or horizontally elongated and clustered in groups and is called a ray initial. The type of cambium shown in Fig. 7 is common in most hardwoods such as birch, poplar, willow, alder, sycamore, etc. and is called non-storied cambium. The cambium of conifers is similar (Fig. 8), except that the fusiform initials are as a rule longer — in fact in some red woods they may be as much as 10 mm. long — and that the ray initials are usually arranged in single series. The cambia of some other hardwoods, such as ash and black locust (Fig. 9) have very short fusiform initials, as little as 0.3-0.5 mm. long, and have rather large clusters of ray initials. Irrespective of these differences between species, it is clear that basically the cambium has only two types of cells, the fusiform and ray initials, and these two types of cells by tangential divisions produce all the different kinds of cells in wood and bark. But whereas the conducting cells such as the vessel elements in wood which transport water and minerals from roots up the trunk to the leaves, and sieve elements in the bark which transport the photosynthetic products from leaves down the trunk are produced only by the fusiform initials, parenchyma cells are produced by both. Fibres which provide strength to wood and bark are also produced exclusively by the fusiform initials. Besides differing in shape and size and nature of cells

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3 The only exception known is that of Alseuosmia macrophylla and A. pusilla which have been shown to have only fusiform initials in the cambia of their stems (5).
Fig. 7 left  Tangential longitudinal section of the cambium of birch. Note that the fusiform initials are narrow and elongated whereas the ray initials are short and clustered in groups. The derivatives of ray initials on either side extend as sheets of cells called phloem and xylem rays (Fig. 6, R).

Fig. 8 middle  Tangential section of the cambium of pine.

Fig. 9 right  Tangential section of the cambium of black locust.
they produce, the fusiform and ray initials also differ in frequency of tangential divisions—the fusiform initials dividing far many more times than the ray initials in any one season.

What makes these two cells behave differently? As yet we have no explanation. There are vague suggestions of differential pressure and subtle differences at the molecular level but nothing concrete. Under the electron microscope the two types of cells show a basic similarity of structure which explains how the two may be interconverted one into the other but leaves the question—why the two behave differently—abegging.

2. The concept of initiating ring: The second noteworthy feature is that the production of new cells internally to the cambial ring entails a continuous net movement outward for the cambial initials and the bark tissues, and, furthermore, that the cambial initials show a remarkable degree of synchrony in their activity.

Figure 10 is a mock-up of the tangential activity of a single fusiform initial over part of a growth season. The mature (or previous year's) xylem and phloem are distinguished from the current year's growth and the cambial initial is distinguished from its derivatives. The initial divides and the internal of the two cells—cell 1—differentiates as a xylem element; it expands and pushes the cambial initial and mature phloem cells outwards. The cambial initial divides again, produces xylem derivative 2; derivatives 1 and 2 expand further and the cambial initial and mature phloem cells are pushed still further outwards. The cambial initial divides again but this time the outer of the two cells differentiates as the phloem derivative 1. The cambial initial divides again to produce xylem derivatives 3, 4, phloem derivative 2, and so on. This is, of course, a highly simplified model and does not assume tangential divisions in the young xylem and phloem derivatives. These divisions probably occur at a high rate in a growth season.

It should be remembered further that it is not simply one cambial initial that is engaged in this tangential activity. There are thousands of cells in the cambial ring—like soldiers marching in a row they are acting in concert, cutting cells toward xylem and less frequently toward phloem and as a net result moving outwards.

When soldiers march in a row and it is a hot day once in a while one of them pitches forward or backward and his neighbors move in from the sides and close rank. The same thing happens in a row of cambial cells—one of them drops out, or
Fig. 10 An entirely hypothetical drawing showing the activity of a single cambial initial over part of a growth season. The mature or previous year's xylem and phloem are indicated by a double line and marginal stippling, respectively. The cambial initial is the cell with the broken line. Numbers indicate the order in which new xylem and phloem cells have been produced. The model does not assume tangential divisions in young xylem and phloem elements.

Fig. 11 Loss and addition of cambial initials as seen in cross sections of xylem including the cambial initials, but excluding phloem. Markings are the same as in Fig. 10. The figure on the left dramatizes the loss of an initial by expansion of cells in neighboring rows. The figure on the right is more nearly correct and shows that the loss of an initial may be compensated for by addition of new initials elsewhere in the ring (stippled rows).
more accurately stops dividing and the neighbors close in. It is a competitive world for the cambial initials; they have to keep dividing or else either pitch forward and mature into a phloem derivative or get left behind and mature into a xylem derivative. In Figure 11, for instance, one of the initials has stopped dividing and the neighbors are shown expanded to fill the vacated space (figure on the left). Actually, this kind of expansion does not take place; instead as shown in the figure on the right, new cambial initials are added to the cambial ring. This dropping out or loss, or as we prefer to call it decline, can be sudden or protracted, but it is obvious that for each initial that declines at least one initial must be added if the cambial ring is to maintain its diameter; more than one if it is to increase in diameter. This leads us into the second type of division — the multiplicative or anticlinal division — that the cambial initials undergo.

3. Multiplicative divisions: Let us assume that a tree 20 cm. in diameter, after 50 years of growth, becomes 200 cm. in diameter, and further that the size of the cambial initials (tangential width) remains constant at 20 \( \mu \). Let us further restrict ourselves to fusiform initials. As Figure 12 shows, it can be calculated that the young tree has 10,000 initials in the cambial ring, and this number must be increased to 100,000 when the tree is 200 cm. in diameter, an increase which can be obtained if each initial multiplies a minimum of 9 times over the 50 year period. Actually the initials do increase in size (Table 1) and so the number of necessary multiplicative divisions would be less than 9. Surprisingly, however, in nearly all plants that have been investigated this number is much

<table>
<thead>
<tr>
<th></th>
<th>one year old stem</th>
<th>60 year old stem</th>
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<tbody>
<tr>
<td>Radius of woody cylinder</td>
<td>2,000 ( \mu )</td>
<td>200,000 ( \mu )</td>
</tr>
<tr>
<td>Circumference of cambium</td>
<td>12,566 ( \mu )</td>
<td>1,256,640 ( \mu )</td>
</tr>
<tr>
<td>Average length of fusiform initials</td>
<td>870 ( \mu )</td>
<td>4,000 ( \mu )</td>
</tr>
<tr>
<td>Average tangential diameter of fusiform initials</td>
<td>16 ( \mu )</td>
<td>42 ( \mu )</td>
</tr>
<tr>
<td>Average tangential diameter of ray initials</td>
<td>14 ( \mu )</td>
<td>17 ( \mu )</td>
</tr>
</tbody>
</table>

Table 1. Actual measurements from *Pinus strobus*. Adapted from Bailey (1).
greater than 9, at least 2 to 3 times as much (Fig. 13). The excess cells that are produced either decline completely or bits of them are left in the initial ring by conversion to ray initials. Why should there be such an excessive production of new initials followed by a rejection of a large number of them? The answer to this question is unknown though it seems reasonable to assume that this device enables the cambium to adjust itself to changing conditions of growth and environment. It produces far more cells than it needs and hence can pick those that are wanted and throw out those that are not wanted.

Let me explain this by a few examples:

a. Eccentric wood: Trees normally grow straight but at times due to wind or snow or competition from neighboring trees they
bend in a certain direction. If the tree is sawed, one sees growth rings in the wood that are eccentric rather than concentric (Fig. 14). This figure is further unusual in that it shows that the plane of eccentricity may change with time. In this stem there are at least 3 such planes which are marked by arrows. It should be noted that in the sectors marked by arrows, the cambial initials were not only producing more wood per year, but also there was a larger number of cambial initials than in the sectors on the opposite side.

b. **Repair mechanism:** Another instance of where it is useful to have more cells than are needed is in repair of an injury. If some cells in the cambium and adjacent xylem and phloem are injured, the cambial cells on either side of the injury divide up into smaller cells, each of which behaves as an independent unit; these new initials then elongate, multiply, reject the un-
wanted pieces, elongate, multiply, further reject the unwanted pieces, and eventually give rise to straight elongated initials in a complete cambial ring.

**c. Accommodation with parasitic plants:** Still another way in which the cambial cells show adaptability is in accommodation with parasitic plants, such as mistletoes (*Phoradendron, Arceuthobium*) and dodder (*Cuscuta*). Seeds of these plants germinate on a host branch and send out haustorial appendages which grow in the host cortex and send out aerial stems which flower and seed. Tips of some of these appendages also come to rest against the cambial initials which respond by dividing into a number of smaller cells; the latter surround the haustorial appendage and henceforth the cells in the haustorial appendage divide tangentially and keep pace with similar divisions in the cambial initials (7). Thus, at the end of several years, sections of haustorial appendages — now known as sinkers — appear buried deep in the host wood and draw water and nutrients from the host xylem (Fig. 15). But the advantage from the host's

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*Fig. 14 Section of a stem showing eccentric growth rings.*
point of view is that an accommodation is made with the parasite and unless the infection is very severe the splitting of wood is avoided and the host is able to survive for a long time.

The multiplicative divisions therefore are necessary, not only to maintain the cambial ring and prevent it from bursting because of increasing diameter of the wood cylinder, but they also confer a degree of plasticity on the cambium, which would be absent otherwise. Cambium is hardly the placid tissue that monotonously keeps cutting xylem and phloem cells; it is the seat of active change, of constant multiplicative divisions, of frequent conversions between ray and fusiform initials, and of adjustment to changing conditions of growth and environment.

d. **Spiral vs. straight grain**: Another phenomenon controlled by multiplicative divisions is that of spiral vs. straight grain wood. In straight grain woods, the fibres are arranged axially in line with the longitudinal axis of the stem, but in spiral grain they are placed at an angle and seem to describe a clockwise or an anticlockwise spiral in relation to the longitudinal axis of the stem. How do the straight and spiral grains arise? They have their basis in the multiplicative divisions in the fusiform initials.
In conifers and most hardwoods such as birch, poplar, alder, willow, etc., these divisions are of the *pseudotransverse* type, such that the new cambial initials are nearly half the length of the original initial (Fig. 16). Subsequently the new initials grow at their tips until they reach the length common to the fusiform initials in that region. During this tip growth they, of course, continue to divide tangentially and produce new xylem and phloem cells. The plane of the new division determines the direction of the subsequent tip growth. Usually the divisions occur in the two planes in about equal frequency, so that on elongation the initials and the xylem and phloem derivatives maintain their more or less vertical orientation (Fig. 17). But at times the divisions occur only in one plane. This phenomenon, combined with subsequent tip growth, results in a skewering of the fusiform initials and their xylem and phloem derivatives, either in a clockwise or an anticlockwise direction. Spiral grain is mainly associated with wood but can be seen in bark if it has lots of fibres (Fig. 18). The environmental factors which cause the pseudotransverse divisions to occur in one plane are still unknown, but records show that the spiral can change direction and become straight.

![Fig. 16 Pseudotransverse divisions (shown by broken lines in the figure on left) and subsequent tip growth (direction shown by arrows in the figure on right) in fusiform initials of non-storied cambia.](image-url)
Fig. 17 Straight and spiral grain have their basis in the planes of pseudotransverse divisions and subsequent tip growth of new initials.

Fig. 18 Two trees of a conifer species growing side by side in Nara near Kyoto, Japan. One shows spiral grain, the other straight grain.
4. **Seasonal growth and xylem and phloem production:** I have mentioned earlier that in temperate climates the cambium becomes dormant in autumn and is reactivated in spring. The dormancy and reactivation of cambium are very little understood though there is reason to believe that daylength, temperature and relative concentrations of certain plant hormones play a role. With approaching autumn there is a shortening of daylight hours and a fall in temperature. If trees growing outside in the summer are transferred to growth chambers which simulate the daylength and temperature conditions of summer months, the cambium remains active and continues to produce new wood and bark cells. If these trees are then suddenly taken outside they get killed with the first frost. In contrast, the trees in the field become dormant with the onset of fall and then are able to survive very cold temperatures. In some experiments dormant twigs collected in winter were dropped in liquid nitrogen (−196°C) and on thawing their buds were still able to produce new branches. Just as cambial growth can be extended by appropriate control of daylength and temperature, one can also induce dormancy. In recent years a plant hormone appropriately called dormin (abscissic acid) has been extracted from buds and leaves of plants which were induced to become dormant, and, as expected, external applications of this hormone on growing trees have induced dormancy.

The reactivation of cambium in the spring has been related to another class of hormones, the auxins, specifically IAA. It has been suggested that in spring this hormone is present in increasing amounts in the buds and young leaves and then flows downwards, awakening the cambium so say from its winter sleep by its magical touch (8). That IAA is involved in cambial activation is shown beautifully by a simple experiment. Twigs of poplar, birch, black locust or some other tree are collected in autumn and stored in a cold room (4°C) for a few months. After the cold treatment, which seems to be necessary, they are placed right side up in a small amount of water and their top ends are pasted with lanolin and with lanolin and various hormones individually and in combination. After 3 weeks, sections can be cut to see whether cambium is active and if so whether xylem is being produced, or phloem, or both, and in what proportion. From these experiments it appears that both auxin and gibberellic acid can induce cambial activity but whereas auxin promotes xylem formation, gibberellic acid seems to promote phloem formation (Fig. 19).
The ultimate aim of all biology is to understand why a cell does what it does and how it does it. We want to know why fusiform and ray initials are different, why some cambial initials lose out while others persist in the ring, what triggers a cell to become a xylem or a phloem cell, and so on. Basic questions, perhaps of no economic value, but of fundamental importance to biology to which we still have no concrete answers. In an attempt to find answers to these questions, some investigators have tried to culture cambial cells. They have excised the cambial cells from the tree, and grown them in agar or liquid culture under well defined growth and nutritive conditions. But unfortunately, to date, all these attempts have failed for in culture they no longer behave as cambial cells — they lose their characteristic shape, become spherical, there are no oriented divisions and there is no oriented production of xylem and phloem (Fig. 20). There is a certain element of mob psychology involved here. Outside their own milieu or deprived of
their particular microenvironment in the tree which may include pressure, oxygen tension, and hormonal balance, these cells no longer behave as cambium. That pressure is involved is shown by some other experiments in which flaps of bark including cambium were lifted (see slippage of bark in Fig. 6), a sheet of polyethylene inserted between the flap and the stem, and measured amounts of pressure applied to the flap. The cells in the flap continued to live; the cambial cells continued to divide and produce oriented xylem and phloem derivatives (4).

Fig. 20 Cambial cells in liquid culture. Explants from cambial region of Acer pseudoplatanus. (Slide courtesy of Dr. P. Albersheim.)
To recapitulate I have tried to show that the cambial ring moves outward with increasing diameter of the wood cylinder and that whether or not a cell behaves as a cambial initial depends to a large extent on how well it is able to maintain itself in the initiating ring. I have further tried to show that the cambial cells are in a state of constant flux and are the seat of changes which enable the tree to adjust itself to changing conditions of growth and environment. Finally, I have tried to show that the dormancy and activation of cambium as well as differentiation of the xylem and phloem are at least in part controlled by physical factors such as daylength, temperature, and pressure and relative concentrations of at least three different types of plant hormones — dormin, auxin, and gibberellin.

These bits of information on the structure and physiology of cambium whet rather than assuage the curiosity for a greater understanding of this remarkable tissue. Arboreta, being the repositories of trees, have an important role to play in directing and supporting research on cambium. On this one hundredth anniversary of the Arnold Arboretum, I am happy and proud to say that the Arnold Arboretum has fulfilled this role admirably and, hopefully, will continue to do so in the future.

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The Wood Collection—
What Should Be Its Future?

A wood collection maintained for scientific purposes is much the same as an herbarium in that it contains a preserved portion of a plant with associated documentation filed in an organized manner. By and large, wood collections so defined, are maintained by institutions rather than by individuals. There are about 14 wood collections in the United States housed in almost as many institutions. In the entire world there are only 115 institutional collections of wood. Pre-eminent in terms of numbers of specimens is the collection housed at the U.S. Forest Products Laboratory in Madison, Wisconsin where there are about 100,000 woods.

Until a few years ago, there were six major collections of wood in the United States: the Samuel James Record Memorial Collection housed at the School of Forestry, Yale University; the Harry Philip Brown Memorial Wood Collection at the New York State College of Forestry, Syracuse; the collections at the Field Museum of Natural History, Chicago; the collections at the U.S. Forest Products Laboratory, Madison; the woods at the Smithsonian Institution, Washington; and the woods forming the collections at Harvard University. Today, only four of these collections survive at the founding institutions: the Brown Wood Collection at Syracuse, the Smithsonian collections, the wood collections at Harvard, and those at Madison. The Field and Yale collections have been consolidated with those at the U.S. Forest Products Laboratory.

The wood collections of the Field Museum in Chicago were among the first collections of any kind at the Museum and they formed the original material of the world-renowned economic botany collections. Following the dismantling of the displays which comprised the World Columbian Exposition at Chicago in 1893, much of that material was transferred to form the nucleus of the collections at the Field Columbian Museum which was established shortly after the great exposition. The first curator of botany was Dr. Charles F. Millspaugh, a West Vir-
ginian, who had served on the jury of awards of the World Columbian Exposition. He was responsible in large part for the collections resulting from the Exposition which were left to the newly founded museum. The first exhibit materials of the Department of Botany of the Museum consisted of exotic woods, in the form of boards, remaining from the Exposition. These were put on display in 1894 in what had been the Fine Arts Building of the World Columbian Exposition.

Millspaugh augmented the exotic woods derived from the Exposition with native woods from the United States, and some of the earliest collecting activities of the Department of Botany were dedicated toward this end. Millspaugh himself participated in these early expeditions and travelled to the southern states, Louisiana and Mississippi, for example — during the winter, of course. Later, additions to the collections were made through the efforts of Huron H. Smith, a loner, who collected wood specimens with herbarium vouchers from distant parts of the United States, particularly on the West Coast. It was these woods, in the form of boards and tree trunks, and herbarium specimens, which formed the basis for the displays in the Museum's Hall of North American Woods. After his tenure at the Field, Smith accepted a curatorship at the Milwaukee Public Museum.

Exotic woods were also gathered for the Museum, notable among which were the collections of Llewelyn Williams from Peru and Acosta-Solis from Ecuador. But, as originally, most of the wood specimens were used primarily as examples of economic products of plants and to serve as bases for displays of useful timbers.

Llewelyn Williams had travelled to Yale where he took courses in wood anatomy and identification under the tutelage of Professor Samuel J. Record. Subsequently he returned to the Field Museum where he undertook studies in wood anatomy until the beginning of World War II. Williams' work on the woods of northeastern Peru, published in 1936, resulted in part from these studies and from his field work in Peru. But, Williams' investigations were probably the only research in the comparative anatomy of wood based on the Field collections actually carried out at the Museum. Nevertheless, collections of wood continued to be amassed in the hopes that there would be a full-time curator of dendrology or a wood anatomist on the staff to organize and direct a viable program of research in wood structure which could be carried out in situ. Those who had charge of the collections over the years — Llewelyn Williams, B. E. Dahlgren, John W. Thieret, Theodore Just, Louis O. Wil-
liams, and research associate Archie Wilson — made the specimens available for study elsewhere by botanists and others with an interest in studying wood structure, while at the same time they continued a holding operation for the future of the Museum.

It finally became apparent that chances of establishing a program based on wood study at the Field Museum were remote. Reluctantly, after more than seven decades, the wood collection proper was turned over to the U.S. Forest Products Laboratory in 1971 where it was hoped more use could be made of the specimens than was possible in Chicago.

The exhibits of North American timbers are still being maintained in a revitalized and decorative format. This amazing series of cases, containing dioramas and displays on the botanical aspects and economic products of woody plants, constitute the most complete pictorialization of the raw material of our forest resources in any museum today.

The wood collection previously housed at the School of Forestry, Yale University, was begun almost coincident with the founding of the School itself and records show that a collection existed in New Haven in 1901. However, this group of specimens was burned in 1903 and the now famous Record Memorial Collection had its origin in 1905. Samuel James Record joined the faculty of the School in 1910 and in 1917 he was appointed Professor of Forest Products. His immense interest in woods sparked several trips to the tropics — Guatemala, Honduras, British Honduras — and to many portions of the United States for purposes of observing forest trees and for the collection of wood specimens. It was Record, primarily, who elevated wood collecting from its former status of guesswork and curio gathering to a truly scientific occupation. He insisted that samples of wood be accompanied by determinable herbarium specimens gathered from the same tree and thus associable with described species of plants. These voucher specimens were kept at the Forestry School, adjacent to the woods, where they could be consulted as the need arose.

By 1916 a committee of the Yale Corporation voted to recommend for favorable consideration the formation of a department of tropical forestry at the School with appropriate support in terms of finances, faculty, laboratory, museum furniture, and so forth. An important arm of the department was to be the museum and collection of tropical woods begun by Professor Record. In 1928, Record had already assembled the then incredible number of 11,000 specimens of wood, largely from
tropical regions. The size of the Yale collection in 1928 was larger than most institutional wood collections of the present time.

Record's success in obtaining wood specimens was not only brought about through his own activities in the field; he had an enormous correspondence and he must have been a very stimulating and persuasive man. He was able to secure financing from external organizations which he used to provide stipends for botanists and foresters in the field so that they could gather woods for him; he helped many United States and Latin American botanists with their endeavors in the tropics, for example, through modest subventions for the collection of wood specimens. It was Record who helped to support the field work of G. Proctor Cooper in Liberia, Panama, and Costa Rica; of Hugh Curran in Argentina, Brazil, and Venezuela; of Armando Dugand in Colombia; and of Adolpho Ducke in Brazil. By the time Record died in 1945, the collection amounted to over 40,000 specimens, far and away the largest and probably best collection of its kind in the world.

Record founded the journal *Tropical Woods* which was published more or less uninterruptedly from 1925 until 1960. He also wrote the two most important works on the woods and forests of the New World, *Timbers of Tropical America* in 1924 and *Timbers of the New World* in 1943. In addition, Record authored several books on the physical and mechanical properties of wood and on the description and identification of wood. His research output was voluminous, much of it being published in *Tropical Woods*.

Record established a unique form of exchange with Professor Laurence Chalk, then in charge of the wood collection at the old Imperial Forestry Institute, Oxford University. In return for specimens of wood, Chalk arranged to have permanent microscope slides prepared of them, which were returned to Record. These slides formed the basis of the large collection associated with the woods at Yale.

Service was also an important part of the work done in conjunction with the collections at New Haven. Many thousands of specimens were distributed as duplicates on exchange to other collections and as small samples for microtome sectioning and research. Record himself performed wood identifications for lay people as well as for the government and industry, for botanists, anthropologists, and foresters. The collections also formed a basis for studies in the utilization of tropical woods and as demonstration specimens in teaching.
Following Record's death in 1945, the curatorship was held for a few years by Record's protege, Robert W. Hess. But Hess left Yale to join industry in the early 1950's, and following an interim appointment of the then retired Arthur Koehler, I assumed the responsibilities of the curatorship; teaching and research in wood anatomy and identification, tropical forestry, and microtechnique; editing *Tropical Woods*; and of the service work which seemed to be received unabated even in 1953 owing to the vast reputation of Samuel Record.

The entire program of research in tropical woods and tropical forestry was made possible by the activities surrounding the great collection of woods. It was an integrated program embodying several facets of endeavor: research, teaching, publication, and service. But these activities had only been viable owing to interests and efforts of the curators of the wood collection and not to any great impetus or encouragement from the School or the University. Following my departure from the School of Forestry in 1960, the entire program so ably commenced and overseen with such vigor and excellence by Samuel Record, fell apart. The new wood anatomist had little interest in the tropics and even less in the “busy work” of curating woods and editing a scholarly publication. Thus, the collection became remote and difficult to consult, *Tropical Woods* discontinued publication permanently, and ultimately the administration of the Forestry School, seeing no hope for a future program, transferred the wood collection to the U.S. Forest Products Laboratory in 1969.

Wood collections at the New York State College of Forestry, Syracuse, came into being shortly after the arrival of Harry Philip Brown in 1917 or 1918. The exact date of accessioning of the earliest specimens is unknown. Brown used these woods in his teaching of wood identification and in his publication, *Atlas of the Commercial Woods of the United States*, which appeared in 1928. Many of these early woods were not authenticated, that is, they were not associated with herbarium vouchers. It was Brown himself who made the early collections and others contributed specimens as well: William M. Harlow, Ellwood S. Harrar, and S. B. Detweiler of the U.S. Forest Service. Later specimens were collected with herbarium vouchers which were not, however, housed at the College; rather, they were deposited at the U.S. National Herbarium, in the herbarium of the Arnold Arboretum, and in the herbarium of the New York Botanical Garden. Records of deposition were maintained at the College.
In the 1920's, at the request of the British Colonial Office, H. P. Brown visited India to organize a botanical section and laboratory for the study of wood at the Forest Research Institute and Colleges, Dehra Dun. There, Brown had the opportunity to work with and to become familiar with Indian timbers through the famous Gamble Collection. He remained in India for a year and a half and following his return to Syracuse, in 1932 he and R. S. Pearson, published the monumental two-volume work on Indian timbers, Commercial Timbers of India.

Besides the use of the Syracuse collections for teaching, considerable service and research in wood anatomy was also carried out: R. A. Cockrell worked on Strychnos and studied woods from Sumatra collected by B. A. Krukoff; E. S. Harrar studied the woods comprising the Queensland (Australia) Forest Service collections; Luis J. Reyes studied the woods comprising the Queensland (Australia) Forest Service collections; Luis J. Reyes studied Philippine woods and in 1938 produced a volume on Philippine timbers; Kafil. A. Chowdhury worked on Indian woods; and A. J. Panshin's research in anatomy involved collections from West Africa. H. P. Brown attracted many students and there was a very active program in the study of wood structure.

At the present time, Professor Carl de Zeeuw is curator while at the same time he teaches courses in wood structure, identification, and utilization. There is still a modest program of incorporation of new specimens and some small amount of research in wood anatomy is carried out. A major effort, at this time, involves the continuing authentication and accessioning of wood specimens already on hand, since many woods were received in the past with but little documentation, despite collection by well-known botanists such as Joseph Rock.

A word must be inserted here about the program of collecting, known at the New York State College of Forestry as "Project I". This project, spearheaded by H. P. Brown, was an attempt to collect wood specimens, ecological and habit data, and herbarium vouchers, from all the woody plants growing within the continental United States. To this end, Brown enlisted the aid of collectors from all parts of the country and in return for duplicate specimens these persons were asked to gather appropriate material from the forest trees native to their parts of the country. Accordingly, botanists, foresters, range and wildlife managers, were "drafted" to help with this monumental undertaking. Although at first Brown only admitted woods of commercial or potential commercial use, he later relented and the more recent collections comprise material from all woody plants. The project is still being carried on to a modest degree
and to date there are over 850 collections. Duplicate sets of the wood specimens have been distributed far and wide and the herbarium vouchers and associated documentation are deposited in the herbaria mentioned above.

The wood collection presently housed at the U.S. Forest Products Laboratory at Madison was founded sometime prior to 1910 by Arthur Koehler, the notable “expert on wood” at the Lindbergh kidnapping trial in 1935.

Woods were then housed in Washington, D.C. before the construction of the present facilities in Madison. Initially, the collections were strictly of native forest trees. In those early days the specimens were used predominantly as comparative material for identification and only secondarily for research, description, and the construction of keys. Present emphasis at the Forest Products Laboratory is much the same as it was in 1910, that is, most of the activities are devoted toward the identification of wood specimens and the maintenance of the wood collections themselves. For example, there are on the average over 1000 inquiries during a typical year and these amount to some 4000 identifications.

Arthur Koehler worked closely at the Laboratory with Eloise Gerry, a classmate at Columbia University of the anatomist-morphologist-geneticist, Edmund Sinnott. When Koehler retired, his position was assumed by B. Francis Kukachka, who had been at the Laboratory since 1945, and who is now in charge of the program of service and research associated with the wood collections. The major emphasis at the U.S. Forest Products Laboratory has always been service to the public, largely in the form of identifications. To this end, the Laboratory amassed a collection of specimens of wood, many consisting of pie-shaped radial segments, which numbered about 23,000 specimens in 1967. With the addition in 1969 of Yale’s Record Memorial Collection of 55,000 specimens and subsequent augmentation in 1971 of the Field specimens comprising 18,000 specimens, the wood collections at the Forest Products Laboratory now number about 100,000 specimens, easily the largest wood collection in the world.

With this great and rather precipitous increase, the wood collections, associated staff, and facilities at the Laboratory have been styled by the Director as a “Center for Wood Anatomy Research”. It is hoped, with this vast increase in physical assets in terms of wood specimens, that there will be additional staff beyond the two permanent staff members now associated with the wood collection to enable an increase in activities, primarily
in the field of codifying information on wood structure for incorporation into a program of data processing. Work continues to integrate both the Yale Record collections and the Field collections into the already existing specimens at the Forest Products Laboratory. The herbarium of voucher specimens once housed at Yale is being intercalated among other vouchers already housed at the Forest Products Laboratory.

Wood collections at the Smithsonian Institution were originally part of the Division of Arts and Manufactures of the Museum of History and Technology, and it was not until 1960 that they were transferred to the Department of Botany in the Museum of Natural History at the urging of Albert C. Smith, then Director of Natural History. In 1915, when the first wood specimens were catalogued, they were associated with the industrial and manufacturing sections of the Museum. Subsequently, they were stored next to an exhibit hall devoted to the commercial aspects of wood. The first curator, William N. Watkins, had been graduated from the New York State College of Forestry and his primary outlook was that of a wood technologist and expert in wood utilization. Accordingly, he was occupied in the amassing of specimens primarily for use in identification and service to the public. Specimens were made available to botanists and others who required material for their research in wood structure, but Watkins himself, over a tenure of 43 years, did not carry out any research based on the wood specimens. His major contribution to the Smithsonian Institution was designing the exhibit hall noted above over which he held domain until it was demolished in 1960 at the time of his retirement from government service.

The first collections of wood at the Smithsonian were those gathered by the botanist Henri Pittier and they came from forest trees of Panama. All were associated with herbarium vouchers deposited in the U.S. National Herbarium. For a long time, many subsequent accessions were duplicates of those at Yale, and Samuel Record kept the Smithsonian Institution well provided with specimens. In addition, many other excellent collections were catalogued, for example: B. A. Krukoff’s Brazilian, West African, and Sumatran material; the Project I set of the New York State College of Forestry; the entire private collection of Archie F. Wilson; collections of José Cuatrecasas from Colombia; Llewelyn Williams’ Peruvian woods; and my own collections from Panama, the Philippines, Hawaii, and Dominica.

In 1960, at the time the collection was transferred to the
Smithsonian Department of Botany, I was appointed curator of the wood collection which then numbered 15,000 specimens. The wood collection became the basis for a Division of Woods (later changed to Division of Plant Anatomy) and an active program of research in wood anatomy was begun. A modest amount of service work in identification was continued. Watkins had accumulated many thousands of duplicate wood specimens over the years and all these were distributed on exchange shortly after the commencement of my tenure. Two other staff members were added in the next several years, Richard H. Eyde and Edward S. Ayensu. When I left the Smithsonian Institution to return to university teaching in 1967, the collection of woods had grown to over 35,000 specimens. Presently, there is little research in wood anatomy per se being carried out in the laboratories at the Smithsonian Institution, but there is still an active program of accessioning and many blocks are sent on request to botanists and others interested in studying comparative wood anatomy. The collections are in excellent condition, carefully catalogued, and readily available to any who need them.

The wood collections housed in the Herbarium Building at Harvard University owe their origin in large part to the work of Irving W. Bailey and W. W. Tupper. In conjunction with their early studies on size variations in tracheary cells, Bailey and Tupper were obliged to amass a diverse and sizeable collection of woods upon which to base their observations. This began sometime before 1918 and accretion of specimens has continued until the present time. According to my present information, the woods obtained and used by Bailey and Tupper in their pioneer investigations were not necessarily associated with herbarium vouchers. More recently, of course, most of the accessions have consisted of wood specimens associated with herbarium vouchers many of which are deposited in the Harvard University Herbaria.

The principal activities which have centered about the Harvard wood collections have always been predominantly research-oriented. For several decades following 1918 there was a steady stream of what have proved to be the most significant and far-reaching investigations in plant evolution, based upon the study of wood anatomy, ever carried on in any institution. Not only were these investigations carried on personally by I. W. Bailey, but many of the botanists who studied at Harvard University used these specimens as bases for their own researches, both while they were students or fellows at Harvard, and subsequently. Names of these individuals represent some...
of the luminaries in botany today: Wetmore, Barghoorn, Heimsch, A. C. Smith, Carlquist, Tippo, Howard, and Cheadle, and their students of the second generation. The impact of anatomical studies associated with the Harvard wood collections is difficult to assess quantitatively, but it has already had a profound influence on interpretations of plant relationships and phylogeny. No botanist interested in these aspects of study can afford to overlook or casually consider the work of I. W. Bailey and the Harvard plant anatomists.

Service work, although carried on in conjunction with the collections, was indeed second to research and publication, and teaching. It is important to note here, even though his prodigious energies were mainly directed to anatomical research, Bailey was not an intellectual snob who had no real interest in the practical aspects of his profession. For example, with H. A. Spoehr he published on the role of research in the development of forestry in North America in 1929, and a number of his early papers reflected his appreciation of the pragmatic value of woods and forests.

Specimens in the Harvard collection resulted from the quests of Bailey and Tupper in the early days, and from the collections of other botanists later on. Once the collection became established, and it was known that this was one of the major repositories for woods to be used in research and teaching, materials arrived from many sources. Albert C. Smith deposited a set of his Fiji wood specimens there, for example. A set of B. A. Krukoff's Brazilian woods is lodged at Harvard; Llewelyn Williams deposited a set of his Peruvian woods; and there is a set of the Jesup Collection woods of the United States prepared earlier under the supervision of Charles Sprague Sargent. There are groups of woods from various foreign forestry departments, particularly from Borneo and Sarawak. Unlike the Record Collection at Yale, special emphasis at Harvard was given to Asian material. Much of the publication resulting from studies of these woods appeared in the Journal of the Arnold Arboretum, particularly the later investigations of I. W. Bailey, his students, and co-workers.

The Harvard wood collection now numbers somewhat over 25,000 specimens of dried woods. Besides dried wood specimens, the Harvard collections also comprise fluid-preserved specimens and permanent microscope slides containing sections of wood. In a report submitted by Professor Ralph H. Wetmore to Elmer D. Merrill, Director of the Arnold Arboretum, entitled "Annual Report for the Wood Collection, Biological Laboratories"
1940-1941, there were recorded 9,324 fluid-preserved specimens, 11,857 dried specimens, and 24,382 microscope slides.

Since Bailey's retirement and death in 1967, activities both in the accumulation of specimens and in research had declined. Responsibility for the collection has devolved to the present Director of the Arnold Arboretum, Richard A. Howard, and it is through his good offices and personal interest in plant anatomy that specimens are made available to botanists on request for their own researches in comparative plant anatomy.

If we examine the present status of the six major wood collections of a few years ago, the first observation to make is that Yale's Record Memorial Collection and the Field Museum Collection no longer exist as such. Secondly, the research, education, and service activities associated with the Brown Memorial Collection, the Smithsonian Institution collections, and the Harvard collections have diminished over what they were a relatively few years ago. This leaves the collections of the U.S. Forest Products Laboratory, recently augmented by the additions of wood specimens from Yale and from the Field Museum. But, even here, where the traditional emphasis has been on service, the two-man professional staff is hardly able to care for the many curatorial responsibilities and at the same time to provide necessary service to the public and industry. Naming an institution a "Center for Wood Anatomy Research" does not in itself bring one into being. The plain fact of the matter is that wood collections and their associated activities are not being fully supported by the institutions of which they are a part.

There is some argument for a continued consolidation of wood collections, such as has recently taken place at the Forest Products Laboratory, and on the face of it, it seems eminently logical: greater resources in terms of specimens, expanded services and research through increased staff, heightened productivity through enlarged physical facilities — laboratories, libraries, workshops, and the like. There are also cogent arguments against consolidation: centralization raises the possibility of control; destruction of all resources through natural or man-made catastrophe is more likely; research carried on in a single institution is more conducive to channelization.

All of this is academic wool-gathering when we view today's trends in the upkeep of collections of all kinds, not just wood collections. It is a fact that there is a growing impetus for different types of institutions to transfer their study collections to other institutions, owing not only to lack of funding and the related problem, lack of space, but to a lack of interest on the
parts of practitioners to continue the kinds of activities which were once associated with the collections. I maintain that if the practitioners were deeply interested in the collections and dedicated to using them as bases for service, research, publication, and education, institutions would make adjustments to enable the continued maintenance of the collections for the purposes noted above. Basically, it is lack of involvement with the collections that permits administrators to temporize and to cast greedy eyes on space occupied and monies expended, both of which can always be diverted to other "more pressing" needs.

The activities which surround wood collections are subject to the same human whims which accompany any other endeavor. What is exciting today fails to excite our followers. There is inherent glamour in new fields of effort and in new methods, despite the fact that older lines of effort and approach are far from being exhausted and yet have much to yield. We seem always to be seeking the untapped vein when present veins are still ripe with unexplored potential. Thus, the halcyon days, when H. P. Brown, S. J. Record, and I. W. Bailey were pursuing their studies of wood based on their collections, have become attenuated and we find ourselves at a crossroad. We may ask ourselves: what should be the future of wood collections? Do they indeed have a future? Where can they exist and still serve their traditional functions while promoting expansion into new avenues of endeavor?

At this point I must admit my total bias toward the maintenance of wood collections and the continuation and enhancement of scientific activities based upon them. Wood collections represent the only preserved, unadulterated, and uninterpreted sources of facts through which it is possible to study the construction of the axis of the woody plants which clothe much of the surface of the earth. If we were only and exclusively concerned with the maintenance of wood specimens as a record or hedge against the present rapid diminution of our natural resources, I would say this is reason enough to keep these collections as a form of evidence of the natural products of the earth. But, of course, this would be a narrow view; nevertheless, I believe it to be valid and supportable if we but look into the future with an eye on the past.

Except where wood collections exist primarily to serve the public need, they have flourished owing predominantly to the interest and dedication of single persons: H. P. Brown, I. W. Bailey, and S. J. Record, for example. What was lacking then and what is lacking now, is institutional appreciation of wood
collections and institutional commitment to their maintenance. Admittedly, these are frail requirements, but at least they are superior to the commitments of men who, after all, are shorter-lived than institutions. The great museums have the best records for institutional commitment, but as we have seen, even these are not immutable. In the final analysis, then, we can only trust to good faith, the wisdom of administrators and scientists, and chiefly a concern for the future, for the continued existence of wood collections, or for that matter, any other organized collection of natural and cultural products.

One may reasonably ask then, where can wood collections and allied activities be supported in the most favorable environment? I believe the answer to this question depends on the activities which are associated with the wood collection, and not on the collection of woods, as such. I will be frank to admit that service work, in the form of identifications, is a price one pays for being affiliated with any collection. However, unlike the determination of herbarium specimens, bird skins, or mammal pelts, the act of identifying a wood specimen is not a totally satisfying experience, at least not to me. A wood specimen, at best, is only a fragment of an organism and the most accurate identification of the plant from which it was derived really depends on a determination made from a complete herbarium specimen. So, identifying a piece of wood lacks the pleasure attendant upon the identification of a herbarium specimen, and thus the species of plant.

It is true that wood identification can be extremely important commercially and forensically, and it is often a major ethnobotanical and paleobotanical tool. But, many of the pieces of wood for which identification is required as a service come from curiosity seekers wanting to know the name of a bit of driftwood picked up on the beach during a summer vacation or uncovered in a garden. There should be a place where this kind of wood collection-associated activity can be carried on, and that place is probably a government-supported agency such as the U.S. Forest Products Laboratory. Indeed, as noted above, service of this kind has been the mainstay of activity in the wood collection at the Forest Products Laboratory, and I believe, as far as wood collections are concerned, that the Laboratory can perform its greatest service to the public and to industry by continuing this type of effort.

Scientific research, publication, and education associated with wood collections, I believe are carried out most effectively in the inquisitive and stimulating atmosphere of the university,
well apart from directed research and service-oriented drudgery. Ideally, the wood collection should find its most sympathetic support in an institution which has some kind of commitment to the study of trees and other woody plants; that is, an arboretum, botanical garden, a department of botany, or a school of forestry. Thus, we have found in the past, in the United States the most active research in wood anatomy has taken place within the university milieu, at the Yale School of Forestry, at the New York State College of Forestry, and at Harvard University with its Arnold Arboretum and program of study in forest trees. Professor Laurence Chalk's work prospered at the Imperial Forestry Institute at the University of Oxford in England. It is also worth pointing out here that other important programs of research in wood anatomy have been associated with non-university botanical gardens, for example, at the Jodrell Laboratory, Kew, and at such museum-oriented organizations as the Smithsonian Institution. It is up to the staff members of these organizations where there has been a commitment to the study of woody plants and where there is a framework already in existence in terms of a wood collection, to reinvigorate and revitalize research and education in wood anatomy. Lest I am accused of being a wood anatomy bigot, let me hasten to say that I do not believe that studies in wood anatomy can remain viable in a vacuum; rather, they must be integrated with other studies in plant anatomy and with other phases of botanical endeavor.

Assuredly, it is incumbent upon individual botanists to dedicate themselves to the achievement of commitments from institutions concerning wood collections, their associated activities, and their continued existence and increase. Without sincere, vigorous, and persistent involvement of botanists, the present trend toward consolidation of wood collections will swell concomitantly with attrition in basic scientific research. And all that will remain among the ashes will be the mundane service activities required to provide identifications for the curious public, for government, and for industry.

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Many indigenous North American plants are in cultivation, but many equally worthy ones are seldom grown. It often appears that familiar native plants are taken for granted, while more exotic ones — those with the glamor of coming from somewhere else — are more commonly cultivated. Perhaps this is what happens everywhere, but perhaps this attitude is a hand-me-down from the time when immigrants to the New World brought with them plants that tied them to the Old. At any rate, in the eastern United States some of the most commonly cultivated plants are exotic species such as *Forsythia* species and hybrids, various species of *Ligustrum*, *Syringa vulgaris*, *Ilex crenata*, *Magnolia × soulangiana*, *Malus* species and hybrids, *Acer platanoides*, Asiatic rhododendrons (both evergreen and deciduous) and their hybrids, *Berberis thunbergii*, *Abelia × grandiflora*, *Vinca minor*, and *Pachysandra procumbens*, to mention only a few examples.

This is not to imply, however, that there are few indigenous plants that have “made the grade,” horticulturally speaking, for there are many obvious successes. Some plants, such as *Cornus florida*, have been adopted immediately and widely, but others, such as *Phlox stolonifera* ‘Blue Ridge’ have had to receive an award in Europe before drawing the attention they deserve here, much as American singers used to have to acquire a foreign reputation before being accepted as worthwhile artists. Examples among the widely grown eastern American trees are *Tsuga canadensis*; *Thuja occidentalis*; *Pinus strobus* (and other species); *Quercus rubra*, *Q. palustris*, and *Q. phellos* (the last primarily in the southeastern United States); *Acer rubrum*, *A. saccharinum*, *A. saccharum*, and *A. negundo*; *Gleditsia triacanthos* (particularly some of the thornless staminate cultivars); *Magnolia grandiflora*; and *Ulmus americana* (certainly one of the most widely planted trees in the northern United States, but one that is severely threatened by the “Dutch” elm disease). *Cornus florida* and *Cercis canadensis* are, with doubt, two of the most ornamental and widely planted of all eastern Ameri-
can small trees. Among other woody plants can be cited *Ilex opaca*, *Leucothoe fontanesiana*, *Pieris floribunda* (mainly in the North, for it is little planted in the southern Appalachians where it is indigenous), *Hydrangea arborescens*, *Kalmia latifolia*, and *Campsis radicans*. Herbaceous plants include *Phlox paniculata*, *P. subulata*, and the annual *P. drummondii* (all three in numerous color forms), *Phlox divaricata*, *Aquilegia* species and their hybrids, and various species of *Tradescantia*, *Oenothera*, *Coreopsis*, *Gaillardia*, and *Aster*. And, of course, some of the plants derived from Mexico, such as *Tagetes*, *Zinnia*, *Cosmos*, and *Dahlia*, are almost ubiquitous garden plants. But who in the United States would cultivate any of the goldenrods (*Solidago* species), which are colorful garden plants in England; or who would plant *Rhus typhina* as an ornamental shrub, as it is grown in Switzerland; and who would deliberately cultivate *Ipomoea* in the Southeast, where several species are among the most aggravating garden weeds? All of these are much too familiar.

Rehder's *Manual of Cultivated Trees and Shrubs* (ed. 2, 1940) includes some 2535 species of woody plants in 486 genera that are in cultivation in one way or another in northeastern North America. Of these, 1047 species in 228 genera are indigenous to the continental United States. Obviously, it is impossible with an allotted time and space to consider even these, much less the herbaceous ones, in any detail. It seems most practical here to deal primarily with plants of eastern North America (those with which I am most familiar), without meaning to slight the contributions of the western part of the United States and Canada, Meso-America, or the West Indies, all important sources of cultivated ornamental plants. I must also restrict these comments to eastern North American plants as cultivated in the United States without much consideration of those cultivated in other countries. Within this limitation I shall comment briefly on a few of the future potentials of botanical gardens and arboreta in connection with the cultivation of native plants as ornamentals. Some of these ideas are already familiar, but among them may be some that will suggest some directions that are open for work with native plants under cultivation.

**Conservation of Species.** Certainly it is most desirable to preserve wild populations of each plant species in its own habitat through conservation of whole ecosystems in as many parts of the world as possible. Wild populations and their interactions
with other organisms are far better for study, research, and admiration than those in cultivation where only a few individuals can be preserved (and then largely under artificial conditions). It seems likely, however, that in view of the wholesale modification of large areas of the earth some species will survive only in botanical gardens or arboreta, in some instances far removed from the natural distribution of the species.

In North America, the most conspicuous and well-known example is Franklinia alatamaha, which was known from a single colony near what was Fort Barrington, in McIntosh County, Georgia. It was last seen in the wild in 1803; nurserymen attempting to fill orders for the plant may have played a crucial role in its disappearance. No other colony has ever been found, and Franklinia now survives only in cultivation. Other rare plants that may meet a similar fate are the handsome red-flowered mint Conradina verticillata; the rare Gentiana pennelliana, of western Florida; Lilium iridollae, of the same region; and Lindera melissifolia, and Kalmia cuneata, two of our rarest shrubs.

Other plants endangered by man through his careless introduction of disease-producing organisms include Castanea dentata, formerly one of the dominant trees of the eastern deciduous forest. The chestnut still survives but hardly ever fruits in its native habitat, for the sucker shoots which spring from the roots are usually attacked by the blight organism, Endothia parasitica, before they are large enough to flower. Outside its original eastern American distribution and beyond the reach of the blight, the tree still flourishes, flowers, and fruits under cultivation, as, for example, in northern Michigan and in Portland, Oregon. It seems likely that a similar or even more serious fate may be in store for Ulmus americana, since, as yet, no individuals truly resistant to the disease caused by Ceratocystis ulmi have been found, in contrast to the European elm, Ulmus procera (also affected by the fungus but not so severely), which apparently is making a comeback in Europe. It seems likely that both Castanea dentata and Ulmus americana will survive primarily in botanical gardens and arboreta well removed from the sources of infection.

Promotion of Desirable but Seldom Cultivated Plants. In spite of Rehder's inclusion of over a thousand species of trees, shrubs, and woody vines in his Manual, it is evident that many of these are seldom encountered in cultivation outside botanical gardens and arboreta. Botanical and horticultural institutions
Franklinia alatamaha. a, branch before flowering, bearing fruit of two preceding years, \( \times \frac{1}{4} \); b, bud showing outermost sepal and two bractlets, \( \times 1 \); c, flower, \( \times \frac{1}{2} \); d, petal with group of stamens attached, \( \times 1 \); e, gynoecium (pistil), \( \times \frac{3}{4} \); f, diagrammatic cross section of ovary, showing two rows of ovules in each locule, \( \times 5 \); g, capsule from which seeds have been shed — note loculicidal dehiscence above, septicidal dehiscence below, \( \times \frac{3}{4} \); h, seed, the hilum to upper left. (Drawn by the late Dorothy H. Marsh from specimens cultivated at the Henry Foundation for Botanical Research and the Arnold Arboretum. Illustration prepared for a Generic Flora of the Southeastern United States, a project made possible through the support of the National Science Foundation [currently through Grant GB-6459X, C. E. Wood, Jr., principal investigator].)
should make special efforts to bring knowledge of such neglected plants to the horticultural public and to promote their cultivation, for there are many worthwhile ornamental plants that fall into this category. Among these are the witch-hazels, *Hamelis virginiana* (fall flowering) and *H. vernalis* (winter or spring flowering and in shades of deep red to yellow); *Clastis lutea*, yellow-wood, notable for its *Wisteria*-like clusters of white flowers in early summer; our only ericaceous tree, *Oxydendrum arboreum*, sourwood, outstanding in its panicles of small white flowers in summer and brilliant coloration in autumn; *Ilex longipes* and *I. decidua*, two handsome deciduous hollies; *Neviusia alabamensis*, a rare rosaceous shrub with flowers lacking petals but with showy white stamens; *Fothergilla major*, an apetalous relative of *Hamelis* with conspicuous stamens and leaves with brilliant red and yellow autumn color; the brilliantly colored *Rhododendron speciosum*, *R. cumberlandense*, *R. prunifolium*, and *R. bakeri*; the white- or pink-flowered *R. atlanticum* and *R. canescens*; *R. minus*, the Piedmont counterpart of the more frequently grown *R. carolinianum*; the pink-shell azalea, *R. vasye*; the deciduous magnolias, such as *M. macrophylla*, *M. ashei*, *M. cordata* (particularly the yellow-flowered forms), and the pair of close relatives, *M. fraseri* and *M. pyramidalata*; the red-flowered *Aesculus pavia* and the shrubby *Ae. parviflora* with its candle-like racemes of white flowers; the silver-bell trees, *Halesia diptera* (particularly the showy var. *magniflora*), *H. parviflora*, and the very variable *H. carolina* (including *H. monticola*); *Lonicera flava* and the more frequently cultivated coral honeysuckle, *L. sempervirens*; the shadblows or shad-bushes, *Amelanchier arborea*, *A. canadensis*, the dwarf *A. stolonifera* and *A. obovata*, and other species; *Yucca glauca*, some forms of which are hardy far beyond its natural distribution; *Ungnadia speciosa*, of the Sapindaceae, a pink-flowered shrub known as Texas buckeye that has proved to be hardy as far north as Gladwyne, Pennsylvania; *Pinckneya bracteata*, notable for the one or two pink enlarged sepals of each flower; *Cyrilla racemiflora*, mentioned below; *Leucothoe racemosa* and *L. recurvata* and *Clethra alnifolia* and *C. acuminata*, of the Ericaceae, two vicarious Coastal Plain-montane species pairs; *Elliottia racemosa* with its racemes of white flowers; *Zenobia pulverulenta*, with its bell-shaped white flowers and leaves either whitened or green below; *Stewartia ovata* and the equally showy but much less hardy *S. malacodendron*; *Styrax americana* and *S. grandifolia*; various species of *Vaccinium* and *Gaylussacia*; and a host of herbaceous species, among which are *Amsonia*
Hamamelis vernalis. Photo: J. Henry.
Top left: Rhododendron speciosum
right: Halesia monticola

Bottom left: Zenobia pulverulenta
right: Ilex longipes

Photos: J. Henry
species, *Baptisia sphaerocarpa*, *Ipomopsis rubra*, *Phlox bifida*, *Camassia scilloides*, *Zephyranthes atamasco*, *Hymenocallis* species, *Hesperaloe parviflora* (the red-flowered yucca, from central Texas but perfectly hardy at Gladwyne), various species of *Clematis*, and the gray-leaved *Senecio antenariifolius* and the showy yellow-flowered *Eriogonum allenii*, both endemics of the Virginia and West Virginia shale barrens that flourish in open, dry situations as long as they are not shaded out by surrounding plants. The list could go on and on.

**Selection of Unusual Forms from Wild Populations.** A reservoir that still has an enormous horticultural potential is the natural variability of wild populations. The late Mrs. J. Norman Henry brought together over a period of years a remarkable collection of native plants, especially from the southern and southwestern United States. These she grew (most far to the north of their native habitats) at Gladwyne (near Philadelphia), Pennsylvania, where they and others are maintained for study and distribution by the Henry Foundation for Botanical Research, which she established. In the course of her extensive field work she brought into cultivation most of the species mentioned in the preceding paragraph and also made many interesting selections that deserve to be known better. These include intense color forms of *Rhododendron speciosum*, *R. cumberlandense*, *R. bakeri*, and *R. austrinum*; a hose-in-hose form of *R. alabamense*; a yellow-fruited form of *Ilex decidua*; a form of *I. glabra* that has maroon fruits until winter when they become black, as in the kind usually seen; *Phlox nivalis* 'Gladwyne' and 'Azure', *P. carolina* 'Chattahoochee', *P. stolonifera* 'Blue Ridge'; handsome natural hybrids of *Aesculus pavia* with *Ae. sylvatica* and with *Ae. glabra*; a red-flowered form of the cross-vine, *Bignonia (Anisostichus) capreolata*; a number of color variants of *Lilium superbum* and *L. canadense*; a beautiful late-flowering *Robinia*, a small tree with densely gray-pubescent leaves and compact drooping racemes of pink flowers, distinctive enough to be given specific rank, except that it appears to be a natural sterile hybrid of unknown parentage; a pale orange-flowered *Campsis radicans*; a startling number of puzzling variants of eastern American *Yucca*; and several variants of *Calycanthus floridus*, including a green-flowered one — all valuable additions to horticulture.

Still other examples are seen in the numerous cultivars that have been selected from wild populations of *Ilex opaca*. Currently Mr. and Mrs. Don Smith, of the Watnong Nursery, New
Jersey, have been bringing into cultivation a number of excellent forms of *Gaylussacia brachycera* and of *Leiophyllum buxifolium*. Further examples are among the cultivars recently registered at the Arnold Arboretum (Arnoldia 30: 251. 1970): *Cercis canadensis* 'Royal White' (larger white flowers than usual in form *alba*) and 'Silver Cloud' (variegated leaves), *Cornus stolonifera* 'Isanti' (dense, compact growth), *Liriodendron tulipifera* 'Ardis' (miniature in leaf and growth), and *Tsuga canadensis* 'Watnong Star' (dwarf, the new growth very pale at first).

*Acer rubrum*, with its great variability in intensity of flower and fruit color, as well as in autumn coloration; *Robinia*, which hybridizes extensively in the southern Appalachians producing a wide variety of attractive clones that vary in height of plant and size and color of flower; the polymorphic *Vaccinium stamineum* and its relatives, a taxonomic nightmare, but with much variation that can be of horticultural interest; and *Magnolia grandiflora*, with its variable flower size, color of new foliage, pubescence of the underside of the leaves, and stature (including dwarf forms), are all taxa that could yield desirable cultivars.

A slightly different sort of selection that can be tried with other plants is seen in Burpee's 'Gloriosa Daisy', which is an artificial tetraploid derived from color forms of the common and widespread black-eyed susan. By selecting forms that are "double-flowered" or have the inner half of each ray floret brown instead of orange-yellow and then doubling the chromosome number by treatment with colchicine, Burpee's plant breeders produced a much more vigorous, much larger flowered plant that is more showy than and far superior to the wild *Rudbeckia serotina*. One wonders how other members of the Aster Family, e.g., *Gaillardia*, with its polymorphic corolla forms and colors, or members of several other families might respond to similar treatment.

Still another type of selection is going on at the Arnold Arboretum, where Mr. A. J. Fordham is growing seedlings from cones on "witches' brooms" from various conifers. Each witches' broom represents a genetic mutation that has occurred on a growing branch of a tree, the resulting growth having a compact, bushy, stunted, or dwarfed appearance. Seedlings from cones produced on branches of this type yield about half "normal" individuals and half variously dwarfed ones. Selections from the latter group provide slow-growing genetically dwarf plants that are useful for bonsai, or in rock gardens or other
Selection of Ecotypes. Still another type of selection from wild populations that botanical gardens and arboreta should continue is the search for physiological variants or ecotypes suited to various climatic extremes, e.g., for hardiness in northern areas, or to various soil types. In this connection, it is always necessary to remember that one can be quite mistaken in pre-judging the physiological potentials of any plant. Thus, although Franklinia alatamaha came from the warm climate of the Coastal Plain of Georgia, it is hardy as far north as Boston; and there has been for many years on Bussey Hill in the Arnold Arboretum a plant of Cyrilla racemiflora, a species that is not found in the wild north of southeastern Virginia. One can surmise, however, from what is already known of the ecotypic variation in plant species, that, in any wide-ranging species, the
individuals comprising populations in various parts of its range will be genetically (hence, physiologically) adapted to various climatic extremes, as well as to various soil types, and selections can be made accordingly.

Many of the woodland plants of eastern North America have very broad distributions: a very commonly encountered one extends roughly from Quebec, west to Minnesota or southern Saskatchewan, and south to eastern Texas and to Florida. Among the populations of a species distributed so broadly, it is likely that there is a considerable amount of ecotypic differentiation and that the more northern populations consist of individuals more tolerant of cold than those of the more southern ones. Search for various ecotypes suited to special environments should produce some interesting results. Wright, for instance, almost thirty years ago (Jour. Forestry 42: 489–495, 591–597. 1944) demonstrated differences in resistance to cold in white and in red ash, *Fraxinus americana* and *F. pennsylvanica*; and ecotypic variation in response to day-length has been found in species of *Populus*, *Pinus*, and *Alnus*, among others. Certainly the northern populations of white pine, *Pinus strobus*, should prove to be physiologically, if not morphologically, quite different from those in southern Mexico, and the arborvitae, *Thuja occidentalis*, of northern bogs must be physiologically different from the plants of this species that grow on dry limestone cliffs in Virginia. Indeed, J. R. Habeck (Ecology 39: 457–468. 1958) has found evidence of ecotypic differentiation between populations of *Thuja* that grow in poorly drained swamps and those on well-drained upland sites in Wisconsin.

As noted previously, *Cornus florida* is very widely cultivated, but its western counterpart, *C. nuttallii*, with six pointed bracts instead of four notched ones, has repeatedly proved to be too tender to survive the winter of the eastern United States. However, at Boyd’s Nurseries, McMinnville, Tennessee, after twenty years of trials, a single seedling that has withstood –19°F., was found and this plant has now been propagated and is available commercially. Within the range of *C. nuttallii*, from southwestern British Columbia, to western Washington and Oregon, and southward in the Sierra Nevada and in the Coast Ranges of California, there must be other climatic ecotypes that would be suitable in the East. Disjunct populations of this species in central western Idaho offer particularly intriguing possibilities.

As a result of many attempts to grow southern plants at Gladwyne, Pennsylvania, Mrs. Henry evolved the general principle that the hardiest forms of species that grow on the Atlantic
and Gulf Coastal plains and in the Mississippi Embayment of the Coastal Plain are to be found in the Embayment area, where the climate is more continental (hence more rigorous) and plants are subjected to more sudden changes in temperature than on the Coastal Plain of the southeastern United States. This principle leads to the suspicion (expectation?) that harder forms of a plant such as *Styrax americana*, which at Boston is killed back each winter, can be found in the northernmost part of its range in the Mississippi Embayment, in the case of the *Styrax* the part that lies in southeastern Missouri, western Kentucky, southern Illinois, Indiana, and Ohio.

Edaphic or soil ecotypes are also to be sought. Five very striking examples are found in shrubby races of *Quercus chrysolepis*, *Quercus garryana*, *Lithocarpus densiflora*, *Chrysolepis* (*Castanopsis*) *chrysophylla*, and *Umbellularia californica* that were reported from the Siskyou Mountains of southern Oregon and northern California by Whitaker (Ecol. Monogr. 30: 299. 1960). These forms are genetically dwarf and are adapted to growth in soils derived from serpentine, a mineral high in magnesium, while their arborescent counterparts are not. If these dwarfed races are like other plants adapted to serpentine soils, they will grow even better in richer soils, while retaining their dwarf character, and all five have interesting horticultural potentials as shrubs and even as bonsai subjects.

Search should also be made for species and ecotypes that are resistant to air pollution in cities, although, hopefully, steps are being taken to reduce this. Some plants are known to be very sensitive, others are more resistant, but I do not know whether a real search has been made for especially smog-resistant plants.

Hybridization. Both spontaneous and controlled crosses of native American plants in arboreta are far from new, but there are still enormous untouched potentials, as in the genus *Rhododendron*. The 'Ghent' and 'Exbury' azaleas are spectacular examples of complex hybrids that involve eastern American species of *Rhododendron*, but there are many other possibilities among the dozen or so species of section *Pentanthera* that occur in eastern North America. At Gladwyne, Mrs. Henry saw the desirability of extending the flowering period of azaleas into midsummer or later, and in 1953 described *R. × gladwymense*, the hybrid (made in 1944) between the two latest flowering species, *R. prunifolium*, with large, brilliant red flowers, and *R. serrulatum*, with small white flowers. At Gladwyne, the hybrids bloom from mid-July to mid-August, or later, and have proved to

*Stewartia malachodendron. Photo: J. Henry.*
be quite hardy. Mrs. Henry later crossed *R. × gladwynense* with the earlier-flowering *R. arborescens* and made a number of other beautiful hybrids. Fred C. Galle, at the Ida Cason Calloway Gardens, Pine Mountain, Georgia, and Henry T. Skinner, of the U.S. National Arboretum, are currently producing a series of hybrids involving these and other American azaleas.

The use of American species as a source of hardiness in hybrids is well known, as with *Rhododendron catawbiense*, which has provided the hardy genetic background of many red-flowered hybrid rhododendrons, or as with the white-flowered *Nymphaea odorata* in crosses with tenderer species of *Nymphaea* with colorful flowers. Such work could well be extended to other genera. Crosses between *Hydrangea arborescens* and its closest relative, the less hardy blue-flowered *H. aspera*, of Japan, might produce interesting results, as might the hybridization of *Aesculus pavia* with *Ae. turbinata*, of Japan, or other species, such as *Ae. parviflora*, which is placed in a section of its own. (The handsome pink-flowered *Ae. carnea* is a tetraploid that originated through hybridization of *Ae. pavia* and *Ae. hippocastanum*, which belong to different sections.) It would also be interesting to see what results could be obtained in crosses between *Ceanothus americanus* or *C. sanguineus* and some of the blue-flowered western American species that are not adapted to the climate of the eastern United States.

Problems in the Cultivation of Native Plants. Finally, there is much to be learned about many aspects of the cultivation of native ornamental plants. The seed-germination requirements of many of the tree species are well known, but those of many shrubs and of the majority of herbaceous plants have received relatively little attention. There are also numerous problems in connection with the vegetative propagation of native plants. Difficulties in rooting cuttings of American azaleas (*Rhododendron* sect. *Pentanthera*) worked against the propagation and wide horticultural use of these beautiful plants until the discoveries that cuttings should be taken early in the growing season when the new shoots are just beginning to become woody and that root-suckers can also be taken made the rooting of cuttings a routine matter (see A. J. Fordham, Quart. Bull. Amer. Rhododendron Soc. 23: 162–165. 1969). The further discovery that *Elliottia racemosa* will produce root-suckers that can easily be rooted has eased the difficulty of propagating that beautiful ericaceous endemic of Georgia (see Fordham, Arnoldia 29(3): 17–20. 1969). Yet, plants such as *Nyssa sylvatica* and *Sassafras*
Elliottia racemosa. Photo: J. Henry.

albidum, each of which suckers from the roots but is difficult to propagate vegetatively or to transplant, offer further problems.

These examples suggest some of the possibilities that workers at botanical gardens and arboreta can find in native eastern American plants, both in and out of cultivation. Aside from these considerations, however, but basic to all that has been said, is the question of why anyone should bother to cultivate non-food plants at all. I think that the answer lies in the satisfy-
ing connection that plants make with the natural world around us, for there is every indication that man needs to keep in contact with the living world in which he evolved. With ever-increasing urbanization and with the profound changes man is bringing to his environment, cultivated plants are more important than ever in bringing a sense of appreciation for and a sense of the value of the remarkable organisms that inhabit the earth. Man removed to an artificial world would be a sorry animal indeed. Botanical gardens and arboreta have a critical role to play in maintaining and developing a real appreciation for the natural world and our proper place in it.

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Horticulture is the art or science of growing flowers, fruits and vegetables. At one time in the early history of this country it was not differentiated from agriculture, but now, as has been the tendency in many other areas, specialization in the study and use of plants has resulted in the field of horticulture itself being divided into several sub-divisions; namely, pomology, olericulture, floriculture, ornamental horticulture and viticulture. Today there is a fascinating potential for arboreta and botanical gardens in the field of ornamental horticulture.

Ever since colonial days, the economic phases of horticulture have been given prime attention. The early colonists had to grow the vegetables and fruit trees in order to provide food. As more and more plants were established, more interest was taken in new and higher yielding varieties, then in better ways to grow these varieties and to control pests which began to infest them. Near the end of the last century, public institutions supported by federal and state tax income took up intensified experimentation in pomology and olericulture, and later viticulture and floriculture. Many excellent local state and federal stations of experimentation were established, not only to better the quality of the food produced, but also to improve the methods of producing it.

Ornamental horticulture has been a late comer in all this experimentation, and until recently the emphasis has always been on the economic phases of growing plants. This is probably as it should be. At first large estate owners would collect a lengthy list of varieties of apples, or peaches, but usually the owner did not have suitable scientific background for gaining the most information from such collections. It was frequently a personal hobby, and when he lost interest, or finances became tight, the collection was removed. Great collections of apple, pear, grape and peach varieties have now been made at our state and federal experiment stations where there is impartial experimentation by trained scientific observers. In general, little
attention has been given to the ornamental plants that we now consider so essential to beautify the world within which we live. It is here that the arboreta and botanical gardens have their opportunities. They have the large collections of all kinds of plants, those of only botanical interest and those of purely ornamental interest. The experiment stations cannot give such collections space nor proper care. On the other hand, the arboreta and botanical gardens do not have space for large collections of economically important varieties of fruits and vegetables.

Hence as far as horticulture is concerned, our interest is best confined to the ornamental aspects of horticulture. Certainly we who have had to do with arboreta and botanical gardens are far better endowed to deal with the problems which this field presents and let the government experiment stations deal with the economic fruits and vegetables.

When the early settlers first came to America, they were primarily interested in hewing a home from the forest primeval. They brought many seeds and even plants of the fruits, vegetables, herbs and flowers that they were accustomed to in their European environment. The peach, for instance, was brought by the early Spanish explorers, and in the early history of Georgia and Alabama the Indians were known to have grown many different kinds of peaches (all seedlings) which they would use in barter.

Those settlers with large land grants in Virginia were first interested in growing and selling as much cotton, tobacco, or indigo as they could. It was not until this was accomplished that they began to have more leisure and take the time to plant flowers, trees and shrubs for ornament. The earliest writings about plants in America were those by physicians who were interested in herb collections, for medicinal purposes, or by naturalists who were interested in exploiting the plants of the New World.

Prior to 1750 there were the excellent plantings of the gardens of colonial Williamsburg, where living had reached a luxurious level. Many of the plants used here were American natives as well as those brought over from England. It was not until about 1770 that we have the first treatise on American flower gardens written by a Mrs. Martha Logan of Charleston, S.C. The first American book on gardening was by Robert Squibb, the Gardener’s Kalender published in Charleston, S.C. in 1787.

However, things were happening elsewhere as people found more and more leisure to plant ornamentals. John Bartram’s garden was established in Philadelphia in 1728 and although the economic side of horticulture was his prime motive, never-
theless his garden held great interest for land owners of estates who soon became his customers.

After the fighting of the Revolutionary War was over, George Washington himself set a splendid example by settling down at Mount Vernon and planting his gardens. Thomas Jefferson was also a garden enthusiast and made no bones about where his interests were. He is generally given credit for sowing seeds of Cytisus scoparius along the roadsides of Virginia whenever he had to take a trip somewhere, and it may well be that naturalized stands of this European plant now found in Virginia were the results of his efforts. Land owners in New England were becoming more and more interested in ornamental gardening, for here some who had large collections of apple or pear varieties soon took up a new interest in ornamentals. If any specific time can be designated as the period when horticulture began to emerge as distinct from agriculture, it might be in the early 1800's.

Grant Thoburn established the first seed store and florist shop in New York in 1802 while Bernard M'Mahon established his in Philadelphia in 1806. Joseph Breck established his in Boston in 1818. M'Mahon listed over 1000 different kinds of plants and seeds, many of them among the best of European importations. Interest was such in New England that the Cambridge Botanic Garden was established in 1808 and this naturally became a source of great interest to plantsmen of the area. Many nurserymen started into business at about this time — William Prince in 1837. The nursery eventually was to be owned by three generations of the family. William Prince was so interested in obtaining new plants for his customers that he wrote a form letter, in the 1820's, to sea captains asking their assistance in bringing back to him small amounts of seeds or bulbs of plants native about the ports they visited. Parson's Nursery was established in 1838 on Long Island, not far away from the Prince Nursery. Such nurseries, and many others did much to make it possible for home owners to obtain new ornamental plants.

The founding of the Massachusetts Horticultural Society in 1829, and of the Pennsylvania Horticultural Society in Philadelphia shortly before, were two events which gave ornamental horticulture a greater impetus than anything else. It was through the "exhibitions" produced by these Societies that many of the ornamental plants first became known to the public. Even at the first exhibition, staged by the Massachusetts Horticultural Society, prizes were given for the best American holly, Magnolia...
glauca, Rhododendron maximum, and Kalmia latifolia, all of which were native plants, as well as for tulips, Chinese chrysanthemums, hyacinths, carnations and roses. In 1830, there were 30 varieties of Ranunculus asiaticus displayed; a little later, large collections of dahlias, but the emphasis at those early exhibitions was always on fruits. The first exhibit of Indian azaleas was in 1835.

It is interesting to note in the history of the Society that even in 1841 ladies were not admitted to the dinners of the organization, for “if they were, wine could not be”. In 1830 there was a great discussion against giving any lady horticultural honors for it was said that women in the garden had brought trouble since the time of Adam. No lady read a paper before the Society until 1880. However, there were indications of a change in perspective for one report read after the Committee on visiting gardens had found a Mrs. Fay at work in her garden — “what a pity that so few ladies of our land imitate her example, inhaling the fresh breath of the young day and the envigorating aroma of the freshly turned earth, planting the roses of health in their cheeks and nurturing the germs of health and strength and buoyancy of spirit”.

In an exhibition staged in 1845 it was noted that there were 33 bouquets of flowers from 8 contributors, and later President Wilder of the Society was moved to note an improvement in the “arrangement” of the flowers exhibited. What would these “arrangers” have thought if they could have seen some of our modern flower shows?

By 1850 there were indications of greater interest in ornamentals than in fruits and vegetables, for in that year the Society allotted $650. in prizes for flowers, $450. for fruits and $150. for vegetables. Usually however the displays of fruits and vegetables eclipsed those of flowers. In 1856 there was a display of 40 varieties of fuchsias, underwriting the fact that by this time many a New England estate owner also had his own greenhouse. Andrew Faneuil built the first, on Tremont Street between Pemberton and Beacon, in 1715.

Mr. H. H. Hunnewell of Wellesley was a great grower of rhododendrons, and a staunch supporter of the Massachusetts Horticultural Society as well. He underwrote a large display of rhododendrons (under canvas) on the Boston Common in 1873 and this was the first time so many people had been able to see such magnificent plants in full bloom. This, and the Centennial Exhibition in Philadelphia (1876) where 1500 rhododendrons were exhibited by Waterer's Nursery of England were chiefly re-
Cytisus scoparius. Photo: Heman Howard.
Kalmia latifolia. Photo: D. Wyman.
sponsible for bringing these supposedly hard-to-grow shrubs to the attention of the general public.

There had been large collections of plants, privately owned, where the public was invited on occasion, like the collection owned by Pierre S. du Pont at Kennett Square, Pa., later to be opened and called Longwood Gardens in 1937. Then there was Shaw's Garden in St. Louis, Mo., later to be called the Missouri Botanical Garden, and the Hunnewell estate in Wellesley, Mass., later to be known as the Walter Hunnewell Arboretum. Among the first large truly public collections to be established were the Arnold Arboretum in Jamaica Plain, Mass., established in 1872; the Beal Garfield Botanic Garden on the campus of the Michigan State University in East Lansing, Michigan (1873); the Bayard Cutting Arboretum on Long Island, N.Y. (1887); Highland-Durand Eastman Park, Rochester, N.Y. (1890); and the New York Botanical Garden in New York City (1891). After these there were over a hundred others spread about the country, each one open to the public, each one displaying chiefly ornamental plants growing in the open. There is no question but what these have had a permanent effect in creating enthusiasm for ornamental horticulture by the general public. Most of these collections were started in a small way, but as funds became available more and more plants were added and the institutions concerned began using various means of presenting ornamental horticultural information to the public.

Another tremendous impetus given ornamental planting was the great influx of new plants from the Orient, chiefly as a result of exploration initiated by the Arnold Arboretum. These colorful introductions spread over nearly half a century have reached practically every garden in America. It is of interest to note that in gardens and landscape plantings of a general nature in the northern United States, half of the plants used are of oriental origin, a quarter are native to Europe and only a quarter are native to America. The colorful and exotic Japanese crab apples and cherries, tree peonies, azaleas and rhododendrons make any garden interesting.

It was during this same period that the nursery industry grew tremendously. New nurseries were formed in every state of the Union. Many an old established nursery found that it was more profitable to grow ornamental plants than it was to grow fruits. Vegetable sources were of course specialized seedsmen, but since 1920 there have been fewer and fewer nurserymen growing fruit trees.

Julius Sterling Morton (1832–1902) certainly should be men-
tioned as one individual who greatly aided ornamental horticulture. He conceived the idea of Arbor Day and was responsible for establishing the first one in 1872 in Nebraska, when over 1,000,000 trees were planted in that state alone. True it was at first that in the prairie states fruit trees were first thought of, but the idea quickly carried over to the planting of any ornamental tree, and now the day is celebrated nationwide with tree planting ceremonies, with ornamental trees far outnumbering the fruit trees planted.

It might be said that ornamental horticulture really came into its own at the start of the 20th century. By this time there were at least nine active state horticultural societies only two of which were in the mid-west, the others in the east. There were magazines featuring articles dealing with ornamental planting. Some of the great parks like Central Park in New York City (1858) and Durand Eastman Park in Rochester, New York (1890), had been popular places for visitors and this of course was bound to bring ornamental planting to the attention of the general public. Some state Experiment Stations were in operation; others were soon to follow.

The 20th century was a time for the rapid expansion of single plant societies, over 50 of them in all. These were national organizations with annual meetings, dues and usually a publication, devoted to the study, discussion and improvement of one special flower. The American Carnation Society (1909) and the American Peony Society (1904) were probably the first established. However, others have been coming into existence ever since and only last year the International Lilac Society was formed. Some are lacking in finances and general public interest at first, but their very formation shows that people are interested in these ornamental flowers and are willing to grow them and to take up their study and improvement as a special hobby.

By this time, the ladies have long been prominent in ornamental horticulture and in fact have actually taken over much of the garden planning and work. Their general interest in growing their own flowers, in color combinations and the exquisite effects they could obtain in the arranging of flowers have all been factors. The first garden clubs were probably a coming together of men and women interested in growing ornamentals in the garden. Soon however, the whole garden club idea was taken over by the ladies and it has been possibly the greatest factor in bringing interest in ornamental horticulture to what
it is today. One organization alone today has 387,700 members, mostly women. Their interests vary greatly from gardening, to flower arranging, to planting their communities, to conservation, to producing flower shows and awarding scholarships to deserving youngsters for college study.

The majority of the gardeners in America are now closely associated with the garden club movement. Either the garden owner is a member or certainly she has friends who are. When national movements are undertaken by these well organized and very well informed groups, the majority of the gardeners in America at least are cognizant of what is going on and many find they are participating, willy nilly!

More important is the fact that it is through these energetic people that advances in ornamental horticulture are quickly undertaken. With modern travel, radio, TV and newspapers what they are, new plants are soon heard about, new horticultural procedures are quickly passed along and enthusiasms for new and worthy projects are quickly publicized. A century ago such information was hard to come by. Today it might seem with all our horticultural publications that we are overwhelmed with too much information, but the growing of ornamental plants is a very popular project of every garden owner in America.

It should be pointed out that competition among the amateur growers is still as much an incentive as it always was — to grow the biggest or best or newest flower, then to be rewarded for it at some show or exhibition. The garden club movement naturally fosters this idea.

Ornamental horticulture has come a long way since the start of the nineteenth century. It is no longer an asset of the rich. It has become an important part of the lives of most Americans, even those apartment dwellers in the hearts of our large cities. Many individuals are now being trained to take a major part in this field.

There are at present over 60 national horticultural organizations devoted chiefly to the ornamental phases of horticulture, about 50 single flower societies, 41 libraries featuring information on ornamental horticulture and 78 institutions of higher learning offering bachelor’s degrees in ornamental horticulture. There are nearly 500 gardens, experiment stations or institutions where special information can be obtained concerning the growing, care and propagation of ornamentals. Canada, because of its less populated areas, has not proceeded as fast as the United
States in these respects, but Ontario has set an excellent example with its government organized and subsidized horticultural societies, underlining the great importance of ornamental horticulture in this fast developing country.

The first gardens were of herbs because of necessity. Then the early settlers added a few plants popular in Europe, adding more of those native to America. Later there was a mixture of almost anything that was new or took a gardener's fancy. Methods of growing were passed around at first by word of mouth, then information was found in articles by experienced "growers" but not until the Hatch Act (1887) and the formation of state Experiment Stations, was there much scientific knowledge available to help amateur growers. Before this the best practices were those which apparently produced the best results.

Interests and needs changed. With the planting of great municipal public parks there was a great popularity among the rich growers for bedding plants. Only the city park systems, or those rich enough to have greenhouses and employ a gardener, could have a large geometric planting of bedding plants, for geometric designs in gardens were popular everywhere at the end of the last century.

Because of all the large estates and the fact that many Asiatic plants had not become commercially available, at the end of the last century there was a great demand for tall and fast growing trees. Some of these were Aesculus hippocastanum, Catalpa bignonioides, Ailanthus altissima, Populus nigra italica, Picea abies, Salix babylonica and two small weepers, Ulmus glabra 'Camperdownii' and Morus alba 'Pendula'. Now, although some of these are still grown, none of them is in the popular class. They are superseded by smaller trees such as the oriental flowering crab apples and cherries, as well as dogwoods and magnolias.

There have been times when "fads" seemed to capture the fancy of everyone. Morus alba multicaulis in 1824 was called the "silkworm" mulberry and everyone wanted to get in on the ground floor of a new industry. At the height of this craze, when thousands of trees were raised, seedling trees that normally would sell for fifty cents were bringing ten times this amount. The project as we know now proved futile, and now it is impossible to buy a single plant of this variety from a commercial nursery in the United States. Morus alba 'Pendula' which Hick's Nurseries of Long Island termed "the plant of the century" in the 1890's, soon became over-planted, and few are seen today.
Above: Aesculus hippocastanum

Right: Catalpa bignonioides

Photos: Heman Howard.
However, even the sophisticated gardeners of today are not immune. We are still "taken in" by the tubbed banana for the home with fruit advertised as "always available", with "tree tomatoes" producing crops "up to 40-60 pounds a year"; with a "new" rose bush (or a tree) that grows "to the roof of your home" in two years. To show how history can repeat itself, now 250 years after medicinal herb gardens were popular, it may well be that they will become so again. A new book will be published in England this summer by Maurice Messegue, Of Men and Plants, which is an autobiography of a famous "plant healer" who heals people, often miraculously, with the use of hand and foot baths (or poultices) in which certain of our common herbs are soaked. Undoubtedly this will start many gardeners scrounging around among the weeds and herbs in their gardens to find those recommended by the author as helpful when used for particular ailments, in the way he suggests.

There is still a great deal that the arboreta and botanical gardens can do for ornamental horticulture, being the youngest division of horticulture. With smaller houses, higher taxes and smaller home areas, there is now considerable interest in dwarf plants. Nurserymen formerly were not interested in many of these — they grew too slowly to make a display in time to bring a profit. Now such plants are in great demand. Many of the arboreta of the country with large collections of plants have their own propagating units where special studies can be initiated in finding better ways to propagate such plants. No experiment station has sufficient source material or funds to enter into work on this problem on the same scale as some of our large arboreta.

With large varietal collections of plants like lilacs, mock-oranges, weigelas, Japanese tree peonies and many other types, the arboretum is the best place in the country to compare the ornamental qualities of these varieties. Once their ornamental merits are established, the arboreta should publish lists of "the best" and those worthy of discarding. Arboreta across the country can combine their efforts to make such studies more valuable.

The arboretum is the best place to make accurate color chart notations of flower colors — very few such studies exist. Here the varieties are growing under similar conditions and presumably are all on an even basis environmentally for color comparison. Several of the large arboreta have their own publications and can initiate plant information by such means, but they
should also seek the cooperation of nationally circularized horticultural publications.

They should also initiate a “source list” of where rare but good plants are available. This is one of the most difficult things to do for it is never up to date, but it is the best means of making source information available to the public. Without such information of availability, varietal studies have little current value. The information, the availability of the plants, and the national publicity concerning this should all be carefully worked out and coordinated.

Arboreta with the space and the funds should have extensive breeding programs to provide better plants, with more colorful flowers and fruits, more resistant to pests, with better form or height or autumn color than those varieties available at present. New plants will continue to be found in cultivated areas and in the unexplored hinterlands, but the resources of the arboreta in their own collections are not to be ignored in this respect. We certainly do not need more plants but we can always use better plants and a widely publicized list of generally accepted (by other arboreta) discards which should be no longer grown commercially.

Ornamental horticulture has come a long way in the last 150 years. Just the production of ornamentals alone is big business. In 1950 there were 17,400 nurseries in the United States producing ornamental stock, employing 121,800 persons. The sales of ornamental stock alone amounted to $467,346,000 at wholesale prices. The number of ornamental woody plants sold (326,000,000) was three times what it had been 20 years before. Fruit trees (18,100,000) were down to half what they were two decades before and grape vines (302,000) were only one quarter of what they had been. It is obvious then that there is currently a great surge of active interest in ornamental planting.

In celebrating this Centennial of the Arnold Arboretum it is only fair to mention that the Arnold Arboretum has been vigorously promoting ornamental horticulture in many ways throughout its entire existence. It should not rest on its laurels. The modern potential that arboreta and botanical gardens have in the field of ornamental horticulture is unlimited. People today have more leisure than they have ever had, and with more single homes in America than there have ever been, more gardens are being planted. More individuals are interested in flowers and trees and ornamental plants and their artistic arrangement. Consequently more individuals are looking for help
Morus alba 'Pendula'. Photo: Heman Howard.
in growing and using ornamental plants than ever before. It should be a prime function of the arboreta and botanical gardens to recognize these facts and to produce better plants and better information about them so that all Americans can be active in making the world about them more beautiful.

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