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Botanical Gardens and the 21st Century

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Botanical Gardens resemble other forms of natural history museums, but also differ sharply from them. But all institutions are unique individually. For example, the California Academy of Sciences has a natural history museum, a planetarium, and an aquarium under the same room — an unusual combination. At any event, natural history museums of all kinds share many of the same problems and challenges today, and they clearly can find inspiration from one another.

Botanical gardens were first organized in European universities in the early 1500s to provide instruction to medical students about the plants that they could use to cure their patients. In Pisa, Padua, and other early universities, they were regarded as essential; and they soon spread around Europe. Gradually these herbal gardens expanded into more comprehensive exhibitions of living plants, many of them found in the course of the exploration of Asia, Africa, South America, and Australia from the 15th century onward. In contrast to botanical gardens, natural history museums were formed as cabinets of curiosities, often also from distant lands, and were from the beginning designed for the edification of the general public. Aquariums and zoos arose more recently in their modern guise. The oldest ones we have were organized in the 19th century, and most were founded late in that century or even in the 20th century, first in Europe and then in the United States. Historically, zoos are outgrowths of carnivals, general exhibitions of animals, often traveling from place to place. Such exhibitions have been popular for many centuries.

As a result of their different origins, the different kinds of natural history museums have had different histories and different kinds of institutional connections and sponsorships. For example, I do not know of any example of a university organizing or sponsoring a zoo to exhibit living animals to the general public. A few, like the Scripps Institution of Oceanography in La Jolla, California, have organized display aquaria, but that is a fairly unusual occurrence. On the other hand, as I have already stressed, botanical gardens have basically originated within universities, and many are still associated with universities, as are a number of natural history museums, whether solely for research purposes or including exhibitions for the public.

To speak in more detail about the Missouri Botanical Garden, we are an institution of about the same size, age, number of volunteers, membership and budget as the California Academy of Sciences, but we deal primarily with plants. Our Garden was organized in the 1850s, like the Academy, starting with an outdoor exhibition of plants and later developing a research program. Our founder, an English immigrant named Henry Shaw, opened the Garden to the public in 1859, and he ran it himself for the next 30 years. Although courted by Washington University in St. Louis, Mr. Shaw determined that his Garden would be independent. He linked the two institutions, however, by endowing a School of Botany at the University and mandating in his will that its head would also be the Director of the Garden. The first Professor of Botany at Washington University, William Trelease, thus was chosen as director of the Garden on Mr. Shaw's death in 1889. This relationship has been the basis for a strong graduate program involving the Garden and the

University from 1885 onward, expanded in the 20th century to include St. Louis University and the University of Missouri-St. Louis in similar models. We have pursued our goals, becoming a world-class botanical garden through the years, and the university has pursued theirs, with the whole certainly being greater than the sum of the parts.

The common feature of all botanical gardens is that they display diverse collections of living plants. Like zoos, they are not, intrinsically, research institutions. By the 19th century, however, some of the larger ones, such as the Royal Botanic Gardens, Kew, The New York Botanical Garden, and the Missouri Botanical Garden, began to organize extensive research departments comparable to those that were being built up at the larger natural history museums. It must, however, be mentioned that only about 10% of the botanical gardens in the United States list research as their primary activity, and a majority have no research activities at all: so the trend is my no means universal. Unlike zoos, which do not have research departments focusing on large collections of prepared specimens of animals but rather focus entirely on their living collections, some botanical gardens have significantly taken the same track as their counterparts in natural history museums. Over the years, however, zoos have become increasingly preoccupied with conservation issues and studies of populations of living animals, and botanical gardens have in part acquired a similar focus in recent decades, so that the missions of the two historically very different kinds of institutions have converged greatly.

Botanical gardens collectively have very extensive collections of living plants, even if they are often not populations adequate from a genetic basis to insure the survival of the species involved (Fig. 1). Thus, more than 90,000 species of plants are currently in cultivation, the great majority of them in botanical gardens, of a world total of perhaps 300,000 species — a very large sample indeed. Botanical gardens are strong participants, under the leadership of the Center for Plant Conservation and of Botanic Gardens Conservation International, in the realization of the goals of the World Plant Conservation Strategy, adopted by the Convention on Biological Diversity in 2002. Through such participation and their individual actions, they are striving to insure the survival of as large as possible a sample of the world's plants through this century and beyond. In addition, all botanical gardens, through their display and educational functions, are informing and strengthening the role of the public in pursuing the conservation of plants throughout the world.

FIGURE 1. Ron Liesener identifies specimens recently collected in Latin America. The Missouri Botanical Garden adds about 150,000 specimens to its herbarium each year.

Because plants are much easier to maintain in captivity, as it were, than vertebrate animals, their conservation in principle presents simpler issues, and is

intrinsically less extensive. All sexually-reproducing organisms present similar problems of inbreeding depression and the like, but even for larger populations, as mandated for the United States National Collection of threatened and endangered plants, chartered by the Center for Plant Conservation, plants are much easier to maintain than vertebrates. This offers great promise for the future of many species of plants, and it should in principle be possible to conserve the great majority of them even in these environmentally troubled times.

What is of key importance for conservation of any kinds of organisms is an adequate number of people who can recognize them in the field and understand their biology. Although it is commonly asserted that there are fewer systematists today than there were in earlier times, the facts do no bear this out. There are actually many more, but not many who deal with and can recognize organisms in the field. Further, with the extensive environmental degradation that is going on throughout the world, we feel a need for many more systematists to recognize and classify organisms and lay the basis for saving them from extinction. We also now understand that there are many more kinds of organisms in the world than would commonly have been believed a half century ago, and we know that the current numbers of systematists will not be able to deal with them in any reasonable period of time. Finally, we expect a great deal more from our use of these organisms in building a sustainable world for the future, another severe stress on the system and one that demands greater numbers of trained professionals if we are going to be able to realize the potential benefits. The diversity of organisms is the basis for understanding their molecular relationships, but we must first understand the diversity in order to be able to deal with it adequately. The abandonment of instruction in systematic biology by many university departments has led to a concentration of specialists in museums, botanical gardens, and similar institutions, and to increasing doubts about where the next generation of trained professionals is going to be found.

In addition to all of these problems, the pace has increased in modern times to the point at which it is difficult for trained systematists or other professionals to find time among the daily grind of other tasks, and the necessity of constantly writing grant proposals to find funds to support their laboratories, to carry out the science for which they were originally trained. Carl Linnaeus or George Bentham led tranquil lives that they could devote to the calm study of a much smaller number of specimens in producing their magisterial works. Spared the tribulations of Spam, the demand for instant answers to any e-mail message, constantly ringing telephones, service on committees, and all the other demands of a modern professional career, they could simply get a lot more done than most of us feel possible to accomplish today.

It will be important in building a sound future for our disciplines, so that they can be of maximum service to humanity, that we find ways to train additional professionals. It is understandable that university biology departments over the past 50 years have concentrated so heavily in molecular and cellular biology, because the discoveries made in these fields are of such extraordinary scientific and economic importance. Notwithstanding those opportunities, however, it is ultimately true that gene function and the evolution of families of genes, the comparative study of genomes, and similar approaches will be of great importance for the future of biology. This relationship is being recognized as increasingly important, but we have not yet found the appropriate ways to nurture those who have the knowledge of organisms that will make such approaches feasible and of the highest quality. Perhaps better partnerships between natural history museums, botanical gardens, zoos, and aquaria hold the key to future progress, but it has proved difficult in practice to construct such partnerships well and maintain them. I believe that it is definitely worth the extra effort to do so. Perhaps the National Science Foundation, the National Institutes of Health, and similar bodies could develop and sponsor programs that would facilitate such partnerships. It would certainly seem to be worthwhile to do so.

Of all of the challenges facing us, however, extinction is undoubtedly the most important. Although as I have already pointed out, it is easier to maintain plants in cultivation than other kinds of organisms, this by no means makes their preservation automatic. For the estimated 10 million or more species of eukaryotic organisms, of which we have given names so far to only about 1.6 million species, the extinction of perhaps two-thirds is likely by the end of the 21st Century unless we can find ways to achieve a level population, sustainable consumption, and better technology. We are certainly degrading the productive capacity of the Earth now more rapidly than it is being replenished, and encountering great difficulties in improving the situation. Increasing wealth in countries like China can only accelerate the challenge to our future sustainability, and to the future or a large proportion of the organisms with which we share our planet now.

What should we do about this? Biologists in general are divided over whether we should be concentrating on producing an encyclopedia or all life on Earth or finding ways to sample that diversity while it still exists. Certainly with the development of electronic methods of recording information about organisms and making it available, it is feasible to do much more than we would have thought possible only a short time ago. The Smithsonian Institution sponsored "Encyclopedia of Life" program, which promises to create web pages on all known species, is certainly one exciting approach to the problem. Bar-coding using molecular methods like the sequencing of a section of Cytochrome C (COI) seems to be working well for animals, although no suitable analogue has been found yet for plants or fungi. The Global Biodiversity Information Facility (GBIF), set up by a consortium of OECD countries and headquartered in Copenhagen, is providing a growing and useful index to databases of all kinds about organisms, and institutions like the World Conservation Union (IUCN), World Conservation Monitoring Centre (WCMC), and NatureServe are creating databases of different kinds about species for conservation and other purposes. The relatively small sums of money allocated to such purposes, however, indicate that they are still not being taken seriously on a global scale, which is frightening in view of the immensity of the problem and the disastrous consequences that ignoring it will have for humanity in terms of unrealized objectives and global instability over the decades to come.

Another approach would be attempting to bring our knowledge of a few index groups that are relatively well known and others of obvious economic or ecological importance, such as plants, vertebrates, butterflies, mosquitoes, and ticks up to as complete a state as possible and to sample the rest in ways that would give us some idea of the dimensions and variability of the groups involved. For nematodes, mites, fungi, and certainly bacteria, it seems important to devise and implement sampling methods while the respective biota are more or less intact. Funding has rarely been available for such approaches, however, and I recommend that they be considered much more seriously in the future. The truth is that we cannot even speak intelligently at present about the distribution and abundance of, for example, nematodes all over the world — how many are there, are there more in the tropics than there are in temperate regions, are there more in the soil under the Reserva Ducke Reserve near Manaus in Amazonian Brazil than there are in the soil of Golden Gate Park? Such a question seems very basic, and yet we are not even trying collectively to find the answer — a neglect that is likely to be looked up as a major mistake in the future, when the opportunities will be far smaller than they are now. For most groups of organisms, such as bryophytes, fungi, nematodes, and many groups of insects, we do not even know whether there are more species in the tropics than in temperate regions, even though it is almost an act of faith that there should be more in the tropics.

Turning now to the particular problems and opportunities of botanical gardens, one major problem is that we still do not have any dependable method of finding what is in cultivation in around the world: there is no organized database. If I want to find cultivated (and thus easily acces-

sible) individuals of a family of plants that is endemic to Southeast Asia, the only way that I can do it now is to guess where they might be and send an e-mail message or letter, or telephone, and sometimes I am fortunate enough to find what I am seeking. As a result of this lack of coordination and efficient recording and exchange of information, the several thousand botanical gardens all over the world tend to duplicate the same kinds of collections. They certainly lack the ability to add to their collections efficiently plant species that are not cultivated elsewhere. Scientists and other who would like to have access to their material do not know where to find it! Considering the collective budgets of several thousand botanical gardens and their aims, this seems an unacceptable situation. Therefore, the efforts by Botanic Gardens Conservation International to prepare a computerized list of the names of plants in cultivation are most welcome, and I hope that they will form the basis for an even more systematic and comprehensive approach in the future.

Another problem facing botanical gardens is that even when they have research departments, there is often little or no connection between their efforts and the living collections of plants in the same gardens. As in natural history museums, the exhibits certainly need to be broader than the research programs in order to demonstrate the world of plants and the many relationships in it, and between plants and people, but research should be made more explicit in the exhibits. In addition, the collections of living plants, even though they may not be on public view, should be used more often in ways to assist the research. A few botanical gardens, and the Royal Botanic Gardens in Edinburgh present a particularly good example of this, have built up large, synoptical collections that are of direct relevance to their research programs, but this is a relatively rare situation. Internal linkages within the gardens between research, education, and horticulture, often less than ideal, can be of great benefit to the institutions if fostered properly. For example, involving research scientists in developing the educational material is very helpful, and involving education and display professionals in research expeditions can be equally so.

Increasing amounts of effort in botanical gardens, as with zoos, are being devoted to maintaining living samples of threatened and endangered species that can provide material for re-introduction into nature when the conditions become suitable. These populations may become increasingly important because of the growing importance of invasive alien species in destroying natural habitats, a trend that is already of immense importance and can only grow, and with the burgeoning effects of global warming on natural habitats. Regarding the latter, it is obvious that if present trends are not curtailed, the natural habitats of many species of organisms will simply disappear in nature over the course of the present century. Reserves and parks may not be adequate to maintain them in the face of these trends, and thus botanical gardens, zoos, and aquaria may become to an even greater extent modern Noah's Arks, saving species for the future and developing strategies about the best ways to preserve individual species (Fig. 2).

In a general sense, botanical gardens are important for the same reason that all kinds of natural history museums are important. It is the scientific possibilities combined with the teaching and the educational and exhibit possibilities, which include things like pleasure, recreation, joy, or the simple thrill of being there that immerses people in the experience of that particular group of organisms that really makes them worthwhile and very special. We need to emphasize that to a much greater extent in the future than we have in the past. We must remember that when we are talking about conservation, and we all need to be talking about conservation in some way, that conservation is a matter of several elements, and that no one class of institution fulfills all of these. First, there is information; there are databases about the organisms involved, their characteristics and their ranges. Second, there is dealing with and being able to recognize those organisms and their populations in nature, and that would be a role, in the case of botanical gardens, of the gardens and their trained individuals. Third, there should be links to conservation organizations, such as The

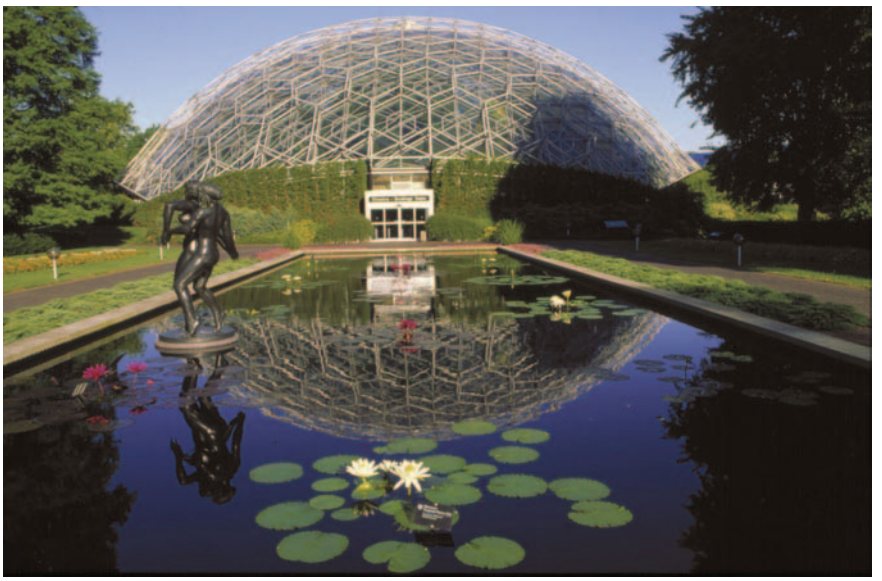

FIGURE 2. The Climatron, completed in 1960, displays tropical plants. It was the first use of a geodesic dome as a greenhouse.

Nature Conservancy, or the World Wildlife Fund, or the Sierra Club, to spread the message. Fourth, there is need for linkages to educational institutions, to the media, and to outreach organizations, which continually inform people about the need for conserving biodiversity. No one institution can bridge all of those areas, which is a strong argument for networking among different kinds of institutions for the purpose of building a sustainable world.

I shall conclude with a few general points that apply both to botanical gardens and to similar natural history institutions. The first point is that we need to consider how effective we are in informing the people who come to our institutions either as visitors or to attend classes. William "Bill" Conway, the legendary directory of what is now the Wildlife Conservation Society, once put it this way: he said, "I somehow think that teaching school children in the Bronx that African elephants have big ears whereas Asian ones have small ears is not going to do the job of convincing them that there's a whole world out there that they need to care about and try to conserve." In order to encourage the development of the kind of a world in which we would like our children and grandchildren to live, we need to be a lot more explicit about those particular items and about the ways in which a sustainable world will help to maintain the quality of life for the people in that world (Fig. 3).

Secondly, we need to improve the quality of our messages, and we need to know how those messages are being received. So often the signs and informational material presented in museums are simply collections of annotations or notes about individual exhibits. Collectively, then, they may give no real sense of the central message of the institution being visited. I urge natural history museums, zoos, aquaria, and botanical gardens to get together, think about the common themes that they are trying to present, and devising ways to impart these themes effectively. For example, if at the San Francisco Zoo, the San Francisco Botanical Garden (Strybing Arboretum), the California Academy of Sciences, and the other public natural history museums, nature centers and parks of the Bay Area would develop together a series of common themes, it would be possible to present these themes concisely and well at all of the institutions and thus to affect the public much

FIGURE 3. Seiwa-En, the Japanese Garden, was completed in 1977. It symbolizes friendship between the United States and Japan.

more profoundly than is the case at present. If that seems a worthwhile challenge, it would be easily implemented.

Natural history institutions are in general vastly out of date in our selection of exhibition techniques. Few of us do a truly outstanding job of presenting any message to the public. When it has been re-established in Golden Gate Park, the California Academy of Sciences has a wonderful opportunity to do well in this area. The Eden Project, which is a set of greenhouses and related exhibit facilities in Cornwall, England, is an exciting example of what can be accomplished with imagination and a flexible view of what is possible. It is called a "project," and not a "botanical garden," because it is seen as continually improving and developing, and so far it has kept the promise implicit in its name. We should all be doing the same!

Three more points I should like to make. First, I think that all of our institutions need to think much more carefully about sustainability in architecture, in engineering, in the use of materials, in the use of energy and in the use of recycling. We need to present outstanding examples in these areas because the world needs to move in this direction and we are prominent public institutions visited by large numbers of people on a regular basis. We should present excellent examples of green architecture, and call them to the attention of our visitors. By doing so, we can contribute in yet another way to the formation of a sustainable world.

Next, we should consistently emphasize internationalism around the world. The United States often has suffered badly from a lack of global vision, and we will clearly suffer the consequences increasingly in the future. With 4.5% of the world's people, we use 25% of the world's resources to support our standard of living and cause equivalent amounts of pollution and environmental damage; yet we depend on all the nations of the world for our own sustainability, and must find a common path with them in the future. The 70 million people that are projected to be living in the

FIGURE 4. The Monsanto Center, a good example of green architecture, houses part of the Garden's research program and provides space for its graduate students and library.

State of California by the middle of the century, consuming at 30 or 40 times the rate of individuals living in the jungles of the Amazon or in Indonesia will exact an enormous tax on the world, equal to the effects of an additional 2–3 billion people living in the tropics. Our consumption rates and lack of development of appropriate technologies pose truly formidable threats for our future, and that of everyone else as well. Consequently, long-term partnerships with institutions around the world, but particularly in developing countries, are of great importance. Even more important will be informing our own visitors about the dimensions of the problem and their individual responsibilities and opportunities in this area.

As Bill Conway has often stressed, it is critical for our institutions to think harder about moving our visitors beyond awareness of these problems to action. Extinction and our non-sustainable use of the natural world are important ideas, but what can we do about them individually? People should be encouraged to live more sustainable lives, to think about energy conservation, recycling, sustainable architecture, being interested in expressing their informed views as members of the body politic, or taking local action for conservation and sustainability and of doing all the kinds of things for which a democracy empowers us.

In summary, the power and scope of botanical gardens and other natural history museums are huge and underexploited. We can and must take many constructive steps forward if we are to contribute to the fullest extent to the realization of sustainability based on knowledge in our communities, and for all people in the 21st century.