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Essential Similarities and 21st Century Responsibilities of Great Natural History Museums

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Abstract The great natural history museums of the world have one common denominator—they combine research and collections with exhibits and education programs in a synergistic interaction that benefits both of these primary functions and ensures the long-term growth and stability of these collections-oriented institutions.

Key words: Museology, natural history.

This essay poses the question of what the essential characteristics are that one finds in all great natural history museums; that is, what is the formula for success of these distinguished museums that have long and strong records of accomplishment in building collections, research on those collections to improve our knowledge of biological and geological diversity, and programs to pleasurably inform the public about the natural world in which we live - the earth itself and its plants and animals, now and in the past, and of the history of humanity through time? The answer to that question as presented below is based on a lecture given at the Natural History Museum and Institute, Chiba, in October, 1992. The descriptive comments about various American museums that follow in the first part of the essay were accompanied by a series of slides showing various features of these museums.

Major Natural History Museums of the United States

A consideration of any group of outstanding natural history museums will make clear what are their most important common features. For my examples I will use museums in America, simply because I am most familiar with them. But please do not get the impression that I think that these museums in America are better than those of other countries, for that is not the case, even though America does have a larger number of great natural history museums than any other country. This is perhaps an outgrowth of the American fascination with the wilderness (the Wild West) that had to be tamed relatively recently by the pioneers, and our fulfillment of ideals to set up vast natural park systems to retain at least some vestige of that wilderness for future generations. Americans have built natural history museums in all of our major cities, to bring the flavor of nature into the inner city where people otherwise have felt themselves to be too isolated from the plants and animals of natural ecosystems.

The major natural history museums in the United States are the American Museum of Natural History and the New York Botanical Garden in New York, the Academy of Natural Sciences of Philadelphia, the Smithsonian Institution in Washington, D.C., the Field Museum in Chicago, the California Academy of Sciences in San Francisco, the Los Angeles County Museum, and the Bishop Museum in Honolulu.

Time will not permit me to discuss two others: the Missouri Botanical Garden in St. Louis, one of the best botanical gardens and systematic research organizations in the world, but because it is exclusively botanical, I will not include it among the comprehensive natural history museums even though it is incomparably good at what it does; and the Milwaukee Public Museum, a smaller museum that nevertheless has a wonderful record of

public programs and innovative exhibits.

American Museum of Natural History

The American Museum of Natural History is on Central Park in the heart of Manhattan. It was founded in 1869, and the museum entrance has recently undergone a renovation, but it still advertises its special exhibits and its huge screen Imax theater and planetarium. Its entrance rotunda has a giant long-necked *Barosaurus* standing up on its rear legs to defend its young from the attack of a meat-eating *Allosaurus*, recreating for the 3 million visitors per year a scene from 150 million years ago. The museum has several such halls of dinosaurs, and this is also one of the strengths of the collections and research of the museum. Another signature piece of the museum is its elephant group located in a hall of subdued lighting in which the eyes of the visitors are drawn to the surrounding classical dioramas created by Carl Akeley, who first developed this technique at the Milwaukee Public Museum. Another special strength of both the exhibits and the collections and research is anthropology, as can be seen in the exhibit with an American Northwest coastal Haida Indian war canoe. The museum is justifiably proud to have had the famous anthropologist Margaret Mead on its curatorial staff for her entire career, including her years living in Polynesia. The research collections behind the scenes also aid the exhibits, as in the case of dinosaur eggs that were collected by curators during the numerous expeditions to Mongolia which the museum has had over many generations. The bird collection is one of the largest in the world, including not only skins but skeletons. A typical collection of alcohol preserved fishes includes those stored in jars, larger specimens in steel tanks, larval specimens in vials, dry skeletons in boxes, and cleared-and-stained skeletal preparations in plastic boxes full of glycerine.

The American Museum is unique among the major U.S. natural history museums in not including botany, which for local historical reasons is the province of a separate organization, the New York Botanical Garden, in a pleasant area of the Bronx. Like the Missouri Botanical Garden, the New York Botanical Garden has both public gardens and a huge herbarium. Its herbarium cases are full of millions of sheets of plants for research purposes, with great strength in the neotropics. The New York Botanical Garden also has an excellent ecological institute and biochemical laboratories.

Academy of Natural Sciences of Philadelphia

The oldest natural history museum in America, and one of the smallest of the major ones, is the Academy of Natural Sciences of Philadelphia, founded in 1812 when Philadelphia was the intellectual capital of the United States, although the political capital had already moved from Philadelphia to Washington. Being the oldest, the Academy has a magnificent collection of antiquarian natural history books and journals that many other museums around the world use as a resource for loans and photocopying. Unlike the other museums mentioned here, the Philadelphia Academy does not include anthropology. Instead, anthropology is covered by the University of Pennsylvania museum in Philadelphia. Every museum in America has its always popular dinosaur exhibits, sometimes supplemented by rubberized movable dynamation models that are especially popular with children. Also popular are the areas of the museum where children can touch living animals, especially if they are animals of which some adults are afraid, or attend live animal shows. The Academy has a rich collection of sea shells, especially in those of the Indo-Pacific, and is also rich in birds, including those collected and painted by the early American naturalist John James Audubon. Fishes are another great strength of the Academy, some of which specimens go back to the 18th century when old European collections, like those of the Bonaparte kings of Spain, Italy, and France, were purchased by benefactors in Philadelphia to help the newly founded Academy improve its collections. These ancient collections are especially valuable now not only systematically but also for the base-line evidence they can provide from chemicals in their bodies of past environmental conditions in comparison to those at present. The most unique collection of the Academy is

that of diatoms mounted on glass slides, built up over many decades by the limnology department in its programs of assessment of water quality in U.S. rivers, with the species composition and population abundance of these unicellular fresh-water algae used as indicator species for river health.

Smithsonian Institution

Washington, D.C., is the home of the federal museums of the Smithsonian Institution, which differ from all others in America in being supported by the national government and having free admission, whereas all of the other museums in other cities that I will be talking about today charge an admission fee, typically about four or five dollars per person. The complex of Smithsonian museums on the Mall in the center of Washington includes the museums of Natural History, American History, Air and Space, Asian Art, African Art, Modern Art, and the old original museum buildings around what we call the Castle that are now the central administrative offices. The Smithsonian was founded in 1846 and is second in seniority after the Philadelphia Academy. With 15 museums, mostly on the Mall or a few streets away but with two in New York, and assorted research centers located from Harvard University (for astrophysics) to Panama in Central America (for tropical ecology), the Smithsonian Institution is the world's largest museum complex and helps make Washington a national and international tourist destination. About 25 million people a year visit the Mall complex of museums, and attendance figures for the major museums like the Natural History Museum are as high as 7 to 8 million people a year, second only to the 9 to 10 million people a year at the Air and Space Museum, which is the world's most visited museum. These figures are several times higher than those of the other great museums of any kind around the world, including the Louvre in Paris, which usually have no more than 3 to 4 million visitors a year.

The Natural History Museum is the largest unit in the Smithsonian, housing about 1,200 staff, of whom about 200 are Ph.D. level researchers; 125 curators from the Smithsonian proper and the others full time associates or scientists from allied federal agencies like the Fish and Wildlife Service, the National Marine Fisheries Service, and the Systematic Entomology Laboratory of the Department of Agriculture that have laboratories in the building. The building has 100,000 square meters of space, with about 25% in public halls and the rest devoted to research and collections. The annual operating budget for all aspects of the Smithsonian's Natural History Museum is about $55 million dollars, excluding salaries of the staffs of the allied federal agencies and capitol improvements to the building like expansion and major renovations. The main entrance rotunda of the old building dates from 1910 and has what we claim as the world's largest bull elephant, shot long ago by an expatriate Polish prince. One of the two most popular exhibits is the complex of halls devoted to dinosaurs and other fossils, the same as in every other natural history museum in the world. The other most popular exhibit hall is gems and minerals, with the center piece being the 45 carat Hope Diamond, once worn by Marie Antoinette of France and whose subsequent owners are believed to have had equally bad luck and often to have met untimely if not bizarre deaths. Exhibits about American Indians are also especially popular, and the newest museum on the Mall, presently being developed, will be devoted exclusively to Native Americans. There are about 120 million biological, geological, and anthropological specimens behind the scenes at the Smithsonian's natural history museum. The museum has one of the world's largest fish collections, with about 500,000 jars containing an average of about 7.5 specimens per jar, or a total of about 4 million fish specimens. It also has an enormous bird collection, which, like its other collections, is cared for by a cadre of professional collection managers. This allows the curators to devote themselves mainly to research, while usually providing only policy guidance on the care and utilization of the collections, and identifications of specimens within their specialty. There are about two collection managers or other support staff for each curator. There is an enormous and growing collection of insects,

especially as they continue to be collected by our programs of assessment of biological diversity in South and Central America. In the exhibits area there are live insects and spiders in an Insect Zoo that is especially popular with children. The large collections related to the peoples of the world encompass both ethnographic anthropology, including Japanese armor vestments, and physical anthropology, including Peruvian skulls showing the trepanning holes that were therapeutically drilled to correct badly healed skull fractures, and usually not, as is often stated, to release evil spirits. In the zoological departments the mammal collection includes elephant skulls squeezed into an upstairs attic space. We have essentially exhausted our collection storage space in the building on the Mall, and a few years ago the Smithsonian built a huge collection storage center in the suburbs of Washington, consisting of four large interconnected buildings with state of the art environmental controls of temperature and humidity, and systems to guarantee high security and rigorous pest management. Vast ranges are being configured into our storage space of the future, and already about 20% of our collections (the least actively used ones) have been moved to this satellite facility to be placed in a variety of new cases, for a museum that does not continue to have its collections grow, even to the point of overflowing the building and requiring new buildings to be constructed, is indeed a dead museum.

Field Museum of Natural History

The Field Museum of Natural History in Chicago is on the shores of Lake Michigan. It was founded in 1893 by merchant prince Marshall Field as the Columbian-Field Museum in commemoration of the discovery of America, with the Shedd Aquarium next door to it. It has a classic central spacious atrium off which are the exhibit halls. The exhibits are particularly strong in anthropology, both of ancient civilizations, such as Egypt, with a reconstruction of a tomb that one can walk through, and American Indians, with a Pawnee earth and timber lodge, so different than a buffalo hide tepee that one sees in American cowboy and Indian movies, from which so many of us obtain our ideas about the original Americans. It has exhibits of civilizations impacted by explorers, as in one on Tahiti today versus how it was before Captain James Cook. And, of course, dinosaurs. The collections are rich in both fossil and living organisms, such as fossil and extant species of the same genus of plants, dinosaurs in plaster jackets, primate skeletons, and all the other things you would expect in a great museum.

California Academy of Sciences

On the west coast of America the California Academy of Sciences is relatively old, for America, being the outgrowth of a meeting of scientists in 1853. It is in the middle of the magnificent Golden Gate Park and includes the excellent Steinhart Aquarium and Morrison Planetarium. It has classical dioramas of all groups of animals, and an exhibit of elephant seals that bellow with full recorded voice at the visitor. And, as everywhere in the U.S. mainland, exhibits about American Indians, especially those of the Southwest. The aquarium has big fishes in huge circular tanks that surround the visitor. Behind the scenes are the traditional assortment of research collections, including insects, herpetological specimens, and fishes, with the latter being one of the great Indo-Pacific marine collections because of its incorporation of the Stanford University holdings originated by David Starr Jordan and his colleagues, who had a special interest in Japanese fishes.

Los Angeles County Museum of Natural History

The Los Angeles Natural History Museum, located in Exposition Park, was founded relatively recently, in 1913, and thus is the youngest of the major American natural history museums, but it already is almost as large as those in Washington, New York, and Chicago. It has the usual assortment of exhibits, including dinosaurs and classic dioramas of many mammals. But for fossils it has the unique advantage of having a satellite museum at the La Brea tar pits a few miles away in the middle of Los Angeles where so many late Cenozoic animals like the mastodon elephant and saber

tooth tiger became entangled, entombed, and preserved in pools of sticky thick oil oozing up to the surface from below ground. Being a relatively newer museum, it has a large portion of its collections in movable compactorized storage units, such as for insects, fishes, and birds. It also has one of the world's largest collections of bird eggs.

Bernice Pauahi Bishop Museum

Last but not least is the Bishop Museum in Honolulu, a memorial founded by Charles Bishop in 1889 to honor his wife, Princess Bernice Pauahi, the last direct descendent of the royal line of King Kamehameha. It and the California Academy in San Francisco are among the smaller natural history museums but are gems of high quality that I would encourage you to visit, not because of their special emphasis on Pacific natural history and anthropology, but simply because they are superb museums. The Bishop Museum is especially rich in exhibits on Polynesian culture, but even in Hawaii there are also exhibits of dinosaurs. The collections include plants on herbarium sheets, which document both the native flora and the introduced species, and a renowned fish collection whose emphasis is naturally Oceania, but is exceptional because of the masterful scuba diving collecting of the incomparable Jack Randall.

Commonalities of These Great Museums

The above introduction to American natural history museums has probably already made clear much of the central thesis of this essay—that all great natural history museums combine public programs with research and collections, because the exhibits and educational activities for the museum's visitors are given strength, vigor, and currency of content through the synergistic interactions of the museum's public programs staff with the scientists and their collections behind the scenes. Another commonality is fine libraries, for the library of organisms in our collections cannot be studied without an equally strong library of books and journals.

There are no examples of museums with outstanding comprehensive natural history exhibits that do not also have collections overseen by research staffs that are working hand in hand with the public program staffs. Even an organization like that of Walt Disney, which is extremely successful in attracting visitors to entertainment theme parks, would not be able to create natural history exhibits that are both interesting and informative without having a large staff of research advisors and collections. Even if a theme park tried to stage a natural history exhibit, it is unlikely that the advice from the scientists to the theme park managers would be followed and that the advisors would be called upon in the future to update the exhibits. Realistically, the type of interaction between public programs and research and collections that makes for a great natural history exhibit that is kept current in its content can only be accomplished in a natural history museum setting.

My point is that the most important hallmark of a great natural history museum is the interaction between the scientists, with their scholarly knowledge based on collections, and the public programs professionals who must interpret this for the visitors, who are the life blood of a museum dependent on public patronage.

Therefore, curators must be willing to do their fair share in contributing to exhibits relevant to their expertise, and the majority of curators that I know in museums around the world do make such contributions of their time and knowledge. In fact, there are usually more curators with a willingness to carry through on the implementation of their good ideas for exhibits in their fields of expertise than there are space in the museum and money to pay for their proposed exhibits.

In at least the larger museums it is possible to accommodate those fewer curators who are so highly focused on research alone that they do not volunteer for exhibits work—a big museum should be able to let such eccentric individuals alone, for expert though they are in studying their preserved specimens, they may be social recluses who are simply incapable of dealing with people.

But just as most curators fulfill their responsibilities to public programs, so also do the

public programs staff have the responsibility of informing the museum's visitors of the great and irreplaceable value of the collections behind the scenes and of the scholarship of the researchers who are working on those collections, especially because less than 1% of a museum's collections are typically on exhibit and yet the other 99% are expensive to maintain, as I will document in a moment.

Even for the most reasonable and best adjusted staff of the museum, there is always a dynamic tension between the research curators' desire to impart depth of factual information to an exhibit and the need of the public programs professionals to explain in reasonably simple terms what are often complex scientific matters. But this interaction, which is critically important to the health of the museum, can be creative rather than confrontational.

Curators at a museum should always be called upon to either provide the factual contents in exhibits themselves or, if a contract has been given to an outside scholar to provide the text for an exhibit, to approve the script submitted by that person. The curator who serves as the content specialist for a new exhibit and the head of the exhibits team should equally share the control of the final version of the intellectual content of the exhibit. Those occasional deadlocks in opinion that are bound to occur should be resolved by the respective higher level administrators of exhibits and research, with the director of the museum being the court of last appeal.

In short, great natural history museums, both those that are regional and those that are international in scope, have two major facets, one is public programs and the other is researchers with collections, and these interact to bring vitality to the exhibits and educational programs by which the visiting public judges the success of a museum and the financial support to be given to it through admission fees and tax subsidy from the government.

There are some other common features of these museums that are worthwhile mentioning, besides the fact that they all have dinosaurs, or some other huge prehistoric animal like the fossil elephant from the Boso Peninsula here in the Chiba museum.

Most of these museums have a higher administration of a director and deputy director and several associate and assistant directors, with the associate directorships for science and for public programs being the largest units. The director establishes the policies of the museum and spends a great deal of time on external affairs, including fund raising, while the deputy director oversees the internal day-to-day affairs of the museum. The associate director for science has responsibility for the research departments, collection management, and special facilities like SEM labs and Molecular Systematics labs. The associate director for public programs has responsibility for exhibits and education, and special programs like an insect zoo or other live animal exhibits or shows.

As for the budget of a typical great natural history museum in America, the costs for research and collection maintenance are an especially expensive feature, more than the routine costs of the public programs that the visitors see. There is an inverse relationship between what the public sees and what the public pays for, which is all the more reason to have exhibits and educational programs at museums that tell the visitors what is going on behind the scenes with the research and collections. And at all these museums the salary cost of the personnel is the largest budget item, typically about 80% of the total.

The Rationale for Supporting Natural History Museums

It is legitimate to ask for what reason all these millions of dollars are being spent to maintain natural history museums and their expensive collections and to support research curators, whose only immediate and direct apparent benefit to the public is the enlightenment they give to the exhibits. In other words, what are we doing at present to justify our museum way of life and what should we be planning to do in the future?

We must continue to build and study our systematic collections and share with the public both our knowledge of these organisms and our rationale for the importance of this

systematic, ecological and anthropological research, for these collections are records of the biological and geological world and of our place in it throughout time. Such studies improve our basic fund of knowledge and are of intrinsic value unto themselves in helping satisfy humanity's inherent curiosity and quest for greater knowledge about and control of our surroundings. The more one knows about our biota the more one can enjoy the beauty of nature for its own sake, to marvel at the diversity of the plants and animals around us and their often strange forms and functions.

But we must also through our exhibits let the public know that another justification for the expense of building, maintaining, and doing research on systematic collections, as well as ecological studies, is that they form the basis for the knowledge that often is directly useful to man's medical, agricultural, and spiritual betterment (including the management of forest wilderness areas, national parks, and endangered species). One recent example of the occasional immediate applicability of our work is the young systematic botanist on a collecting expedition in a remote valley of Mexico who found and recognized the primitive ancestral teocinte wild corn that already is a germplasm resource for new strains with improved disease resistance, and perhaps even perennial growth so that corn may not have to be replanted each year.

It is nearly always the case that before we can rationally utilize the natural resources of plants and animals, we have to be able to identify and distinguish between them and know about their life histories in order to better manage the resource for long-term sustainable yield; or conserve them for their value to our souls. The required studies of biological diversity and life histories are the central thrust of modern systematics. Systematics is the basic grammar of biology, and ecology is its synthesis, both of which we need in order to write and to read the book of life.

Somewhat less than 2 million species of plants and animals have been described, but reasonable calculations of how many species actually exist range from 5 to 10 million, or more. Our ignorance of much of nature is reflected by the wide range in even the estimates of the number of species alive today, the collection-based study of which is the province of systematists at natural history museums. And we all realize the urgency of the task, as species become extinct at an alarming rate through human activity. We need to study biological diversity before much more of it is destroyed in order to know the patterns of phylogeny through time, the processes that led to our present biotic mixture, and the place of species in the intricate webs of ecosystems. We must continue to describe the species of our biological diversity until we know all of them and their systematic and ecological relationships, both to add to our base of knowledge of the world in which we live and to use that knowledge to conserve and rationally utilize our biota rather than destroying it.

The goal of describing essentially every species for the vast majority of groups of organisms in our biota is not an impossible task; it is, indeed, a grand task but one that can be completed in a reasonable time frame for most groups of organisms and at a relatively low cost in terms of most other major scientific endeavors. A full knowledge of the systematic and ecological relationships of our biota has at least as much intellectual appeal and socioeconomic applicability as other great undertakings of science, from atom smashing to reveal the smallest particles of matter to the cataloguing of the human genome and the exploration of outer space. The biotic inventory project in which we natural historians are engaged is much less expensive than these other examples of major projects, but like them it also is aimed at discovering fundamental units—the species being to biology what the quark is to the atom and nucleotide pairs are to the DNA of the chromosome.

While I think that we should explore outer space, I also think that the exploration of our own earth and its biota should be of even higher priority, given the urgency of the task. If the savings from even a slight slowing in the pace of just the manned space station program, for example, were applied to biotic inventory it would allow for a far more comprehensive and timely knowledge of our earth's resources at

the same time that we are seeking knowledge of other planets.

At the current rate of description of species by the several thousand systematists throughout the world, one can envision the basic descriptive part of biotic inventory requiring only several hundred more years to complete for the vast majority of orders of organisms, with only insects and perhaps some of the groups of marine invertebrates taking longer. As more and more of the descriptive part of the task is completed for most groups of organisms, systematists can spend a greater percentage of their time on deciphering relationships and reconstructing phylogenies that will improve our picture of the overall patterns and processes of evolution, and ecologists can use that expanded data base for improving our knowledge of how each species fits into ecosystems, and how we can best conserve our biotic resources.

While this long-term task of systematically describing our biota and its phylogenetic and ecological relationships continues, we must of course try to preserve whole ecosystems in as large of parcels as possible, preferably in sizes of millions of hectares. It is far more effective to preserve large portions of distinctive ecosystems containing thousands of species that may be in jeopardy than it is to focus our attention on one particular species, even though one of the contained species may be more glamorous (a bird with spectacular plumage or a mammal with warm loveable eyes) than others and useful for purposes of publicity and fund-raising.

No one can speak out more knowledgeably on the importance of biotic conservation than systematists and ecologists, who study the organisms that are the product of eons of evolutionary adjustments to fit their environment. These products of evolutionary history should be conserved for their own sake for philosophical reasons alone as well as for their contribution to the intricate network of ecosystems, for the truly irreplaceable uniqueness of their genomes, and for their potential utilization by humankind.

Our work as collections-oriented museum scientists inventorying and relating the world biota has been and continues to be intellectually exciting and innovative. As I look back through the history of systematic and organismic biology, I am impressed that three of the most profound revolutions in how we think about nature and our place in it have been instigated by collection-oriented researchers associated with natural history museums and gardens.

The first revolutionary I would cite is Karl Linnaeus, who brought us binomial nomenclature and rigorously rational (although typological) classifications in the 18th century. Linnaeus was one of the most prominent plant systematists of his era and collected and exchanged specimens with museum colleagues throughout the world, and was the director of the botanical gardens and herbaria in Leiden, Holland, and eventually in Uppsala, in his native Sweden.

The second revolutionary is Charles Darwin, who, in addition to developing his evolutionary theory during the voyage of the *Beagle*, sent back specimens from around the world to the museums in Cambridge, London, and Kew. Being independently wealthy, and often in poor health after his return from his epic travels, he did his research and writing at his home, Down House in Kent outside of London. It was here, for example, that he spent eight years studying the systematics of barnacles, partly as a deliberate exercise in understanding the basis of the classifications that were so important to his evolutionary theories. After the publication in 1851 and 1854 of his two thick volumes on the living Cirripedia and two thinner quarto volumes on the fossil barnacles, Darwin wrote that he was "sending ten thousand barnacles out of house all over the world", mostly the return of loans, and Darwin's barnacles are now in the collections of the museums of Cambridge, Oxford, and the British Museum in London. Darwin was among the most creative and knowledgeable of biologists who did collection-oriented research associated with museums.

A third and 20th century example of a biological revolutionary from the museum community is the late Willi Hennig, of the Staatliches Museum für Naturkunde in Stuttgart,

whose cladistic approach to establishing the branching patterns of phylogenetic relationships by using shared specialized characters alone has enormously changed the way we think about relationships and brought greater rigor and precision to our analyses, forcing us to better document and justify our hypotheses of relationships. Hennig was a museum-based collection-oriented systematic entomologist all his life.

Although I am reluctant to nominate people still living to this titled crown of "beneficial revolutionary", I would make an exception for E. O. Wilson, of the Museum of Comparative Zoology at Harvard University, for three reasons: his innovative work in island biogeography and in sociobiology; his already classic studies of the systematics, behavior, and ecology of ants; and his championing of the cause of systematic studies, museum collections, and biotic conservation. To my mind, he is the complete systematist.

Future Obligations and Opportunities

Let me turn now to the future—what are our natural history museum obligations and opportunities in the 21st century and what are the pitfalls we should avoid?

The expense of maintaining natural history museum collections and the demonstrably false impression of some university administrators that systematics is old fashioned and not intellectually exciting has led many universities to terminate their programs in systematics and to dispose of their collections. This requires that we scientists at the free standing natural history museums, such as yours and those in America which I have used as examples, must do two things.

First, we must be willing to adopt the important orphaned collections that are being abandoned, carefully choosing from among them those that are irreplaceable and worthy of transfer to another museum's perpetual care.

Secondly, we must assume more of the responsibility for the training of tomorrow's natural historians than we are doing at present. This means that more and more research curators should be encouraged to take up adjunct professorial appointments at universities and devote the requisite time and energy to teaching courses in their specialty and guiding the research of graduate students through the doctoral degree. Museum administrators should support their curators in this critically important endeavor of helping to keep systematics alive and well through the infusion into our profession of bright and well trained new recruits for the task of inventory, discovery, and creativity that we can expect to lead to whatever will be the next intellectual revolution conceived in museum-based systematics. That support should include funding for doctoral students to be in residence in our museums and release time for the curators to supervise graduate research. This may slightly decrease their published productivity but be more than made up for by the stimulation they receive from the inquiring minds of their students and the likelihood that this will improve the conceptually intriguing quality of their own research.

Museums must keep at the forefront of using all the available tools of biosystematics and not just the traditional microscope, and administrators should provide, for example, laboratories in chromosomal and molecular systematics and in morphometrics when there is sufficient staff interest, and of course allow for scientists, even older ones like me, to be brought easily into the computer age of data analysis and for collection managers to computerize and internationally link their data bases.

Funding for field and laboratory studies should be provided to those museum systematists who wish to study their organisms alive as well as preserved, perhaps to work on both classification and on behavior and ecology.

Curators have a responsibility to help with public programs and to incorporate in exhibits and their lectures the message of the importance of systematic collection-oriented research and biotic conservation. By sharing their enthusiasm for natural history with the public, curators can help repay their museums for the privilege of a museum curatorship—the privilege to be paid to study to their heart's content the organisms that they probably have been fascinated with all their lives.

Those museum curators who work in ivory towers exclusively on their research without

contributing to public programs when the need exists, whether by lack of volunteering or by refusing to serve when asked, have inadvertently helped contribute to the occasional reductions in public financing for museums, especially during the cyclical periods of recession that seem to be built into our international economic system. When the public and the philanthropists and the government officials who provide funds for museums do not readily understand the intellectual value and long-term, if not usually immediate, benefits of collection-oriented research, it is all too easy for these decision makers to reduce their level of support for our activities.

We museum professionals have an obligation to keep our potential supporters informed about the value of what we do, and no one can do that better than an enthusiastic and knowledgeable curator working hand in hand with a museum administrator and fund raiser. Curators should be willing to make that sacrifice of time away from their research for the ultimate good of the museum and in their own enlightened self-interest. It is not sufficient for the curator to simply dream-up a wonderful idea for an exhibit or a fund raising strategy and expect someone else to do all the work to implement the idea. We scientists must be willing to pitch in and give a hand to the effort personally. Administrators should consider offering substantial bonuses to curators who have been especially cooperative with public programs and fund raising (as well as for outstanding publications, popular or scientific).

There is a need to make exhibits as lively as possible, including such things as dynamation movement for dinosaurs, hands-on exhibitry, and interactive video displays. But the textual materials must retain high standards of intellectual content as translated by the public programs professionals. Showmanship must not replace scholarship but be complimentary to it.

We need to reach out into the local communities around our museums to assure that we are servicing the educational needs of children and, especially in a multicultural country like America, of our citizens of all ethnic and minority groups. Volunteers of the docent corps drawn from the local community can be an especially effective vehicle for outreach activities.

In trying to increase income, museum administrators should beware of attempting to make it appear that much of the research within the walls of their museum has money making applicability in the short-term, and also of trying to convert systematic research into a pay-by-the-species identification service for profit making environmental monitoring companies. A museum may wish to encourage some of its curators to bring in money through fees charged for providing identifications in service to conservation efforts but those monies should be set aside to help support the research of that unit of the museum and there should never be any form of coercion on the curator to participate in such activities.

We must also beware of trying to make systematic research appear to be exceptionally relevant or utilitarian to a particular topic that happens to be attracting special interest in the popular mind and press. We must avoid diversions that would cause us to lose sight of the long-term goal of knowing our biota and its relationships. Our intellectual discoveries along that path are the things that give museum-based collections-oriented research its unique contribution to our knowledge of humankind and the world in which we live. In the long-run it is that basic increase in knowledge of the natural world that the public will appreciate and support in the tangible form of operating funds for our museums.

As we look to the future we must constantly emphasize high levels of quality in all our museum activities. It is quality that should be on our minds more than quantity. For example, we should expand our collections only with well-preserved specimens of particular groups of organisms or faunal areas of special interest that are in accord with well considered acquisition policies of our museums—we cannot afford the space and cost of maintenance of irrelevant collections that simply fill-up storage shelves without improving the overall quality of our holdings. Being the biggest is not equivalent to being the best. Curators and collection managers must be rigorous in their decision making about acquisitions and then be

faithful in providing excellence in their maintenance of those collections.

Likewise, our research publications should be reflections of peer-reviewed quality. We should recognize that research curatorships are ideally suited for comprehensive long-term studies that lead to monographic systematic revisions bringing together new data and analyses with that which is of importance from the results of previous work on a group of organisms.

We must insure that the standards of high quality in our public programs include fair and honorable treatment in our portrayals of the cultures of minority, ethnic, or racial groups (such as, in United States museums, Native Americans and African Americans) along with compassionate and sensitive consideration of reasonable requests for repatriation of their ethnographic artifacts, and of reburial in the case of skeletal materials. Our anthropological research needs to be as untainted as possible by the biases and prejudices on the dominant culture of our respective countries. Because I work in a museum in a racially diverse and multicultural society, I am especially aware that in both our research and exhibits we must guard against the perpetuation of negative or misleading stereotypes, including those based on gender and religion, as well as on ethnicity and race. In short, our viewpoint should not be restricted to that of males of the dominant culture of our society.

Conclusion

I am sure that all of us can be confident as we move into the 21st Century that museum professionals will live up to our great expectations of them with great performances. We have good, dedicated, and hard working museum staffs everywhere in the world and for the future we need to insure that we have equally strong leadership to clearly state the challenges facing us and to provide consistent funding to achieve our goals. We can and will meet these natural history museum goals of describing and relating the earth's entire biological diversity, while preserving samples of it in our collections, relating our discoveries to the public, and helping train the next generation of natural historians.

Discussion

Following the formal presentation, there was an extended period of questions (Q) and answers (A), of which the following is a condensed version.

Q. Would you please give us your opinion on the policy, or at least the custom, in Japanese natural history museums of having collections that are international in scope maintained only at a federal institution like the National Science Museum in Tokyo, while prefectural museums like that in Chiba have collections and exhibits that are strictly limited to the local organisms of that particular region?

A. As a guest of this museum who has only been here in Chiba a few days I would not want to comment on a particular situation about which I am not fully informed. Also, I already know a number of especially bright and intelligent members of the audience who can probably figure out a solution to whatever problem you are having with what the question seems to be implying—that there may be somethat unrealistic restrictions being placed on the scope of your collections here in Chiba. However, in general, I think that it is perfectly appropriate for a prefectural museum to have a regional emphasis in its exhibits, as you do here in Chiba on the natural history of the Boso Peninsula. But even within that regional context you obviously can still have international themes incorporated into your exhibits. The principals of systematics, ecology, and anthropology are international and can be fully expressed in such regional exhibits as you are doing very well here.

For collections, I think that it is extremely important for a natural history museum to have clearly stated acquisition policies and to decide early in its existence about which areas in which to specialize, and not to try to be all things to all people. Collections are so expensive to maintain that one needs to very carefully determine what groups of organisms and from what general regions to collect now and into the future. I doubt that the acquisition policies of the prefectural museums are so narrowly drawn that in Chiba, for example, you

are only allowed to collect and maintain specimens of the Boso Peninsula, for obviously the organisms do not respect prefectural boundaries and the limitations that you place on your collections must reflect biological rather than geopolitical factors. In any case, museum scientists nearly always need to make extralimital comparisons, and even if the group of organisms on which they work is primarily Japanese in distribution, the other groups with which comparisons should be made could well be from far distant regions. A prefectural museum should allow for the maintenance of these extralimital materials even though the main thrust of its collections is regional rather than international. The important thing is for museums to have rational and defensible acquisition policies, and to follow through on them over time so that you do not clutter up your expensive to maintain collections with inappropriate materials.

Q. How does the research being conducted in U.S. natural history museums like that at the Smithsonian differ from that in museums elsewhere in the world, such as here in Japan?

A. I do not think that U.S. museum-based research is much different in either kind or quality than that, for example, in Japan. One related difference about which I am aware is that in American museums we tend to have a significantly higher level of support by assistants for our Ph.D. level curators. This support comes from the professional cadre of collection managers and research assistants, and allows the curators to spend the great majority of their time doing the independent original research for which they have been trained. In Japan there are far fewer support staff per curator and the curators do much more of the routine collection management and have less assistance with their research. Because they are able to spend more time on research, while still making their appropriate contributions to public programs, I think that curators in American museums are able to be more productive than their Japanese colleagues, at least quantitatively in the number of publications—I am only speaking in regard to a difference in the quantity of their publications, not of their quality, although museum scientists in western cultures have a somewhat better record of creativity than those of the east. Another difference is that curators at American museums routinely have their research and office space in an individual room where they can have the kind of privacy and quiet that is conducive to thoughtful specimen examination and writing, while here in Chiba I notice that you are already so crowded in your relatively new museum that curators have to share a common and not so quiet office space.

Q. How much time do curators in America spend helping with public programs?

A. That is highly variable but at the major museums about which I have been talking it typically is only a small percentage of their time over the course of a curator's career, probably less than 10% in most cases. For example, at the Smithsonian many of the curators of paleontology spent up to half of their time, and in some cases essentially all of their time, over a several year period when the dinosaur and other fossil halls were completely renewed. But, with that project now completed, the paleontology curators will not have to spend much if any time on exhibits again during the rest of their life-time at the museum. By contrast, for example, most of the present curators of ichthyology have not yet been called upon for a major time commitment to exhibits; but they may be asked to do so in the future when the hall of aquatic and marine life in renewed, requiring a substantial contribution of their time and effort over a period of one or two years. Still, over the course of their careers, this contribution will probably amount to less than 10% of their time. Individual curators often volunteer to do a special exhibit of particular interest to themselves, such as the curator of ichthyology who put together a fine show called "Drawn from the Sea" consisting of the original color paintings of marine fishes executed by the shipboard artists that accompanied the U.S. expeditions of exploration in the Pacific around the end of the 19th Century. We are fortunate that most curators so willingly accept their responsibility to make a contribution to the public programs of the museum that are so important to sustaining financial support for what we do in museums.

Some curators also help in fund raising and in giving lectures to the public, even if only on a relatively limited time basis.

Q. Is there a computerized network of collection management data bases in the U.S.?

A. Because the Smithsonian has the largest collections in America and they are the property of the federal government, Congress mandated in 1979 that we computerize our collection data bases both to better manage them and to be more accountable for them, especially those of great monetary value like gems, minerals, and ethnography. While museums with relatively small collections can relatively easily computerize all of their materials, doing so with a huge collection like that at the Smithsonian's natural history museum is an enormous undertaking, but in the past 13 years we have made relatively good progress. For example, essentially all of our collections in gems, minerals, and anthropology (both physical and ethnographic) have been inventoried and computerized, and computerization of collections like fishes are about 50% complete and for mammals about 65% complete, to give just a few examples. Overall, about 35% of all of our collections are inventoried and computerized, so progress has been good even though we still have a long way to go to finish computerizing all of the collections—at least another 15 to 20 years worth of work.

We have been trying to take an international leadership role in computerization of natural history collection data bases and for the past several years have been requesting special funding from Congress to allow us to do this, including the networking of our Smithsonian data bases with others in America and Europe and elsewhere. Congress has not yet given us the additional funds (beyond that for our ongoing efforts in inventory and computerization) for this but we are still asking for it each year in our budget request. However, there is already some networking going on with American collections by consortia of museums to make the combined information about their specimens available through both centralized and dispersed data bases. The best examples of this so far are two projects in botany, one by about 50 herbaria in California and one by about 120 herbaria in the southeastern region of the U.S., in each case with about 6 million sheets equaling about 10% of the holdings of all U.S. and Canadian herbaria. In fishes there is an ongoing project by the Philadelphia Academy of Natural Sciences and the University of Michigan for a centralized computer data base on the systematics and biogeography of all neotropical fresh-water fishes from collections throughout North, Central, and South America, and Europe, using the MUSE program.

Q. Are you concerned about security against improper use of networked collection data bases?

A. Certainly. One must have safeguards built into the system to avoid its being used improperly, just as we have safeguards built into our long standing system for the examination and loan of specimens in our collections, with all such usages having to have the approval of a curator. Similarly, a curator would have to give approval for anyone to have access to a particular collection data base of that institution in the cooperative network, and only a curator at a particular division of a particular institution would have the authority to allow access to that division's part of the data base. I am told by people that know far more about computerized networks than I do that this can be done relatively easily, with appropriate blocks placed in the way of access to the data. For example, only users who have been approved for password identification codes could access either various parts or all of the data base, and certain fields or records can have access privileges limited by variations in the passwords. Not everyone must be given full access to the data base, and this judgement is left to the curators, just as it is with access to the specimens themselves.

Q. Are you having to downsize at the Smithsonian?

A. Unfortunately, we are having to do this to a certain extent at the Smithsonian during this time of reduced budgets associated with the international recession and deficit reduction efforts in the United States, as are all other federal agencies. At the Smithsonian we have a flexible freeze on the hiring of new staff to fill vacancies in all categories of employment. We

hope to be able to meet our budget reductions through normal staff attrition. We hope that these savings in salary of staff positions not immediately refilled when they become vacant will allow us to meet our budget reductions through a decrease in staffing of no more than about 5% during a period of one or two years. But historically the Smithsonian has been a relatively well financed institution because of the high regard in which it is held by the citizens of the U.S. and their elected representatives in Congress. So there is every reason to believe that our budgets will increase again in a few years, just as soon as the economy improves and the U.S. budget deficit is brought under better control and is at least on its way to significant reduction. Our present budgetary woes are temporary and we will rebound, as we have been doing for generations after every such budget crisis.

Q. Are you able to retain the positions of the people who retire, and who controls these?

A. Yes, we retain the positions and can refill them whenever we have enough money in the budget to do so. Right now we have more positions than money to fill them, whereas in better financial times we typically have more money than authorized positions. Theoretically, all vacated positions revert to the Office of the Director of the museum for possible reallocation when funds are available to rehire staff. However, the director is under enormous pressure from the various constituency groups (for example, research versus exhibits, or one research department versus another) to return each vacancy to the same unit from which it originated. The director has to be both a politician and a saint in order to properly balance the interests of all of these constituent groups. To do this fairly requires the wisdom of the Biblical King Solomon. There is a great deal of stability built into such a system. There is not much fluctuation in staffing between the various departments—the status quo tends to be maintained.

Q. Does your museum have any special programs in biodiversity and biological conservation in south-east Asia?

A. We have several such long-term programs and modest field stations in tropical Latin America, especially in the Amazon basin and the northern rim of South America, and the Smithsonian has a major ecological institute in Panama, but we have no such large formal programs in south-east Asia. Many of our curators have individual research projects that involve field studies and collecting in Asia, so you are likely to run into Smithsonian curators all over Asia. We do have some special programs, such as that on global volcanism, that have strong ties with Japanese institutes. The National Zoological Park in Washington, which is part of the Smithsonian, has a major research effort in biological conservation, including in both tropical America and south-east Asia.

Q. How is your museum involved in education of school children.

A. Most of the school children among the approximately three million people in the greater metropolitan Washington area will come to see the exhibits at the Smithsonian's Natural History Museum sometime during their school years, but the great majority of them will do so with their families and not as part of a school group. About 150,000 students come to the museum each year in groups from their schools, about 80% of these groups being escorted through the museum by the teachers from their own school, usually along with some parents that help the teachers maintain discipline. The other 20% of the students visiting the museum make advance reservations with our education department to have one of our museum educational staff escort them through the museum with professional explanations about the exhibits.

Our education department has about 30 full time museum educators and about 400 part time docents. These unpaid docents are trained professional volunteers who commit to serving about 100 hours per year as teachers to people visiting the museum, either for individuals who come to the museum asking for a guide around the halls or, more usually, for groups of both adults and school children who want a professionally led tour of the exhibits. So school groups are taken through the museum by either their own teachers or by our docents, but most students visit the museum with their

families.

The 30 full time educators on our museum staff manage all the educational programs in the museum, such as the Insect Zoo, Discovery Room, and Naturalist Center, as well as the development of new educational programs, training of the volunteer docents, scheduling of the tours of the exhibits, and participating in the development of the museum's exhibits to make sure that the exhibits are truly enlightening and have text that will be understandable to the public.

In addition to the school children, the educators service about 130,000 people in special activities for individuals and families who come to the museum to participate in Identification Days (bring in any unknown natural history object for identification) and Draw Ins (drawing natural history objects with the help of the museum's professional scientific illustrators), Boy and Girl Scout Days, Native American Public Programs (education and handicrafts with the help of Native Americans), and special programs associated with temporary exhibits. So education of both adults and school children is one of our major enterprises at the museum, and it is one of our sacred responsibilities to do it well.

Q. Are most American doctoral students in natural history able to obtain jobs in museums and universities after they graduate?

A. Clearly, many graduate students in America who receive Ph. D.'s in natural history subjects do not obtain good jobs—there has been some over-production of Ph.D.'s in the natural sciences relative to the job market and some of these students end up in jobs not even related to biology, much less in museums and universities where they could do research. But the number of positions for natural historians in America has been relatively constant and if anything can be expected to gradually increase in the future as the need for biotic studies becomes clearer, for which we must all do our part. At least the best of the younger Ph.D.'s obtain good jobs in museums and universities through a highly competitive selection process. Those who are successful in passing through this filter are the best prospects for productive careers of excellence.

At the Smithsonian there has been a small but significant increase in the number of curatorial staff, including those in our relatively new biochemical systematics lab, in the past few years and I think that this trend of slow but steady increase will continue into the long-term future. The curatorial staff at the Smithsonian has always gradually increased over time.

We are doing our fair share to strengthen collection-based museum scholarship and in the future I would like to see those of us in museums training more of the young Ph.D.'s for the important tasks of biotic inventory and analysis. I think that an excellent example of this museum-based training is that at the American Museum of Natural History in New York where such people as the late Donn Rosen and his colleagues have not only trained one of the most professionally skilled and successful groups of systematists in America but also have helped bring about the cladistic revolution in how we practice our systematics. These educationally activist curators at the American Museum have adjunct professorial appointments at universities in New York city that permit them to train doctoral students and guide their research while the students are resident in the museum, in offices close by their curatorial professors.

The world depends on America, and hopefully increasingly so on Japan, for much of its strength in systematics and I believe that both of our relatively rich countries have a special obligation to help secure the future well being of museum-based scholarship by becoming more deeply involved in graduate education. There are so many intelligent, industrious, and productive Japanese museum scientists that I hope that they too will find ways to help in this process of graduate education that is so important to our future. I realize that certain changes would have to be made in the structuring of professorial appointments in Japan for it to be possible for curators to oversee the Ph.D. training of graduate students, but knowing how bright and energetic the scientists are in Japan I am confident that you can finds ways to bring this about.

Summary

Q. Can you summarize what you have described as the essential similarities and future responsibilities of great natural history museums?

A. With the risk of being overly simplistic, let me summarize the main themes about which I have been speaking. Those natural history museums that have received sustained and increasing levels of funding over many generations are those that combine research and collections with exhibits and education through a synergistic interaction that makes the public programs of the museum interesting and exciting to the public upon whose good will the museum depends for its livelihood. To accomplish this the museum scientists must willingly make contributions to public programs, while the educational functions and exhibits of the museum must tell the public about the value of the collections and the importance of the research that goes on behind the scenes. Only by so doing will natural history museums continue to be well supported and dynamic into the indefinite future and be able to fulfill our goals of biotic inventory and analysis of relationships. For the future we must continue to maintain and build our collections, expand our research, and offer fine public programs, while taking on a greater share of the training of the next generation of collection-oriented museum scholars who will provide further innovations and creative breakthroughs in our understanding of nature.

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大規模な自然誌博物館のもつ本質的な類似性と21世紀における責任

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世界中の大規模な自然誌博物館にはある共通性がある．その共通性とは，研究・資料収集を展示・教育プログラムと上手に組み合せ，共働させることによって，これらの機能のいずれにも益をもたらしていること，並びに，収蔵資料に基づいた研究の長期的成長と安定を確保していることである．