Can Natural History Museums Capture the Future?

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As natural history museums prepare to enter the twenty-first century, much of their core still sits in the 1800s. Despite enormous expansion in collections and exhibits during the past 100 years, many museums still resemble Victorian cabinets of natural history. Many still behave as isolated island endemics undergoing genetic drift, eschewing the hybrid vigor and collaborative power of a community.

The future of natural history museums requires saltational doses of the very process we study—evolution. It asks for bold, decisive steps—"convention-busting procedures" in the words of Daniel Seymour (1993), president of Q Systems, Palm Springs, CA—if museums are to fulfill their mission to science and society. The future of natural history museums demands that they not be prisoners of history because, as the saying goes, every time history repeats itself, the price goes up.

Natural history museums face a number of fundamental challenges for the twenty-first century. In this paper we address only four:

- **The challenge of the biodiversity crisis.** Museums must immediately harness their vast, authoritative, collection-based information if the millions of specimens they house are to be relevant to understanding biological diversity and sustaining the earth's plants, animals, microbes, and natural environments.
- **The challenge of education.** University natural history museums (and associated academic departments) must radically alter how they educate graduate and undergraduate students if the next generation of biodiversity research scientists is to be adequately equipped to tackle and decipher complex biological phenomena.
- **The challenge of public programs.** Natural history museums must rethink their educational and exhibit programming if they are to engage the people in becoming the environmental conscience of the nation.
- **The challenge of management and leadership.** Museums must evolve their management culture if they are to meet these and other challenges.

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Although formidable, these four challenges encompass the main responsibility of natural history museums—to deploy their vast research collections, systematics expertise, and knowledge of the planet's biodiversity to inform the stewardship of life on Earth. Others, most notably Alberch (1993), have sounded this call to arms for natural history museums, but it seems to have been ignored.

In this article, we sound the call to arms again and suggest some answers. More important, we invite dialogue and solutions from all members of the natural history museum community—research curators and faculty, collection managers, students, educators and exhibit specialists, administrators, development personnel, directors, and board members.

The challenge of the biodiversity crisis

Natural history museums have a commanding mission—nothing short of understanding the life of the planet for the benefit of the earth and its inhabitants. Their business is the science of biological diversity. They document and study life on Earth, its animals, plants, and microbes; its history, patterns, and processes; and its levels of organization, from genes to species to clades to ecosystems. They do so for the sake of knowledge and the biodiversity solutions this knowledge can inform. Whereas medical science is concerned with the health of one species on Earth, biodiversity science at natural history museums is concerned with the evolutionary and ecological pulse of the earth's other 15 million or more species.

This mission has never been more important to humans than it is today. The grand challenge for the twenty-first century is to harness knowledge of Earth's biological diversity and how it shapes the global environmental systems on which all of life depends. This knowledge is critical to science and society—for managing natural resources, for sustaining human health, for ensuring economic stability, and for improving the quality of human life. Urgent need for this knowledge increases daily as the conversion of natural systems to human-managed systems accelerates the decline of biological diversity. At the current rate of species extinction, biodiversity science has approximately 50 years or so to answer this challenge (Raven and Wilson 1992, SA 1994, Wilson 1998). The coming century, as Wilson (1998) predicts, will be the century of the environment. Natural history museums should be poised to inform the environmental management of the planet.

Deploy the information. How can natural history museums help meet the challenge of the biodiversity crisis? By deploying their libraries of life—knowledge of the planet's biodiversity gained during 300 years of biological exploration of the earth. This knowledge is grounded in research collections and associated data, from the 7 million specimens of animals and plants at the University of Kansas Natural History Museum and Biodiversity Research Center to the 500 million in all US museums to the 2–3 billion in museums worldwide.

These specimens document the global composition, identity, spatial distribution, ecology, systematics, and history of known life forms (approximately 1.8 million species). They provide the raw research material for revealing the patterns, processes, and causes of evolutionary and ecological phenomena. These specimens comprise our invaluable knowledge commodity—we use "commodity" in its economic sense because, in the end, stewardship of global biodiversity and ecosystems is an economic necessity.

We have the technological ability today to harness this enormous information store and leverage centuries of investment in biotic surveys, research collections, and the systematics enterprise. But the biological collections community is deploying its enormous archives of specimen-based biodiversity information much too slowly to affect its own research objectives in systematics, ecology, or broader earth systems science, or to influence education and public policy. Collections from single natural history museums rarely contain enough information for comprehensive biodiversity analyses of a clade, geographic region, or geologic period. Only by pooling and integrating biocollections data through information technology can museums begin to enable their widespread use in research and education, especially research into complex biodiversity phenomena that were hitherto intractable.

The first task for natural history museums in meeting the biodiversity challenge is to rescue their research collections from their information sinks. Each year, numerous studies recognize that such an information enterprise is fundamental to national and global biodiversity solutions. Recent examples include the Australian government's *Darwin Declaration* (Environment Australia 1998), the President's Committee on Science and Technology's *Teaming with Life* (PCAST 1998), the National Biodiversity Information Center's *Consensus Document* (NBIC 1994), the systematics and biocollections communities' *Systematics Agenda 2000* (1994), the National Science Foundation's *Loss of Biological Diversity* (Black et al. 1989), and the Committee on Environment and Natural Resources and National Science and Technology Council's *Strategic Planning Document—Environment and Natural Resources* (CENR, NSTC 1994). As the last of these examples recommends,

> *Enhance access to information on the nation's plants and animals. Existing collections of data for millions of specimens will be computerized and made more accessible to the nation's scientists and the public. Increased information...on...geographical occurrence and associated environmental conditions would greatly increase the ability to sustain terrestrial and aquatic ecosystems and to conserve biodiversity in harmony with land use.* (Chapter 3, p. 6)

Essentially, natural history museums must realize that access to their collection-based knowledge for biodiversity research, education, and expert decision-making is as important as the knowledge itself. It is time for museums to bring the intellectual content of the world's biocollections into currency for science and society. They must do so intelligently, quickly, and as a community. In short, it is time for the "knowledge networking" of biodiversity information.

Biodiversity informatics. How can natural history museums provide access to their vast stores of vouchered biotic information? By employing current information technology, they can furnish instant, powerful, and shared electronic access to their collection-based archives of biodiversity data. Furthermore, they can integrate these data across biotic, geospatial, genomic, and atmospheric domains—for example, with terrain, land cover, climate, and gene sequence data—to create new classes of biotic information for computational analysis and modeling. Such interdisciplinary integration is a prerequisite for investigating and advancing knowledge of complex evolutionary and ecological phenomena.

Biodiversity informatics describes a new, synthetic discipline that integrates biological research, computational science, and software engineering to deal with biotic data—their storage, integration, retrieval, and use in analysis, prediction, and decision-making. The National Science Foundation (NSF) identifies bioinformatics as having the highest priority for knowledge creation in the biological sciences, whether it is mining neuroscience data, genomic data, or biodiversity data (Bloch et al. 1995). *Systematics Agenda 2000* (1994, pp. 6, 14) presaged the task in its Mission Three: "To organize the information derived from this global program [of biodiversity inventory and systematic analysis] in an efficiently retrievable form that best meets the needs of science and society."

At the global level, the Organisation for Economic Co-operation and Development (OECD) Megascience Forum recommends establishment and support of "a distributed system of interlinked and interoperable modules (databases, software and networking tools, search engines, analytical algorithms, etc.) that together will form a Global Biodiversity Information Facility" (OECD 1999, p. 2). The challenge for the biological collections community is to enable its participation in such global information architectures through development and maintenance of its own informatics infrastructure. Specifically, the biocollections community needs to be able to share and disseminate specimen-based biodiversity data and to integrate this information across research domains.

A number of museums have begun to do this, among them the Natural History Museum, London (NHM 2000), and the Museum of Texas Tech University (Baker et al. 1998, Parker et al. 1998). Another example is NABIN, the North American Biodiversity Information Network, and its prototype projects (Peterson et al. 1998, 1999). Web-based software developed by a consortium (University of Kansas Natural History Museum, Bishop Museum, California Academy of Sciences, the US National Museum of Natural History, the Missouri Botanical Garden, US Geological Survey–Biological Resources Division)[1] of systematists and computer scientists enables any user to query multiple collection databases in the United States, Canada, and Mexico simultaneously. Once retrieved, the information is assembled and integrated in a matter of seconds with geospatial and computational tools and data, permitting analysis, modeling, and prediction of species occurrences based on locality data and underlying environmental and climatic variables.

This system, dubbed the Species Analyst (Vieglais 1998), uses the ANSI/NISO Z39.50 standard for information retrieval, which has proven successful in enabling data-sharing and knowledge networking in the bibliographic and geospatial domains (Kaiser 1999). The application for predicting species distributions, called the Biodiversity Species Workshop (SDSC 2000), provides an online facility for creating distribution maps from biocollections data on species occurrences and electronic maps of climate, land cover, and soils. The NABIN infrastructure provides a direct connection with the Biodiversity Species Workshop system at the San Diego Supercomputer Center (SDSC).

With the collaboration of other institutions (SDSC; Universidad Nacional Autónoma de México; and Consejo Nacional para el Uso y Conocimiento de la Biodiversidad, CONABIO), researchers have employed this open technology to retrieve specimen data from different collections in North America to predict, among other examples, the occurrence of *Hantavirus* with *Peromyscus maniculatus* in Mexico and the United States, the fate of rare and endangered species of birds in Mexico under scenarios of global climate change, the spread of invasive species, and priorities for conservation based on concentrations of rare and endemic species. As an Internet-based testbed application for public use, the NABIN facility has stimulated novel biodiversity research applications at the Environmental Resources Information Network in Australia, the Academy of Natural Sciences in Philadelphia, CONABIO in Mexico City, the Canadian National Collections in Ottawa, the University of Kansas, and other institutions.

Barriers. Natural history museums should unite to establish and develop a biodiversity informatics infrastructure along the lines recommended by OECD (1999). But the barriers are formidable at the community and institutional levels. Although the museum systematics community views its research enterprise as global, it still regards its collections information enterprise as local. Biodiversity data may be more complex than those from other biological and scientific disciplines. Yet, unlike the geospatial, genomics, and library communities, biocollections institutions still lack a standards-based informatics infrastructure for network communication of specimen data. This deficiency, in turn, has hindered integration of biocollections data with information and tools across research domains.

At the institutional level, most collection data are not captured in electronic databases. Those that are (perhaps 5%) feature multiple, idiosyncratic information systems within and across that rarely scale technically beyond their original installation; usually have no mechanism for long-term support and maintenance; and are not engineered for network authoring, updating, dissemination, and integration of specimen data. Use of these databases typically does not extend much beyond local collection management and answering individual data requests.

Many biocollections have policies that discourage or do not permit data-sharing. Ironically, such policies deliberately quarantine museum collections and their essential specimen information from research on the very biodiversity phenomena that those collections were intended to help elucidate. Lacking interoperability—the ability to integrate data across taxa and research domains—museum biocollections lack synthetic power. Without a community informatics infrastructure, the vast libraries of life in our museums remain largely unseen and unread. To paraphrase what Umberto Eco said about books: The good of collections and their data lies in their being read; without an eye to read them, they contain signs that produce no concepts; therefore, they are dumb.

Solutions. These barriers can be overcome if natural history museums are willing to come together to build and support a dazzling biodiversity informatics infrastructure in an open, collaborative, and community-based manner. Information technology is not the limiting factor. Efforts during the past 3 years (e.g., ASC 1993, Krebs et al. 1995, Morris 1997, Berendsohn 1999) have produced detailed, robust information models for biocollections data that are the basis for the design of sophisticated institutional and community systems.

A community enterprise can mobilize biocollections information for institutions large and small that, alone, could not finance, develop, or support the essential elements of a biodiversity informatics infrastructure. Museums need to follow the collaborative informatics examples set by the geospatial, bibliographic, genomic, and neuroscience research communities and reap similar benefits of increased research opportunities, accomplishments, funding, and economies of scale. Only then will museums be

[1]Research funded by NSF grant DBI 9811443–SGER: An experimental Z39.50 information retrieval protocol testbed for biological collection and taxonomic data.

able to deploy their enormous store of biodiversity knowledge for science and society and expand their descriptive systematics enterprise into a predictive, prescriptive one.

Finally, in anticipation of criticisms we have heard before, we do not say, believe, or mean to imply that biodiversity informatics is the only or even the major "fix" for biodiversity problems. But it is one of the most powerful tools that natural history museums can employ to finally contribute their collection-based knowledge to that fix. To be sure, museum collections and their databases are imperfect—they need to encompass more taxa and specimens, be checked for accuracy, and be geocoded for geospatial use. But these improvements can be ongoing while verified databases are being employed for successful biodiversity modeling, prediction, and conservation. In fact, geospatial mapping and modeling of collections data expose the outliers in the database for correction (if the records are erroneous) or for exciting research (if they are real).

Some systematists and museum personnel worry that successful use of electronic biocollection data for biodiversity conservation will convince administrators and government authorities that new biotic surveys and collections are no longer needed. On the contrary, integration and visualization of museum voucher collection data will demonstrate both the power of existing collections and the geographic, ecological, and taxonomic gaps that need to be filled by additional surveys and collections. Furthermore, integration of existing museum biocollections data may be the best tool for systematists and funding agencies worldwide to prioritize, plan, and support cost-effective, nonoverlapping biodiversity surveys.

Critics also worry about errors in species predictions based on habitat data, because species don't always occur where the habitat is right. Although these errors can occur, as with most of science, predictions of species occurrences are statistical statements subject to falsification, whether the predictions are based on vouchered collection data, on-the-ground observations, or remote sensing data. Continued use will only hone the predictive models and their algorithms.

Prisoners of history. After devoting 250 years to the vertebrates and selected nonvertebrate and plant groups, isn't it time for natural history museums to commit massive curatorial and systematics resources to the approximately 90 percent of biodiversity that remains a black box, such as soil biota, arthropods, fungi, marine invertebrates, and microbes? Instead, systematics resources, education, and expertise at too many of our institutions remain a paean to the past, out of kilter with the biological diversity of the planet and its needs.

We emphatically are not advocating that the collecting of and research on vertebrates is complete or should diminish. But, with regard to the unstudied 90 percent of biodiversity, the systematics community needs to heed Raven and Wilson (1992, p. 1099): "In order to propel systematics into its larger role foreordained by the biodiversity crisis, its practitioners need to formulate an explicitly stated mission with a timetable and cost estimate." *Systematic Agenda 2000* (1994) set forth one such explicit mission and helped launch NSF's innovative PEET program (Partnerships for Enhancing Expertise in Taxonomy; NSF 2000) to address the vanishing expertise in the systematics of the world's poorest known taxa. Larger NSF initiatives along these lines are brewing, but the systematics practitioners in natural history museums must be ready as a community to take advantage of these opportunities.

Furthermore, as others (Soulé 1990, Alberch 1993) have reminded us, it has taken the systematics enterprise 250 years and roughly 3 billion specimens to document 1.8 million species on Earth. At that pace, museums and systematics will have little or no impact on remaining biodiversity, which number at least 15 million species. More to the issue, documenting the rest of biodiversity or even a fraction of it with voucher specimens will result in survey collections and associated biodiversity data that are massive and unmanageable with current protocols.

In addressing these issues, Alberch's (1993, p. 372) diagnosis of what ails museums is brutally blunt:

> *Natural history museums are at a turning point in their history. They can now play a central and critical role in the development of research leading towards the understanding, conservation and sustainable use of biodiversity. To achieve this goal, however, they must radically change their mode of operation and public image, to clearly define goals, objectives, and new research strategies. If museums are unable to meet the challenge, other institutions will be created* de novo *to fill the niche.*

One of the next steps in the systematics revolution should be systems-level studies of biodiversity, namely, the interplay between multiple phylogenetic lineages and ecological patterns and processes. NSF is working with the systematics and ecology communities to formulate a new, integrative research program along these lines involving a network of environmental and biodiversity observatories (Mervis 1998). This program promises to expose a good deal of the unknown 90 percent of biodiversity to survey, systematics, and ecological analyses, with vouchering of large new research collections and associated data in the nation's museums. Such a systems approach will require the combined proficiencies of the traditional disciplines—mammalogists working with coleopterists, botanists with ornithologists, ichthyologists with nematologists, cladists with ecosystem ecologists—as well as the collaboration of systematists with information technologists, geographic information specialists, climatologists, computer scientists, mathematical modelers, and so on, which brings us to graduate education.

The challenge of graduate education

Biodiversity is suffering from two emerging extinction events: One involves the planet's species, the other the rare and endangered scientists who study them. As mentioned above, NSF's current PEET program is a landmark attempt to reverse the loss of taxonomic expertise, especially for poorly studied groups of animals and plants. Biodiversity scientists—systematists, ecologists, population geneticists, and evolutionary biologists, among others—who will work in the twenty-first century are now being educated and trained in university natural history museums and associated departments. But these educational programs are insufficient, both in number and kind (Humphrey 1989), to prepare the biodiversity scientist for the needs of the new century. How can we meet this challenge?

Taxonomic training. First, beginning in the high school and early undergraduate years, we need to recruit an army of students to study the 90 percent of biodiversity that remains unknown, in addition to the high-profile vertebrates. Otherwise, our educational curriculum in biodiversity science fails the present and the future. Moreover, as articulated by Bazzaz et al. (1998, p. 879), we hope these students "will be ready and willing to devote part of their professional lives to stemming the tide of environmental degradation and the associated losses of biodiversity and its ecological services, and to teaching the public about the importance of those losses."

Interdisciplinary training. Second, systematists for the twenty-first century must be trained beyond areas of taxonomic expertise to work in teams with other evolutionary biologists and ecologists, earth systems scientists, informatics specialists, and so on. Universities and university natural history museums are where such interdisciplinary, cross-domain education should be occurring; however, it is not, or at least not sufficiently.

Citing a study by the National Academy of Sciences, Jasanoff et al. (1998, pp. 2066–2067) conclude that "more than at any time in the recent past, there is a demand for mechanisms and incentives to foster interdisciplinary research, education and problem solving....[T]oday's young scientists will find their advancement restricted unless they are trained from the start to diversify their expertise and career objectives." A recent NSF report (Bloch et al. 1995) echoed this recommendation for the biological sciences in general and for biodiversity science in particular. In short, we should be educating biodiversity scientists for the future, not the past.

Doing so will require a radical shift in academic culture and practice toward much more collaboration in education and research across disciplines, faculty, and students. Without such a shift, students—and worse, future knowledge creation in the biological sciences—will be shortchanged. Why? To paraphrase Jasanoff et al. (1998), biological phenomena are vastly complex systems. Their causes are multiple, diverse, and dispersed. Therefore, they cannot be understood, managed, or controlled through scientific activity organized on single or traditional disciplinary lines.

Furthermore, the data and tools (conceptual, physical, computational, and so on) required to investigate the causes of complex biological phenomena are beyond the scope of any single investigator and often beyond the mission, infrastructure, and expertise of any single institution. Therefore, such research requires cross-domain approaches involving interdisciplinary, collaborative teams within and across institutions. Finally, there may no longer be disciplines or knowledge domains in the classical sense, as the growing continuum between individual humanities, social sciences, and natural sciences is collapsing the boundaries of classical core disciplines (see, e.g., Wilson 1998).

Skeptics ask: Once trained in this manner, where will all these students get jobs? The answer is throughout academia, government, nongovernmental organizations, and the private sector, where the need and demand will be great for cross-disciplinary expertise across the environmental and biodiversity sciences in the policy, educational, and research arenas.

The challenge of leadership and management

Organizations, including natural history museums, are akin to complex ecosystems (Blackburn 1973). They have an evolutionary history that bequeaths structural constraints; a vital web and flow of resources, energy, and information; homeostatic mechanisms that tend to keep the organizations conservative and stable; niche specialization and diversification among their personnel; successional change from new paradigms to maturity; periods of chaos; and occasional catastrophic events.

If natural history museums are to meet the challenges of the biodiversity crisis, graduate training, and public education, they will need bold, innovative leadership that is especially skilled at managing the museum's organizational ecosystem, charting the landscape of the future, and navigating adaptation to that landscape. Otherwise, as Alberch (1993) warned, natural history museums will be out-competed by new institutional species that will emerge as champions of the very initiatives the museums should be leading.

Management training. Although the task of leading a natural history museum several years into the future is complex and demanding, directors of most natural history museums, including ourselves, have little to no training in how to do so. Many of the biodiversity scientists educated at universities will eventually move into leadership and management positions in natural history museums, academia, and government. At least we hope they will—editorials in *Science* and other journals regularly bemoan the absence of scientists in high-level policymaking positions. Yet, we do not train our academicians to understand the complexities of organizational ecosystems and how to lead, manage, represent, or effect change within them. We suppose, naively, perhaps even arrogantly, that these talents will somehow spring from having a PhD.

Directing a natural history museum requires more than common sense and a PhD in paleontology or ornithology—we say this from personal experience. Most directors, including ourselves, were trained on the job, but experience is an expensive teacher. If museums were airplanes, one expense of such seat-of-the-pants-flying could be crash landings and loss of passengers, unfortunate events for some of our natural history museums. Another expense is that museum pilots may think they are in the air and flying comfortably into the next millennium when in fact they are still in the hangar.

One solution is a two-headed approach to leadership, adopted with greater or lesser success by a number of the nation's large, freestanding natural history museums—a CEO with corporate or university experience in management, development, and strategic planning, and a subordinate with established scientific credentials in charge of the museum's research and collections enterprise. Such a system is fragile. Its success demands that the CEO and subordinate share a common vision of the institution and its scientific rationale and work well together in implementing the museum's mission, goals, priorities, investments, and actions.

Students as future pilots. Rather than hope for "naturals"—born leader–managers—to come along, universities and their natural history museums should be imparting modern management, administrative, and leadership skills to their students at the same time they are teaching them systematics, ecology, and the evolutionary history of life. Teaching biodiversity students that an organization's priorities must be tailored to its mission invokes the same principle that governs the students' educational and research priorities. Teaching students that organizations can work together to accomplish nationally what each alone cannot invokes the same principle that governs interdisciplinary research teams. And teaching students how to manage and effect change in complex organizations may one day help them lead a museum, a government agency, or an international research expedition in new, daring directions.

What management paradigms are important to learn and teach? Ones that replace the folklore of "This is how we do things around here" (Seymour 1993), which is maladaptive for the mission, demands, and responsibilities of our museums in a new era of exponential change. As Hunter et al. (1987, p. 19) observed, "Traditional American management philosophies have become obsolete. Most managers in this country have been taught how to control, rather than lead."

During the past three decades, such corporations as Hewlett-Packard (Fuller 1985), Ford Motor Company, and Nashua Corporation (Karney 1988); several colleges and universities, including Oregon State University and Virginia Tech (Sherr and Teeter 1991); and various government entities, such as city and state government organizations in Madison, Wisconsin (Hunter et al. 1987), have been radically transformed into organizations that are focused on serving their customers and meeting or exceeding their customers' needs. They have eschewed the traditional authoritarian, top-down management style that has been the corporate tradition and the model for universities and museums for more than a century. They have devoted themselves to improving the quality of their goods and services, consulting their customers, and treating their employees as the most valuable resources of their organizations.

Do natural history museums pass this test? Not yet. They place great value and resources in collection management but pay scant attention to people management—the very people they depend on to manage and use the collections in research and education. Museums trumpet the quality of their scientific "goods," the irreplaceable research collections and associated data that document Earth's biota through time and across space. Yet the quality of museum services is poor in providing those goods (e.g., accessible and interoperable specimen-based biodiversity data) to address global biodiversity issues and other scientific and societal needs. It is too easy and intellectually dishonest to blame this state of affairs on previous technological shortcomings. Rather, most museums chose not to do business as a community with their most valuable knowledge commodity.

The challenge of public programs

How well do natural history museums fulfill their mission of bringing their collection-based knowledge of biological diversity to society? For example, many permanent, classic dioramas at natural history museums are, essentially, nineteenth-century trophy halls. They marry art and science to produce a snapshot of a wild scene, often contrived, pretending nature is still pristine, untouched by humans. Their fidelity to biodiversity typically ends with the larger vertebrates and a few background plants. They are quaint, reassuring, and appreciated, but the stories they tell need to go beyond the superficial lesson that a moose lives in the boreal forest. Otherwise, they will continue to be largely ineffective at increasing the public's sense of responsibility for environmental stewardship.

The challenge for natural history museums is to tell the real stories of biological diversity and connect them to the everyday life of our visitors. For example, museums need to instill the lesson of Easter Island, our Earth in a microcosm. When the islanders destroyed the biodiversity of their own island world, they extinguished themselves and their culture. Museums need to deliver the splendor of biodiversity and the consequences of its ongoing extermination, from our own backyards to Amazonia. Museums need to show visitors how our planet's biotas are fundamental for human life, providing "free" ecosystem services valued at trillions of dollars annually. And museums need to do so with the visceral impact that inspires the citizenry to become the environmental conscience of the nation.

Meeting this challenge will require great resources and great resourcefulness, but no less should be expected of museums if they are to increase public attendance, understanding, and support for education and research. One course is clear: "Natural history museums should not try to become theme parks...because a museum is not likely to be very good at being one" (Fri 1997, p. 49).

Conclusion

Natural history museums must define and capture their future. To do so, whether freestanding or university-based, they need to enact their mission of understanding the life of the planet to inform its stewardship. They need to expand their collections and systematics enterprise to encompass the 90 percent of biological diversity that awaits discovery, documentation, description, and comprehension. As a community, they need to erect an informatics infrastructure to deploy their vast collection of information on the planet's known biological diversity and transform this information into knowledge for science and society. They need to engage the public with this knowledge into becoming the biodiversity conscience of the nation. They need to educate their students to be proficient in the ecology and behavior of organizations as well as the ecology and systematics of organisms. And they need to adopt practices of management and leadership that can enable their complex organizational ecosystems to meet these challenges with foresight, collaboration, adaptability, and excellence.

Our natural history museums are sentinel observatories of life on Earth, peering over its past 3.8 billion years and assaying its present condition. Now it is time for them to be stewards of its future.

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