Natural History Museums in a Postbiodiversity Era

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Biodiversity research has been the mainstay of natural history museums, but the traditional uses of biological collections in taxonomy, systematics, and evolutionary biology account for only part of these collections' value. Biological collections today are meeting diverse needs. New uses for specimens—as "biological filter paper," for example—have little relationship to the taxon-oriented research on which collections are based, yet they often have tremendous import for helping us understand changes in populations, species, and the environment. As the major issues in exploration and systematics are resolved and society's interest in biodiversity wavers, museums need to embrace important new uses for natural history collections and, with new partners, begin laying new foundations for a postbiodiversity future. Proactively opening a domain focused on exploration and basic biodiversity to an increase in applied research can enable museums to grow to meet present and future challenges and to bring their true strengths, their collections, to bear on broader issues for both science and society.

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Museum biological collections and the science developed from them are the foundation of our understanding of life on Earth. But what happens to this grand enterprise when the foundation is laid and few new species remain to be discovered? What about collections of taxa that are "done"? Recent trends suggest that vertebrate collections, for example, often undergo diminished development as institutional emphases shift to other organismal groups or to other pursuits (e.g., Gee 1990, Pennisi 2001, Stokstad 2003). How will museums continue to develop the relevance of their biological collections and thrive in a changing world?

Debates over the directions that museums should take to retain and increase public support are common. Most discussions focus on the public side (Spalding 2002, Thomson 2002), but the outcomes often have direct effects on the scientific side, through, for example, erosion of staff positions and a diminished role for scientific staff and collections (Stokstad 2003). Changing emphases among museum sciences can have similar effects. It is healthy to examine museum policies to meet the disparate demands of entertainment, education, and science, but it often seems that collections-based science, probably the one area in which museums can outcompete all other institutions, does not emerge as the core strength that it is (Mayr and Goodwin 1956, Duckworth et al. 1993).

Much biodiversity research remains to be done, and the time left to accomplish a full inventory of life on Earth is limited (Ehrlich and Wilson 1991, Raven and Wilson 1992). But at some point societal interest begins to flag. The meter is infinitely divisible, pi can be calculated to astonishing accuracy, and there is a finite number of species. When it comes to the finer details, interest and resources are usually diverted to other pursuits. For example, new vertebrate or tree species command more public attention than new invertebrate or fungal species—this is human nature. When does society tire of the exercise? An exclusive focus on traditional biodiversity research risks a future in which these collections prove weak for addressing other questions, many of which may be more broadly important.

Collections as natural libraries

The mission of museum natural history collections is to document biodiversity and its distribution and to serve as a resource for research and education. Collections primarily support scientific pursuits that use the comparative method, "one of the two great methods of science (experimentation being the other one)" (Mayr 1982, p. 102). Outside of systematics (the study of organismal relationships), oversight of this fundamental contribution to science—specimens as objects having comparative utility—has resulted in decisions that diminish the scientific potential of museums by overlooking those strengths inherent in the one asset that they alone possess: their collections. Such oversights may arise in part because the context in which an object has comparative value changes with time. Temporal changes in the use and importance of collections have been neglected.

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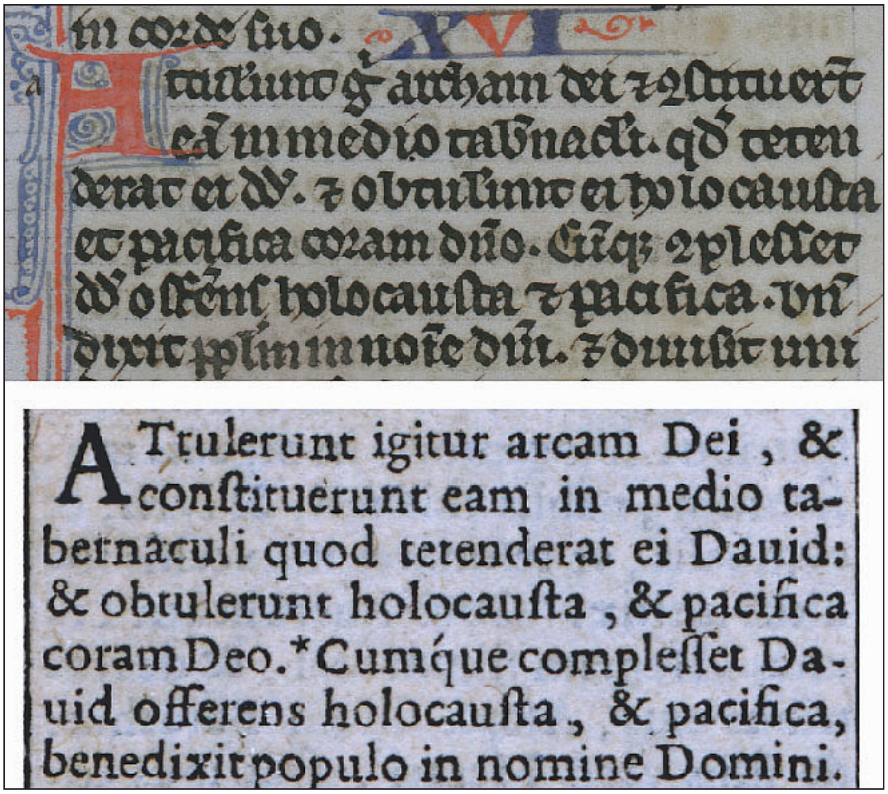

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Figure 1. A Vulgate Bible passage hand scribed on vellum (animal skin) by a monk in about 1250 (top) contrasted with the same passage printed by mechanical means on paper in 1628 (bottom). These objects document several details of their times, enabling us to gauge many profound cultural and technological changes that occurred between their dates of production—as well as even more profound changes occurring between then and now (such as electronic publication, the emergence of English as the world's lingua franca, and the burgeoning of Western science). The parallels with biological specimens as objects standing constant in a stream of cultural and environmental change are only beginning to be widely appreciated.

Systematics collections are often compared to libraries. In providing a series of users with information, specimens are similar to reference books. But each specimen is unique, providing multidimensional documentation in geographic space (locality), biodiversity space (taxonomy), and position in time (date). Largely unappreciated by traditional users of nonpaleontological collections is that a specimen's position in time can be much more than an indicator of short-term phenomena such as geographic movement and stage of development. As collections have aged, the year in which samples were obtained has become increasingly important. This should be no surprise, because we are fascinated by our own cultural history. But bringing this perspective to biological collections is important, and this can be done by extending the library analogy.

Classically preserved specimens of mammals and birds, for example, are like old books, in that they are products of animal skin and plant materials (the stuffing). With care, we can expect them to last as long as books are lasting—certainly many centuries (figure 1). As a product of science, the useful life of these specimens is much longer than that of the scientific papers written about them. The temporal relevance of scientific publications is tracked using half-life statistics. Only about one-third of biological journals exceed half-lives of 10 years, meaning that in just a few decades most of the science published today will be largely irrelevant. Thus, the "freshness date" of specimen-based science quickly expires, while the relevance of the specimens themselves may grow appreciably. Collections growth is being driven (or, in many cases, stopped) by the ephemeral, short-term scientific objectives of generating publications today, despite the amazing mismatch in temporal relevance between the two products.

Unlike the case with books and libraries, with nonpaleontological specimens we cannot reach back in time and add important historical works (specimens) to our collections. Nor can we copy those that were preserved. As more organisms pass into rarity, extirpation, and extinction, collections run the risk of becoming frozen glimpses of the past. Passenger pigeon (*Ectopistes migratorius*) and great auk (*Pinguinus impennis*) specimens have tremendous impact as preserved relics of extinct animals, but their scientific relevance today is largely symbolic. How useful is a library that stops acquiring books?

Canaries in the coal mine

Museum specimens are increasingly used as "biological filter paper"—samples from "experiments" in natural environments. These uses have little relationship to the taxon-oriented research on which collections are based, yet they often have tremendous import. For example, research using old egg specimens showed that DDT was having disastrous effects on avian reproduction (Ratcliffe 1967, Hickey and Anderson 1968), resulting in legislation benefiting health on an ecosystem scale (Grier 1982). Museum specimens enabled demonstration of increased mutations following the Chernobyl nuclear accident (Ellegren et al. 1997) and of the origin and transatlantic movement of the crop pathogen that caused the Irish potato famine (Ristaino et al. 2001). Old seabird specimens enabled documentation of a rise in mercury levels in the North Atlantic over the past century (Thompson et al. 1998), and historic specimens are being used to demonstrate greater levels of environmental stress among extant avian populations (Lens et al. 2002). Museum specimens have also enabled retrospective studies of emerging zoonotic diseases, such as Lyme disease and hantavirus pulmonary syndrome (Persing et al. 1990, Marshall et al. 1994, Yates et al. 2002); they have also revealed long-term, ecosystem-scale changes in oceanic primary productivity in the Bering Sea, one of the world's most important fishing grounds (Schell 2000, 2001). Specimens are highly effective for monitoring and measuring changes in populations, species, and the environment. Such measures have profound implications for humans and managed biota, and these studies demonstrate the critical nature of historic samples.

Bird collections provide a microcosmic view of the waxing, waning, and uncertain future of natural history collections. Collections grew during historic biodiversity exploration, but, as birds became a comparatively well-known group, national emphases on bird collecting waned—probably because the traditional biodiversity questions for which these collections were developed seemed largely answered (figure 2). However, given the important role of these collections in the new science of monitoring change, they suffer from temporal inadequacy, poorly representing the present, especially in developed regions. Apparent declines at the national level in the United States are not reflected across the country (figure 2), but patterns of continued growth show individualistic variation. At the national level in many other countries, such as the United Kingdom and Canada, growth of bird collections from modern specimens is also quite low in contrast to historic levels. The future utility of these resources for answering questions about changes in the biosphere is in jeopardy.

New science, new clients

Natural history collections are proving useful, if not indispensable, for questions unrelated to the reasons for their establishment. Many environmental, ecological, societal, and management-related areas benefit from the sample-based approach of the museum tradition: Sentinel species, resiliency, baseline rates of disease incidence and genetic diversity among wild hosts, organismal distributions in relation to development and environmental disturbance, emerging infectious diseases, genetic diversity in managed populations, food web changes, contaminants, biological responses to climate change, the emerging fields of genomics and proteomics, and even bioterrorism research indicate the great breadth of areas in which collections are relevant. Natural history museums are involved in many of these areas, but they can play a more effective role in each.

Museums are not blind to these new demands and opportunities. For example, destructive sampling (e.g., tissue sampling for molecular studies or stable isotope studies) has emerged as a routine use of collections. And museums are service-oriented institutions, but they must ask how their services will be supported and how present activities can improve tomorrow's services. New clients—many of whom do not yet directly support these collections—present new opportunities for support and growth for institutions long considered to be chronically underfunded (Mayr and Goodwin 1956, Pennisi 2001).

This is not to denigrate the critical role that museums play in biodiversity research. Rather, it is to recognize the need and opportunity for museums to support the wider client base that requires specimen resources. Biodiversity research properly remains at the core of natural history museum science, and some would argue that environmental monitoring through museum specimens is just a modern extension of traditional emphases; but the science is quite different—only the specimens are held in common.

Museums are the cornerstone of an object-oriented approach to the natural world. The data that their specimens can supply also have a high value, and, despite several unresolved issues (such as quality control and new collections support; Winker 1999), making specimen data electronically available is expanding the visibility and accessibility of collections. But along with positive gains, there is a tendency to divorce the data from the objects, and few outside the museum community recognize that the objects themselves have primacy as wellsprings of yet-undeveloped data. Making a direct connection between use of electronic collections data and financial support of the source of these data (i.e., collections maintenance and growth) is presently a challenging and contentious issue, one with high stakes for the future of collections. Electronic accessibility is a key component to developing new partnerships and diversifying the funding sources supporting collections.

Enhancing partnerships and support networks by embracing emerging collections-based science and by planning collections growth to address future needs can benefit the participants and society. For example, efforts to monitor bird populations tend to focus on simply counting animals. This is like compiling health and disease statistics without addressing causation. Sampling and archiving should be integral parts of monitoring programs, and whole-organism sampling has no peer in terms of cost-effectiveness for answering many pressing management questions. Biotic populations are renewable resources; specimen collections are not.

Sample-based retrospective research is an exceedingly powerful analytical approach for assessing changes in populations and environments. For environmental monitoring, series of common taxa from multiple trophic levels preserved regularly through time would be invaluable. Few collections of urban and suburban macroorganisms are being archived. Traditional biodiversity science would see few short-term gains from such collections, yet the long-term value of samples like these is probably quite high. This is equally true for the managed biota of preserved areas, such as refuges and parks. Effectively coupling research areas like population and environmental monitoring with museum expertise would produce stronger science and better-informed management.

Growth potential in applied collections-based science is strong. But the growth of this new science should not mean simply out with the old and in with the new. Taxonomic

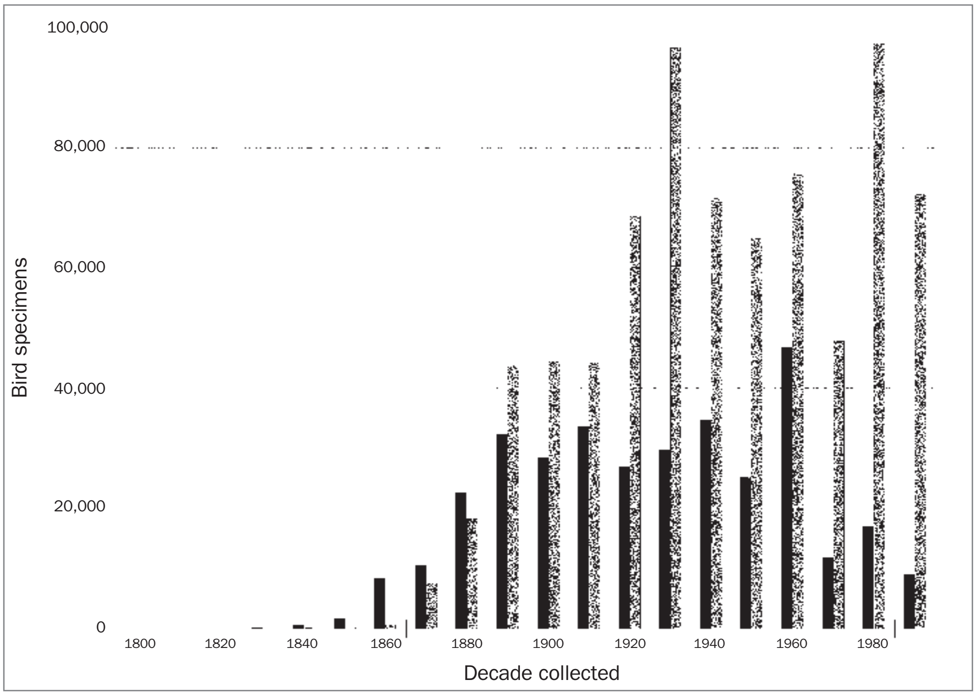

Figure 2. The age profile of the US National Museum of Natural History bird collection (solid bars), graphing the decade of collection of each specimen (340,193 computerized specimens). From this perspective, the heyday of bird collecting for science would seem to be past. On regional scales, however, this pattern of decline is absent, and aggregate growth for six collections across the United States (gray bars) remains about as strong as it has ever been (754,823 specimens). The processes behind this aggregate pattern are capricious, being driven largely by individuals rather than institutions. Institutional and regional inconsistencies through time are the norm, making long-term scientific gains largely accidental.

expertise, for example, remains a central service provided by museums. New investments are needed. New clients should enable the business to grow. And we need to proactively address these issues so that 2, 10, and 50 years from now we will have the samples needed to measure and understand the consequences of change in Earth's web of life.

Investing for long-term gains

The business model for natural history collections has to change. To reap the long-term benefits that these collections can clearly deliver, we must become better at coupling short-term scientific gains with long-term outlooks and activities. The individual pursuits of curators and collections managers are generally too narrow to satisfy this diversity of needs, and present reward systems tend not to include collections growth as a priority. Further, collections' strengths seem too often to be unrecognized or ignored by resource managers, administrators, and politicians. Collecting permits that are overly restrictive, often because of a misdirected sense of conservation and a misunderstanding of population biology and science (Remsen 1995, Winker 1996), can actively prevent strong collections growth. Conservationists in particular need to recognize that collecting and collections growth bring tremendous benefits to conservation science, and that these gains come with essentially no costs to the renewable resources (populations) being managed. In museums, elimination of staff positions for collections squanders the strengths of the collections themselves, leaving it to chance that these strengths will be realized by external users. And as attention falters, collections get left behind in time, mothballed with little or no further growth. If museums can be constructed or redirected to document—through collections—social phenomena such as the Holocaust, Communism, and apartheid so we can learn from our past (Spalding 2002), then surely we can document our present environment and its biota for similar reasons. Reward systems must change, and new clients who find collections useful need to have a role in those collections' development and share in the support required to maintain and grow these resources.

As natural history collections are increasingly used for nontraditional purposes and the importance of systematics declines as major problems are solved and society's interest wavers, will the quality of science emanating from museums also decline, for example, into more management-oriented, applied aspects of the life sciences? There is a lot of room for growth for museums and their collections into more applied environmental sciences, and such involvement should increase to reap new benefits from these important historic investments. At the same time, however, there is a lot of excellent basic science to be derived from specimens, and natural history collections will continue to inspire future generations—as long as museums and their collections continue to grow and remain in touch with the needs and opportunities of the present. The greatest successes will come from creatively coupling these different avenues.

Natural history museums tend to focus on the rapidly dwindling unexplored aspects of Earth's biota. Longevity and relevance will be enhanced by including the explored and developed portions of the planet and forging new partnerships focusing on these areas. Programs to stimulate environmental monitoring among consortia that include museums deserve support (see, e.g., *www.nsf.gov/bio/neon*). Archiving and sample-based approaches to research and inventories provide huge strengths when employed, yet museums generally have little success in generating contracts or consultancies (but see *www.nhm.ac.uk/science/consulting*). Museums should be part of the environmental impact assessment industry. Is it possible to bring to museums the private sector–university partnerships now being widely explored? Should we establish museum industrial parks?

Proactively opening museum collections, a domain focused on exploration and basic biodiversity, to expansion in applied research can enable museums to grow to meet present and future challenges—and to bring museums' true strengths, their collections, to bear on broader issues for both science and society.

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