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Preserving Natural Science Collections: Chronicle of Our Environmental Heritage

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Preserving Natural Science Collections: *Chronicle of Our Environmental Heritage*

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This report is the product of the Conservation and Preservation of Natural Science Collections Project, undertaken by the National Institute for the Conservation of Cultural Property (NIC) in partnership with the Association of Systematics Collections (ASC) and the Society for the Preservation of Natural History Collections (SPNHC).

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Contents

Preface

In the report from a 1988 workshop on collections resources, the Association of Systematics Collections (ASC) noted the need for improved collections preservation, including research on conservation methods and training for natural science conservators. That same year, the natural science organizations and institutions that are members of the National Institute for the Conservation of Cultural Property (NIC) recommended that NIC undertake a project to address these topics.

The Conservation and Preservation of Natural Science Collections Project was established by NIC as a collaborative effort with the Association of Systematics Collections (ASC) and the Society for the Preservation of Natural History Collections (SPNHC). The goal of the project has been to improve the care of natural science research collections by:

- gathering and analyzing information from a variety of sources concerning the care and preservation needs of natural science collections;
- synthesizing the information and identifying priorities;
- developing strategies to address the challenges;
- proposing curricula for graduate programs to train conservators in bioscience and geoscience collections;
- identifying training methods in preventive conservation for collection managers and other professionals;
- publishing a report summarizing the findings of the project;
- disseminating the report to leaders in the natural science and conservation fields; and
- using the report as a basis for disseminating information to audiences in the private and public sectors in order to stimulate new support for conservation initiatives.

Information on three topics was gathered and analyzed for the project:

- basic problems affecting the overall care of natural science collections;

- specific conservation problems in need of research; and
- collections care and conservation training.

With assistance from ASC and SPNHC, NIC representatives met with nearly 200 research scientists, collections managers, conservators, conservation scientists, educators and institutional administrators to develop an understanding of the conservation needs of natural science collections. Meetings were held with members of disciplinary organizations in the natural sciences to survey their views on the preservation of these collections and to identify the issues common to all the natural sciences, as well as those that may be specific to a particular discipline.

With funding from the National Science Foundation (NSF), NIC then convened four multinational, interdisciplinary panels to discuss conservation research for natural science collections. Because of the complexity of the materials in these collections, the panels included specialists in natural and synthetic polymers, materials science, organic and physical chemistry, geochemistry, biochemistry, microbiology and mechanical engineering as well as conservators and natural scientists. The panelists suggested the technology transfer and research approaches necessary to meet current conservation needs and to address the preservation of specimens that will be collected in the future.

Following the materials conservation panels, two working groups met to synthesize the information from previous meetings and recommend education and training initiatives to support the conservation of natural science collections. Based on the efforts of the panels and working groups, an advisory panel composed of administrators from museums and other collecting institutions reviewed a draft of material for this report and developed recommendations and strategies.

This report reflects the overall views of the many project participants and our effort to integrate their ideas into a plan of action. We hope it will serve as a catalyst for further discussion and a stimulus for collections care initiatives in natural history institutions and in funding organizations.

We extend our sincere appreciation to our project staff, Catharine Hawks and Katherine Bussey, for organizing the meetings, preparing transcripts of nearly 100 hours of meeting tapes and assembling draft documents for review; to Ellen Cochran Hirzy and NIC Editor Paula Peters Chambers for bringing clarity and order to our ideas; and to ASC Executive Director Elaine Hoagland and SPNHC President Gerald Fitzgerald for their advice, cooperation and steadfast attendance at meetings throughout the project.

We are extremely grateful to NIC President Lawrence L. Reger and the NIC board of directors for their willingness to commit substantial resources to this project and to the NSF Division of Environmental

Biology for its generous support of the materials science panel meetings, the working group and advisory panel meetings, and the production of this report. We also acknowledge NSF Program Officers David Shindel and Leonard Krishtalka for their advice and assistance in the development of the project.

Finally, we are deeply indebted to the many professionals who have graciously contributed their time and expertise to this effort. The participation of these men and women is eloquent testimony to the importance of natural science collections and to the breadth and depth of the concern for their care.

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Museums are in the discovery business…their central role in the biodiversity crises arises from the fact that most of the world's life forms have yet to be discovered…. Although the estimates of total diversity are still crude (ranging over an order of magnitude), it is clear that the number of species remaining to be recognized for the first time is far greater than the total that has been described since Carl Linnaeus gave us our system for naming species more than 250 years ago.

—Michael Smith, 1991

Executive Summary

Natural science collections are documents of change, the fragmentary archive on which we base our knowledge of the natural world. Encoded within these collections are the past of our planet, the ledger of our interaction with nature and the record we decipher to ensure a future for our own and other species. These vast yet incomplete reference collections are the primary source that scientists consult to understand biological diversity, explore evolutionary relationships and monitor global change. Against a backdrop of disappearing habitats, species extinctions and the destruction of sites of geological and paleontological significance, the specimens in natural science collections have become nonrenewable resources of vital importance to science and society.

> There are many reasons one can give for the preservation of natural history collections.... At present, the most important reason of all is preserving essential information for managing and preserving life on earth.
>
> —Frederic Verhoog, 1993

As scientists seek to comprehend the mysteries of the natural world, each new research technique they employ expands access to the wealth of information inherent in the natural science specimens and increases the value of the collections to society. Specimens have been utilized to shed new light on the extinction of dinosaurs, trace the history of AIDS and the epidemiology of Lyme disease, and prospect for mineral resources. Through exhibits and other public programs, the collections instill a sense of wonder and an appreciation for nature in millions of people the world over.

While virtually unparalleled in their size and diversity, these collections represent just a fraction of the estimated 10 to 30 million species thought to exist. Consequently, the collections continue to grow, reflecting the fundamental human desire to understand nature. Virtually all explorations during the past 300 years, from discoveries on earth to forays into the solar system, have resulted in additions to the collected resource in the natural sciences. The specimens range from fossils to living microbes and—with the materials used to prepare, store, exhibit and record them—they encompass every known class of material.

During the 19th and early 20th centuries, the pace of collecting was matched by the pace of research into specimen preparation and conservation methods. As time passed, however, the importance accorded to preservation research diminished and the resources to support it diminished as well. The same scientific rigor that is expected in research based on specimens has not been applied to the preparation and contained care of the specimens themselves.

To preserve these complex and valuable collections for our continued use and as a useful legacy for posterity is at once an enormous responsibility and an intriguing challenge. Five factors shape this challenge:

- the size and diversity of the collections and their documentation;
- the many unrecorded treatments specimens undergo, limiting our ability to assess the impact of those treatments on preservation or specimen-based research;
- the inadequate space and inappropriate environments in which many collections are housed and used;
- the shortage of human resources for the care of collections and the limited educational and training opportunities in collections care specialties; and
- the lack of scientific research to address the preservation of these collections and the lack of interdisciplinary dialogue between natural scientists and specialists in other fields.

Conservation is the technology by which preservation is achieved.

—Philip Ward, 1986

Fundamental to meeting this challenge is responsible stewardship of collections by all those who are entrusted with their care. Natural science specimens are intended to be used; prudent planning and attention to collections growth, preparation, post-preparation care, documentation, storage, exhibition and research are crucial to their present and future utility.

An expanded public awareness of the significance of the collections as information resources is also essential to meeting the preservation challenge. By bringing behind-the-scenes activities into public view, institutions can demonstrate that their collections are vital to the public interest and thus worthy of support.

This report recommends action in the areas outlined below. (Strategies for implementation of each recommendation are presented in chapter three, "Meeting the Challenge: Recommendations and Strategies.")

Stewardship of Collections

- Collecting institutions must make collections care a priority in their mission statements, management policies and resource allocations. This commitment should be commensurate with the inherent value of the information the collections contain.

- Collecting institutions must develop strategic plans for improved collections care.
- Individuals whose research results in collections must ensure the long-term preservation of collections by planning for their ongoing care.
- Funding agencies must support collections care initiatives in natural science institutions.
- Collections care and conservation organizations must support institutional collections care initiatives.

Public Awareness

- On the local or regional level, collecting institutions should create programs to enhance public awareness of the significance of their collections and the shared responsibilities of stewardship.
- On the national level, public awareness initiatives must be developed to highlight the value of collections to society and the need for collections conservation.

Staffing, Education and Training

- An intensive graduate program in the conservation of natural science collections must be established immediately to train a core group of conservators.
- An ongoing graduate program in the conservation of natural science collections must be established to train conservators for the future.
- Conservators from other fields should be made aware of the special needs of natural science collections and the areas in which their expertise is relevant.
- Directors, research scientists and collections managers must gain a fuller understanding of their roles and responsibilities in collections care.
- Institutions must develop, support and encourage staff education and interdisciplinary professional exchange as investments in collections care.

Technology Transfer

- The natural science community should seek the transfer of information and technology from other conservation fields, scientific disciplines and industry.

Conservation Research

- A new interdisciplinary conservation research program should be established at one or more leading institutions.
- Regional or centralized conservation analytical services should be made available.
- Agencies that fund collections care should expand the scope of their support to include conservation research.

High school students study natural science collections as part of an NSF-sponsored science education initiative at the Academy of Natural Sciences in Philadelphia. Such programs foster appreciation of research collections and may encourage the development of a new generation of scientists.

Guidelines and Standards of Practice

- The natural science community should establish guidelines or standards of practice in all aspects of collections care.
- Specifications for materials and methods used in preparing, storing, labeling and exhibiting natural science specimens should be developed and updated routinely.
- Efficient methods to document specimen preparation, sampling and other treatments or use should be developed to ensure the research integrity of the collections.
- Databases and networks should be developed and maintained to provide the widest societal access to the information inherent in natural science collections.

Scientists examine the saw-cut surface of a moon rock inside a nitrogen cabinet. Lunar samples are stored and processed under nitrogen to minimize corrosion and contamination.

Chapter One
The Significance and Value of Natural Science Collections

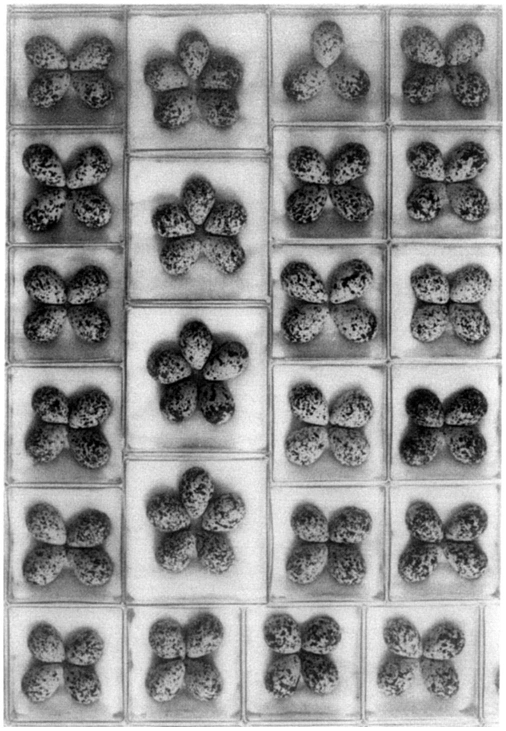
Natural science collections are the foundation for human understanding of the natural world. The specimens in these collections are the means by which scientists monitor global change, explore evolutionary relationships, understand biodiversity and assess the impact human beings have as part of the natural environment. When coupled with the library and archival materials that are essential to their documentation, these collections are of unparalleled size and diversity.

> The collections of museums...are material evidence of the earth's living creatures, past and present, of the life style practiced by its human inhabitants, and of the earth's structure and evolution.
>
> —Des Griffin, 1993

Natural science collections are found in national, state, county or provincial, municipal, university and free-standing museums; in government agencies; in research institutes and foundations; in university departments; in the exhibits and educational programs of nature reserves and wildlife refuges; and among the holdings of corporate entities and private citizens. The specimens in these collections support research in many disciplines, from biological fields such as botany and parasitology to geological fields such as petrology and crystallography. Each natural science specimen is unique and the information that can be derived from it multiplies with the development of new research techniques and as a response to the constantly changing needs of public information and policy development.

Generations of scientists have devoted their talents and intellects to amass, identify, maintain and interpret natural science collections. Like libraries, natural science collections are used heavily. Literally millions of specimens are on loan throughout the world at any given moment. A large national collection in a single discipline may host 500 visiting researchers a year. The research clientele includes government agencies at all levels, scientists and other scholars, businesses and nonprofit organizations (fig. 1-1, p. 10).

While systematics studies continue to be the primary use of natural science collections, they are employed in ever-expanding research inquiries. Fossils derived from drill cores that were originally collected in efforts to find oil now provide evidence about the boundary between the Cretaceous and Tertiary periods, when dinosaurs became extinct. Ash samples collected before the first explosion of atomic devices help determine whether plutonium detected after the eruption of Mount St. Helens volcano is a natural deposit or a human-made contaminant. Medical researchers use museum specimens of mammals to trace the epidemiology of Lyme disease and pathology collections to study the history of AIDS. Botanical specimens are used to identify plants of commercial importance and make predictions about economic potential, and microbial culture collections are used to assay the purity of drugs. The collected natural science resource also supports an immense array of educational programs, instilling a sense of wonder and an appreciation for nature in millions of people of all ages the world over. Natural history displays continue to be among the most popular exhibits in museums.


Oology (egg) collections languished in many institutions until the discovery that the specimens could serve as a records of environmental change. For example, decreases in some bird populations were linked to progressive thinning of eggshells that resulted from widespread use of DDT. Eggshells are now used in many new efforts to monitor environmental contamination.

Scientific collections are a continuing investment by society in the effort to understand the natural world. They educate new generations of scientists, enlighten the public and stimulate endless queries into the evolution of the solar system and the evolution and diversity of life. In the face of disappearing habitats, species extinctions and the destruction of sites of geological and paleontological significance, the specimens in these collections have become nonrenewable resources.

While the loss of specimens to legitimate research may be acceptable in some instances, the loss of specimens to unsound preparation methods, poor storage or exhibit environments, or routine mishandling is not acceptable. The collections must be protected from this preventable deterioration that impinges on both research utility and preservation. The collection and deposition of specimens in a public trust repository implies a contract, with science and with society, to ensure that they are conserved for use in furthering human understanding of the earth and its neighbors in the solar system. Fulfilling this contract is at once an enormous responsibility and an intriguing challenge. The place to begin is the institutional level, with a strong commitment on the part of governing authorities and management to making the stewardship of natural science collections a central part of institutional responsibility.

Historical Perspective

Although natural history specimens have been collected since the beginning of recorded time, true systematics collections began to evolve only after Linnaeus and others applied classification systems to parts of the natural world. Collections had been cabinets of curiosity, valued for their beauty, rarity and ability to stimulate wonder at the diversity of the earth's biology and geology. In the late 18th century, interest in assembling collections that could be used for scientific research coincided with the discovery that long-lived poisons such as arsenic and mercury could protect biological specimens against the insects and other pests that had destroyed many earlier collections.

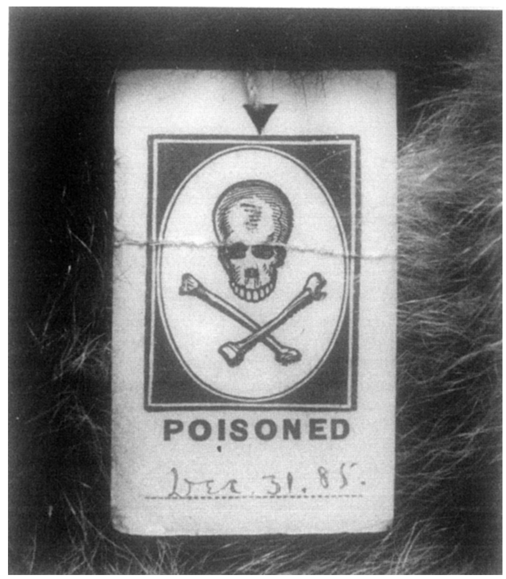
During the 19th century, the growth of systematics collections was a dramatic testimony to the burgeoning interest in science. In less than two centuries, human beings explored the earth and ventured into the solar system. Virtually all of these explorations resulted in additions to the collected resource in the natural sciences, creating large documentary collections to support biological and geological research.

The pace of collecting was matched at first by the pace of research into preparation and preservation methods. Hundreds of publications appeared describing new techniques. Eventually, however, the importance accorded to preservation research diminished, as did resources to support this effort. Thus, while new and sometimes highly sophisticated techniques have been applied to specimen-based research, preparation and storage techniques remain firmly rooted in 19th-century traditions. The same scientific rigor that is now expected in the research based on the specimens is not applied to the preparation of the specimens themselves.

Natural scientists have described preparation methods as being founded on a trial-and-error approach and not on an understanding of the chemical and physical properties of materials or materials interactions. Lunar sample collections and culture collections (microorganisms, cell lines and plant tissues preserved in a viable state), which are relatively recent in origin and rely on modern science and technology, are the primary exceptions. In general, the academic transfer of knowledge relating to specimen preparation has been informal, passed from professor to student in a primarily oral tradition.

Moreover, critical assessments of preservation quality are often lacking, and problematic specimens are sometimes ignored or discarded. There are few efforts to discover why a specimen has deteriorated or why it has been of little use for a particular research inquiry. Indeed, this kind of assessment would in some cases be difficult, because while there may be hundreds of publications describing thousands of preparation methods for the specimens in a single discipline through time, there are few records that link any of those methods to an individual specimen.

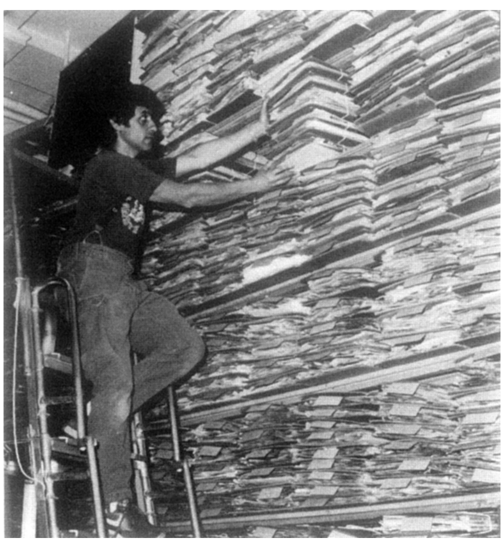
In addition, the early recognition of the efficacy of metal salts in protecting organic materials against pests led to a nearly complete dependence on chemicals. Over the past two centuries, various chemicals have waxed and waned in popularity, so most collections have been treated with several different compounds. Specimens sent on loan may have been treated with still other chemicals by the recipient institution. Because there are few records of the chemicals used on particular specimens, it is extremely difficult to determine the impact of those chemicals on specimen preservation or on the utility of the specimens for scientific research. Conservation research into pest control methods that can be implemented at an institutional level to reduce the reliance on chemical treatments is especially important for natural science collections.



An 1885 tag on a mammal specimen indicates that the specimen was treated with an unspecified toxic chemical, probably an arsenic or a mercury compound. Few natural science specimens are labeled in any way to identify past treatments and this information is not routinely available in other collections documents.

The loss of systematics biology courses in universities also threatens the health of natural science collections and has led to an increase in the number of endangered or orphaned collections in the biological sciences. There has been an even greater loss of support for geology collections at the university level. Private and commercial collections may become endangered or orphaned if the original custodians can no longer maintain them. When offered orphaned or endangered collections, museums are faced with a choice between allowing them to deteriorate from neglect or giving them a more appropriate home. Most choose the latter. The result is an increasing centralization of collections and sometimes an increase in the backlog of unprocessed materials, because orphaned collections rarely come with resources to support curation and care. The annual increases that are an inevitable part of research-related collections growth and the large collections that accompany biodiversity initiatives further contribute to preparation backlogs. The growing emphasis on biological diversity and global change may bring about a renewed appreciation of systematics collections in academic environments, reducing the number of orphaned collections and providing stable repositories for new material.

Many of the historically accepted preparation and other treatment procedures used for natural science specimens are extremely labor intensive. Moreover, specimen-to-staff ratios are massive, ranging from 50,000 specimens per staff member in vertebrate collections to several hundred thousand specimens per staff member in invertebrate collections. Similar ratios prevail throughout the natural sciences. Some research is under way to develop cost-effective preparation techniques that preserve the morphological and chemical/biochemical integrity of specimens. The need for efficient means to process specimens is especially important in an era when the institutional resources available to support collections care are diminishing. Unprepared specimens are not readily accessible for study and, in many instances, steadily deteriorate when in an unprocessed state.



Backlogs of unprepared herbarium specimens are stacked on open shelves in a cold room. The specimens are not easily accessible for research and suffer mechanical damage from overly crowded storage.

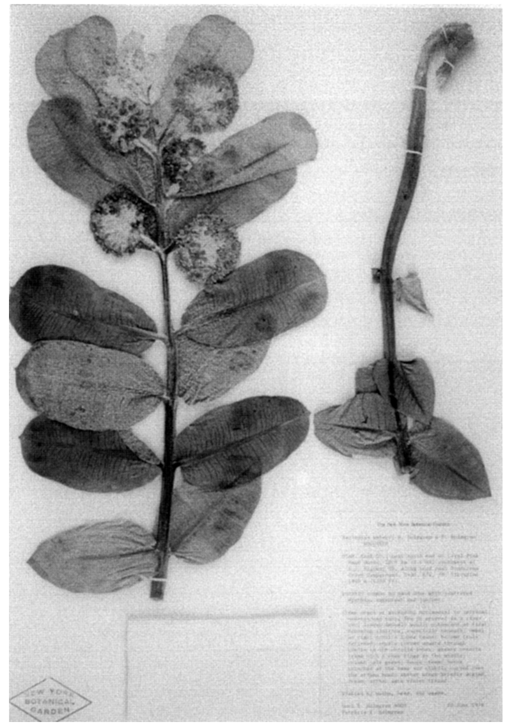
During the past 50 years, many disciplinary journals in the natural sciences have ceased to publish articles on collections care topics. Consequently, when new information became available that was pertinent to the preservation of these collections, it often appeared in museology and conservation journals, where it was rarely seen by the majority of natural scientists. Today, the newsletters of collections-oriented groups within the scientific disciplinary societies and the publications of the new interdisciplinary collections care organizations are important devices for dissemination of knowledge.

Increasingly, preventive conservation is becoming an important aspect of the preservation of collections. Multinational, interdisciplinary collections care organizations such as the Society for the Preservation of Natural History Collections (SPNHC), the International Council of

Museums (ICOM) Conservation Committee Natural History Working Group and the proposed World Council on Collections Resources are part of an effort to share information among all disciplines. Educational programs sponsored by the National Institute for the Conservation of Cultural Property (NIC) and the Bay Foundation, as well as the work of the Association of Systematics Collections (ASC), complement the information provided by these groups. These national and international initiatives share the limited expertise available in natural science conservation and avoid the duplication of effort that results from working in isolation. Initiatives now under way include:

- the U.S. effort to re-create a national biological survey that will result in an influx of voucher specimens to collections and stimulate the development of efficient and effective collections conservation techniques;
- national and international efforts to coordinate systematics programs, such as Systematics Agenda 2000 in North America;
- national and international collecting programs and biological surveys, such as InBio, that link professionals and paraprofessionals to facilitate the exploration and preservation of biodiversity using collections resources;
- status reports on collections developed by the Geological Curators' Group and the Biological Curators' Group in the United Kingdom;
- the Canadian Conservation Institute's conservation research and analytical research services units, which are models for centralized conservation services;
- the effort of the U.S. Department of the Interior Task Force to define specimen repository standards for material collected on federal lands and to address the issue of legal title to these collections;
- efforts by ASC and some disciplinary societies to bring endangered nonmuseum collections into the museum community and to track orphaned collections;
- proposed sorting centers that help expedite the handling of large collections from expeditionary biodiversity activities;
- private and public funding programs that support collections care in the natural sciences; and
- efforts by museum directors to approach preservation as a museum-wide activity.

There has always been a strong interest in collections care in the natural sciences. The disciplinary societies and groups such as ASC have prepared numerous reports addressing general support for collections and collections-based research. The initiatives noted above are witness to this abiding concern, as is the willingness that so many have shown to participate in this project on collections conservation and preservation. While the challenges are as many and diverse as the collections themselves, none is insurmountable, especially with such a high level of interest and support from those who use and manage the collections.



The preparation of this botanical specimen required both skill and an understanding of its potential research uses.

Because knowledge of the kinds of creatures in our world is fundamental to real understanding of their interaction, the great specimen collections are the very cornerstones to studying, comprehending and living within the world system.

—Conference of Directors of Systematic Collections, 1971

Figure 1-1

Users of Natural Science Collections

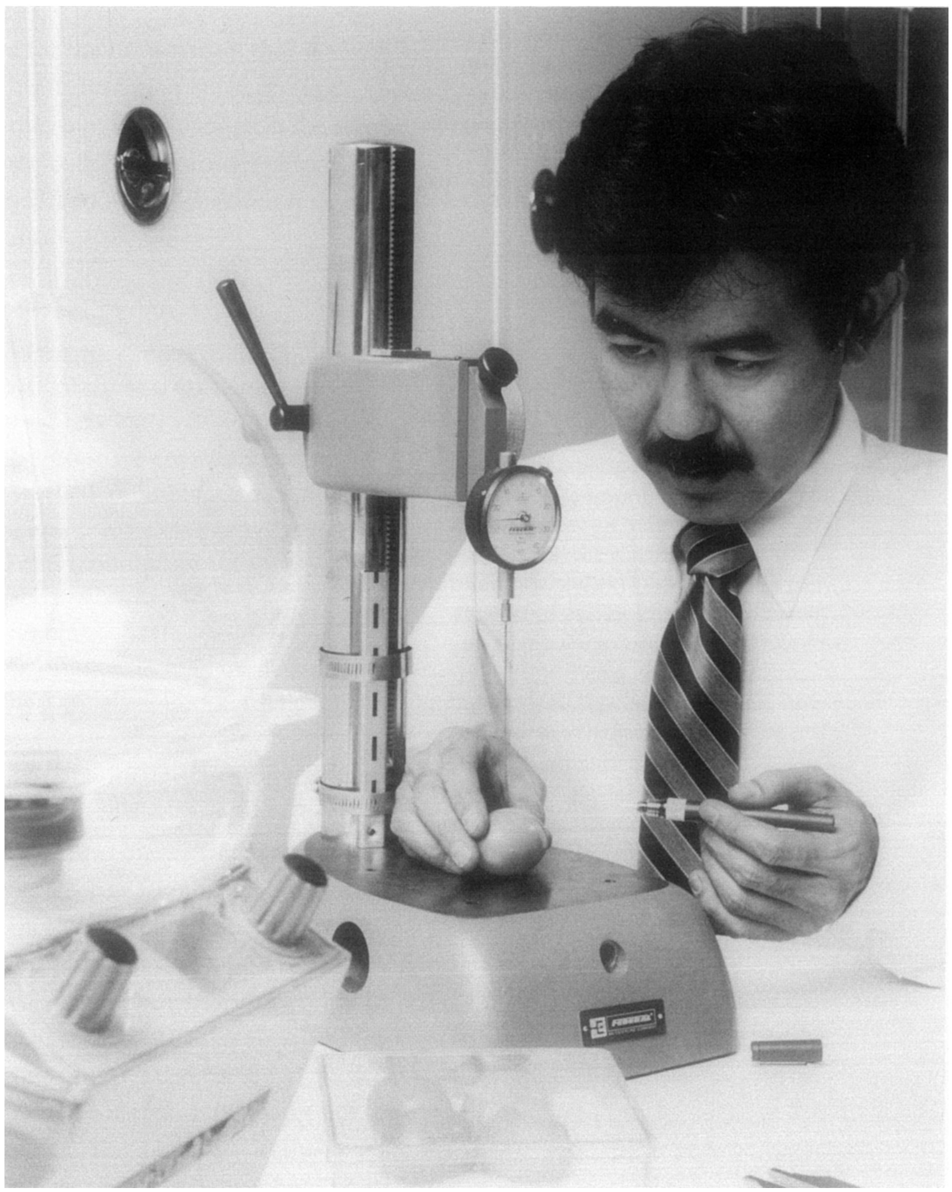
Among the many academic users of natural science collections are:

archaeologists
artists
biogeographers
biomechanics and anatomists
biotechnologists
climatologists
conservation biologists
crystallographers
dendrochronologists
ecologists
epidemiologists
evolutionary biologists
forensic scientists
genome scientists
geo-biochemists
geochemists
geophysicists
germplasm scientists
glaciologists
materials scientists
paleoecologists
paleogeologists
petrologists
planetary geologists
plant pathologists
stratigraphers
taxonomists
toxicologists

The businesses, government agencies and not-for-profit organizations that use natural science collections and the information derived from the collections include:

- agriculture
- aquariums, botanical gardens, nature centers and zoos
- biotechnology firms
- educational institutions (from grade schools through universities)
- environmental conservation groups
- environmental consultants
- federal agencies
  - Agency for International Development
  - Department of Agriculture: Forest Service, Soil Conservation Service
  - Department of Commerce: National Oceanic and Atmospheric Administration
  - Department of Defense
  - Department of Health and Human Services: Centers for Disease Control, National Institutes of Health
  - Department of the Interior: Bureau of Land Management, Fish and Wildlife Service, National Park Service
  - Environmental Protection Agency
- gemstone and lapidary companies
- germplasm companies

industrial consultants
judicial bodies at all levels
land use management groups
legislative bodies at all levels
mining and petroleum geology companies
nature filmmakers
nature study groups and clubs
pest control specialists
pharmaceutical firms
poison control centers
seed and herb companies
state and local governmental agencies



A researcher measures eggshells to look for changes in shell quality that may signal evidence of breeding failures in endangered bird populations.

In the natural sciences, we are dealing with collections that have an entirely different scale from the arts—a different scale in terms of numbers, in terms of years and in terms of information.... It is that scale that quite often has led to the exclusion of collections of this sort from general discussion regarding how we maintain the world patrimony in our institutions.

—Craig Black, 1989

Chapter Two
The Scope and Nature of the Conservation Challenge

Natural science specimens are valued for the information they embody. Preserving them enables access to this information through time. The specimens are meant to be used, and they may be consumed in the course of research. Thus, for natural science collections, conservation is the effort to find a balance between preservation and maximum research utility. Contributing to the conservation challenge are:

- the size and diversity of the collections and their documentation;
- the many unrecorded treatments specimens undergo, limiting our ability to assess the impact of those treatments on preservation or specimen-based research;
- the inadequate space and inappropriate environments in which many collections are housed and used;
- the shortage of human resources for the care of collections and the limited educational and training opportunities in collections care specialties; and
- the lack of scientific research to address the preservation of these collections and the lack of interdisciplinary dialogue between natural scientists and specialists in other fields.

> Several factors have affected the process of collections management in recent years; among them are the establishment of many new kinds of collections, the size increase of traditional collections and the introduction of rapidly changing technologies that have to be mastered. Effective collections managers are therefore highly skilled specialists who are now beginning to acquire the professional status they deserve.
>
> —C. K. Brain, 1990

The NSF Research Collections in Systematics and Ecology Program (formerly the Biological Research Resources Program) has been the primary source of improvements in collections management and care for U.S. biological collections. The program has stimulated institutional commitment to the maintenance of biological collections and provided the resources to help reduce preparation backlogs, computerize collections documentation and purchase storage equipment for many important collections. The program's efforts have brought an essential order to these collections and made them accessible to a diverse array of users. These initiatives have also been emulated in collections that were not the recipients of NSF funding, resulting in a general increase in the overall level of collections curation. The successes of the NSF program constitute an excellent foundation for a conservation initiative in all scientific collections.

Size and Diversity of Collections

The collected resources in the natural sciences have been estimated at 2.5 billion specimens worldwide. In the United States alone, there are hundreds of millions of specimens in various public trust collections. Despite their size, the collections still represent at best a fragmentary record of the natural world. The numbers of species known and described compared with the number believed to exist—10 million to 30 million—has staggering implications for our basic understanding of biological diversity. For instance, although some 220,000 species of flowering plants and ferns are known, an additional 50,000 are believed to exist. Of an estimated 6 million insect species, just 13 percent are described. Multiple specimens are required of a taxon and of related taxa to verify a single identification. Collections continue to grow in an ever more carefully managed fashion, generally at an estimated rate of three to five percent a year. Surveys of the world's biota may add significantly to those percentages. Backlogs, sometimes on the order of millions of unprocessed specimens, already are common in collections and are likely to increase.

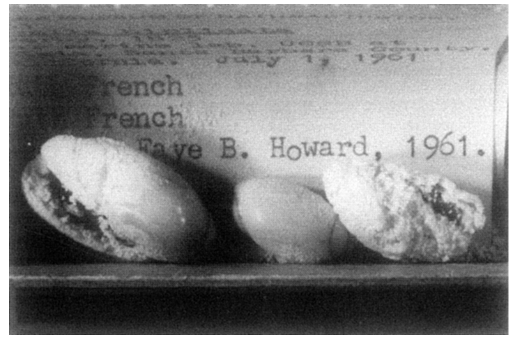
A faulty seal is likely the cause of fluid depletion in this jar of fish specimens. An ingress of oxygen as the fluid evaporates will exacerbate reactions between the specimens and the fluid, the specimens and the container materials, and among the specimens themselves.

Beyond the size of the collections and their obvious potential for growth, another conservation challenge is the immense diversity of material, from frozen tissue extracts to thin sections to complete skeletons of large animals, such as whales and dinosaurs (fig. 2-1, p. 20). Moreover, parts of a single specimen may be preserved in four or five different forms.

The preparation of a specimen is the creation of an artifact. Nearly all natural science specimens are prepared and thus altered in some way before becoming part of a collection. Geological and paleontological specimens are removed from often complex matrices by a variety of physical and chemical means. For biological specimens, significant physical and chemical alteration may be necessary to preserve the organic remains. Each material added to a specimen in the course of preparation increases the complexity of the conservation challenge (fig. 2-2, p. 21). Extensive research is required to determine the least intrusive and most effective preparation techniques.

The diversity of natural science collections encompasses an estimated 250 million specimens preserved in fluids. Fluids are used to fix or denature tissues; to clear, stain, or de-stain specimens or samples; and to serve as a storage medium that will provide, at least in theory, a reasonably stable environment for a specimen or specimen part. Specimens in fluid are found in all natural science collections. In the geosciences, some paleobotanical fossils are stored in glycerin or in silicone oils, and mineralogical specimens that disintegrate when exposed to air are stored in a variety of fluid media. In the biosciences, including the medical sciences, large numbers of whole or partial specimens are fixed or stored in fluids. Fluid fixation and preservation are topics that have not been adequately researched for any group of specimens.

Microscope preparations are part of the collections of every discipline in the natural sciences. Millions of important specimens or specimen parts are prepared for microscopy. The preservation problems associated with these materials are exemplified by the deterioration of Hoyer's mounting medium. The refractive index of Hoyer's is excellent for research on a wide variety of specimens, but because air and moisture can permeate the medium over time, specimens are damaged as it shrinks and cracks. It is not uncommon to find 30,000 to 40,000 slides, many of exceptional historical or scientific value, in jeopardy in a single collection.



These malacology specimens suffer from the formation of water-soluble calcium acetate-formate double salts as replacements for calcium in the shells. The salts result from a reaction between the specimens and acetic and formic acids outgassed by storage materials. The shells have been severely damaged in just 30 years.

The proliferation of new specimen preparations, such as tissues in liquid nitrogen and specimens that are mounted and coated for scanning electron microscopy, has expanded the utility of collections while compounding the difficulties and costs of preservation and management. For example, frozen tissue collections require special storage equipment, emergency power generators and other safeguards to ensure their maintenance. Specialized documentation systems are also necessary to link the tissues to voucher specimens, which may be housed at different institutions.

Specimen and Collections Documentation

In addition to the specimens, natural science collections include specimen and collections documentation considered equal in importance to the specimens themselves (fig. 2-3, p. 25). Indeed, in some disciplines, certain kinds of documentation are considered "specimens." In herpetology, for example, a color image or a sound recording made at the time of capture would be considered part of the specimen.

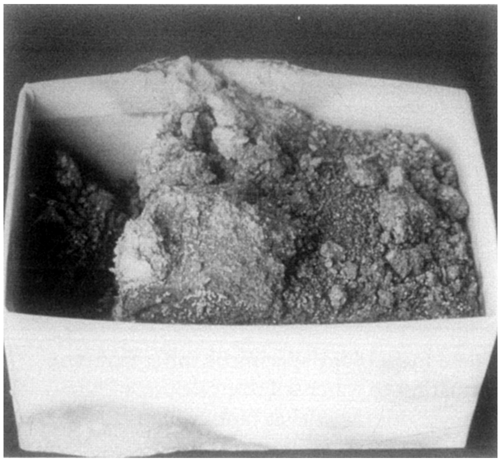
The library and archival materials that accompany scientific collections are a vast and generally unsurveyed resource in terms of condition and care. Technology transfer from conservation disciplines that specialize in these materials is directly applicable in the natural sciences and could be fostered through interdisciplinary seminars and workshops.

Although a sustained and comprehensive effort has been underway in the United States for the past decade to preserve published materials of importance to scholarly research, a similar campaign has not yet been launched to ensure that a significant portion of the archival record will also be accessible for use in the future.

—Commission on Preservation and Access, Task Forces on Archival Selection, 1993

Immense amounts of data concerning natural science specimens are now consigned to electronic or magnetic media, despite the nonarchival nature of this information base and the rapidity with which machine obsolescence can impinge on its utility. The preservation of electronic or magnetic storage media is not as well understood as the preservation of film- or paper-based library and archival materials. However, there are ongoing research and preservation initiatives dealing with these media; this is another area in which the rapid transfer of conservation information is important to scientific collections.

The materials used to label specimens have the potential to damage the specimens or to be damaged themselves by the specimens or by the collections environment. Labeling materials for fluid-preserved specimens are especially problematic. New methods of label production, such as printing, photocopying and bar code technologies, are used in natural science collections with varying degrees of success. Materials for specimen labeling is another area where knowledge from other fields is pertinent and could prevent future conservation problems.



Twenty years ago this was a solid mineral specimen. Repeated cycles of desiccation and hydration in an unregulated storage environment have reduced it to powder.

An especially important challenge to the future preservation and research integrity of natural science collections is finding efficient methods to document the treatment of specimens that may be processed in large groups and catalogued in lots. The widespread use of computers in collections management provides a means to facilitate the accumulation of this information. However, the precise nature of the necessary data and the standardized terminology that would ensure that the data are succinct and meaningful have not yet been determined.

Collections Environments

Designing appropriate collections environments and developing appropriate policies and procedures to reduce rates of deterioration and potential for damage constitute a preventive conservation approach to collections care. Many agents of deterioration—including physical forces, inappropriate temperature, inappropriate or fluctuating relative humidity levels, ultraviolet radiation and excessive visible light, pollutants or contaminants, biodeterioration, vandalism and unintentional losses brought about by breaches of procedure—contribute to the ongoing deterioration and subsequent loss of value in scientific collections.

While the mechanisms for deterioration of specimens and their documentation may be as diverse as the materials themselves, the basic causes are chemical, physical and biological. Damage from organic acid attack is an example of chemically induced deterioration. Mechanical damage from abrasion, shock, vibration or the effects of gravity on inadequately supported specimens are examples of the deterioration by physical forces. Ineffective storage designs permit physical forces to do tremendous harm in natural science collections. Biological agents of deterioration, such as microorganisms and insect pests, can threaten all collections, including those in geology and paleontology. The role of microorganisms in specimen decay merits further exploration, while the role of insects in the destruction of collections and their documentation is well understood.

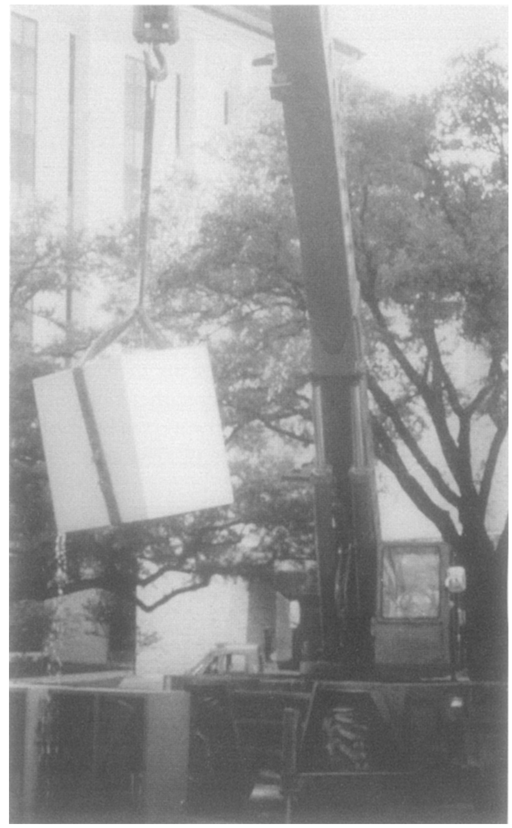
Preventive conservation is possible only because scientific research has given us a better understanding of some of the mechanisms of deterioration. Although that body of knowledge continues to grow rapidly in detail, the fundamental principles are well established. Deterioration is *not* inevitable and "aging" is only a multiplier of known and generally controllable causes.

—Philip Ward, 1986

The lack of climate control in most natural science collections can result in direct damage and provides a milieu that is conducive to deterioration of materials. Inappropriately low levels of relative humidity desiccate hygroscopic specimens and either directly cause deformation or breakage, or increase the vulnerability of the specimens to shock and vibration. On the other hand, high humidity levels promote biodeterioration and chemical reactions, such as the oxidation of iron sulfides in geoscience specimens. Dust and soot attract and hold gaseous pollutants on specimens, thereby serving as loci for chemical reactions, including the conversion of atmospheric sulfur dioxide to sulfurous and sulfuric acids.

Ultraviolet radiation and prolonged exposure to visible light rupture chemical bonds in organic materials and initiate light-induced phase transitions in some mineral species.

Chemical pollutants, especially those released by reactive materials inside closed cases, can cause damage to many specimens. Volatile organic acids released by wood and wood products attack paper labels, metals used as labels or specimen supports, and calcareous specimens, such as shell, eggshell and some invertebrate fossils. Fumigant chemicals can generate acidic by-products that attack acid-sensitive materials and, in addition, may generate compounds that increase the oxidative degradation of inorganic and organic materials. The most common container for fluid-preserved specimens is commercial-grade, bimetallic alkaline glassware that leaches its chemical constituents into the fluids and can become dangerously brittle as it ages. Container seals may react with the specimens or the fluids, and poorly sealed containers permit evaporation or hydration of storage fluids, altering the environment of the specimens. A recent survey by the staff at the Canadian Museum of Nature revealed that materials and staff time to add or replace fluids because of poorly sealed containers cost the institution in excess of $100,000 per year.

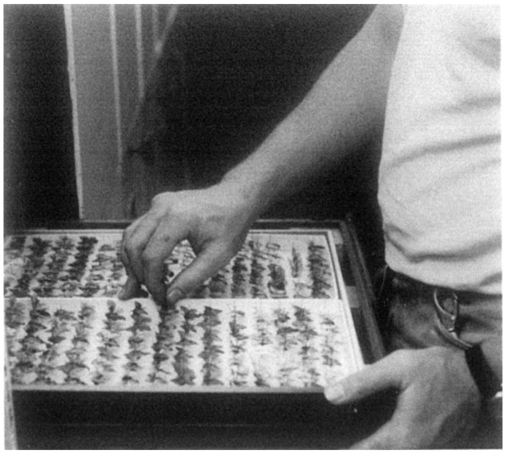


A crane removes a specimen storage cabinet from a building that flooded when a water main burst, immersing the collections in several feet of hot water. Many natural science institutions lack plans to deal with the salvage of collections in an emergency or disaster.

The preparation, storage and use of natural science collections present unique human health and safety problems. Some specimens are inherently toxic. In geology and paleontology, specimens may be radioactive or contain toxic minerals that pose a threat during preparation and handling. In the biological sciences, specimens may be contaminated with pathogens that are a hazard during preparation; preparation itself may involve toxic chemicals such as solvents, fixatives and pesticides. Past unrecorded treatments can complicate the design of storage systems and even of remedial treatments of specimens. For example, the mercury salts still used on some botanical specimens can generate hazardous levels of mercury vapor inside well-sealed storage cabinets and can blacken and embrittle specimens if exposed to oxidizing and reducing agents.

While most institutions have emergency preparedness plans that address personnel safety, few have extended those plans to include the protection or salvage of collections. As a consequence, a relatively minor emergency could become a disaster. The increasing centralization of collections means that a disaster could obliterate centuries of effort in a particular discipline.

Space to house natural science collections is often both inadequate and inappropriate. Lack of appropriate space has led to the storage of specimens in hallways, attics, basements, offices, laboratories and various off-site structures. Many facilities lack fire protection or reasonable security systems. Years, sometimes decades, of deferred maintenance have left a legacy of aging buildings that are prone to roof and plumbing leaks and plagued by inadequate electrical systems. Inefficient ventilation systems permit particulate pollutants to accumulate in collections areas. Local exhaust ventilation systems, whether for dusts and fumes in geology laboratories or for vapors and biohazards in biological laboratories, are sometimes poorly designed and sometimes nonexistent.



Entomology collections contain many thousands of specimens. Despite their size, these collections represent a small percentage of the insects believed to exist. A series of specimens of the same taxon, as well as comparative series of other taxa, are necessary for systematics research.

Staffing, Education and Training

Lack of collections staff at all levels is a common problem in most natural science institutions. To improve collections care, both the adequacy of staffing and the level of staff education and training in collections care need to be addressed.

The attrition of university faculty results in the loss of courses and, very likely, the loss of department collections. This pattern of loss increasingly threatens the future of systematics and other specimen-based science. It also reduces the potential for training a pool of future research and collection staff. Collections that lack active management suffer because they become inaccessible for use, thus losing their constituencies and the potential to attract resources for their care.

Developing the human resources necessary for good collections care will require improving the in-service training available to working professionals and the pre-service education available to those who wish to become collections-based research scientists or collections managers. More conservators and conservation scientists who focus on research for natural science collections must be trained; interdisciplinary professional exchanges must be fostered to facilitate the transfer of conservation information from other fields; and collections staff must have access to preventive conservation information. The staff of natural science collections need to be part of the growing collections care networks that circulate information across disciplines. Such expanded involvement will improve staff access to the array of information resources that are the basis for technology transfer and help them compete effectively for collections care grants.

Gaps in our training system will be filled because they must be filled. It is simply no longer possible to ignore the conservation needs of museums of natural sciences.... Neither is it acceptable to have curators who have no knowledge of the physical needs of their collections nor conservators with no understanding of curatorial priorities.

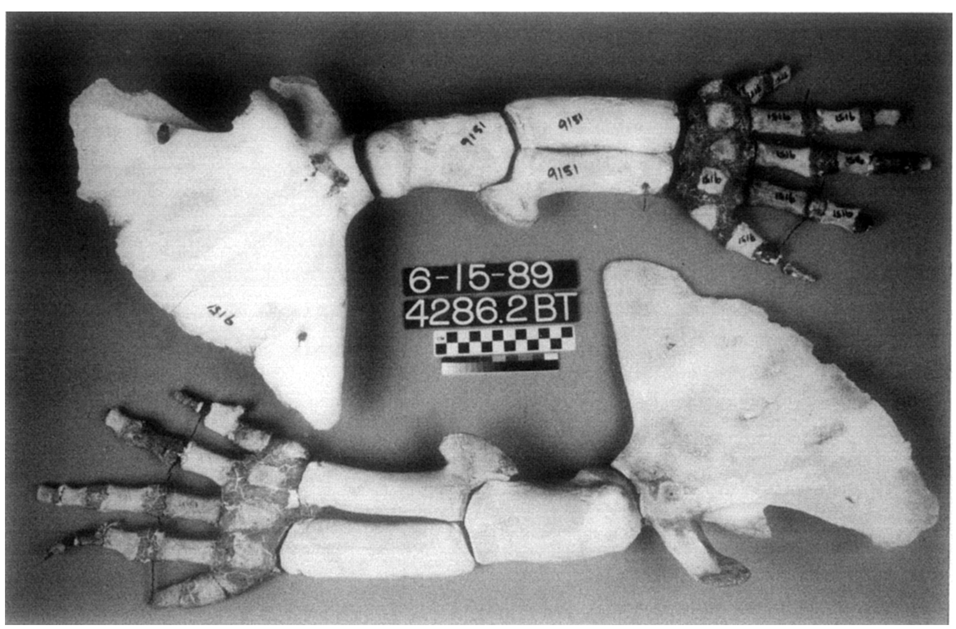
—Philip Ward, 1986

The problems that accompany inadequate staffing and lack of training are compounded by poor communication among staff in different departments within a single institution. It is not uncommon to find that staff in one discipline have spent a great deal of effort to solve a labeling problem or find an appropriate specimen container, only to learn that the same solutions have been in use for years in another division of the same institution. Many aspects of collections care are not enhanced by the constraints on information flow across traditional, discipline-based organizational structures.

In large museums, curators are expected to function as research scientists, and their performance is evaluated primarily on activities that do not involve collections maintenance and management, although oversight of these activities may be part of their general responsibilities. In university departmental collections, research scientists are often the sole professional staff. They must not only teach and carry out research but manage and care for the collections as well. The graduate curriculum for research scientists in collections-based disciplines usually does not include an introduction to research administration, basic preventive conservation or collections management.

In most institutions, there is an acute shortage of technical and collections management positions and trained personnel. There is a need for collections managers who have a sound knowledge of the scientific discipline in which they work, formal training in collections management techniques and an understanding of preventive conservation. The movement to recognize collections management as a profession is a significant step in improving the care of scientific collections.

The staff of natural science collections rarely have access to conservation services. There are only three trained natural science conservators in the United States and three in Canada. In order to develop a cadre of conservators for the natural sciences, specialty graduate programs will be necessary. The conservators on the staff of natural history museums are usually part of the anthropology staff. These conservation specialists could offer valuable assistance to natural science staff if both parties were aware of the potential and if the conservators were made aware of the concerns that research scientists and collections managers have about their collections.

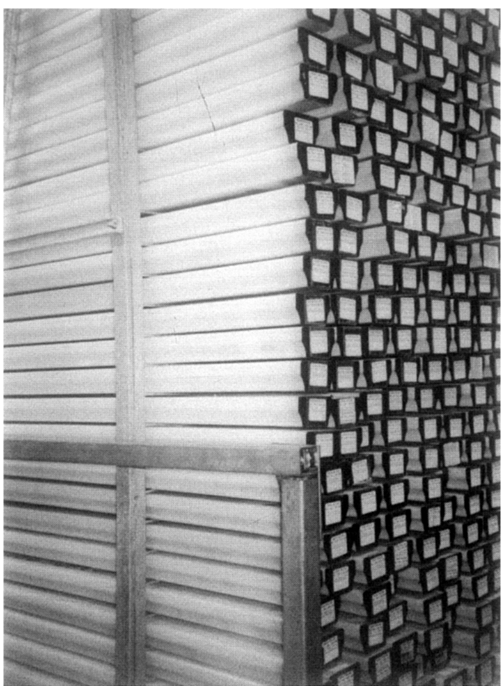


Bones of beaked whales are rarely found in collections. Consolidation was used to improve the strength of these fragile specimens.

Figure 2-1

Examples of Specimens in Natural Science Collections

- baculi/phalli
- blood components
- casts/molds/peels
- cell suspensions
- cleared and stained specimens
- cloned probes
- dissected organs and other dissected tissues
- DNA/RNA (including sequence gels)
- dried/tanned skins
- dry shells or echinoderms
- educational collections
- eggs and nests
- embryos/larvae
- endo- and ectoparasites
- exhibit collections
- exsiccati
- fossils
- freeze-dried specimens
- frozen tissues
- frozen tissue extracts
- frozen whole specimens
- genomes (plasmid, phage)
- herbaria sheets
- horns/antlers
- inherently toxic specimens
- isolated proteins
- karyotypes
- large specimens (e.g., blue whale skull; large fossils in plaster field jackets; complete dioramas with historical, artistic and scientific value)
- micromounts
- mummified specimens
- non-Recent, sub-fossil material
- paraffin blocks
- pinned specimens
- polished sections
- powder diffraction mounts
- radioactive specimens
- reference sample collections (hair, feathers)
- scats
- sectioned teeth
- seeds
- shell ultrastructures
- single crystal mounts
- skulls and skeletons
- specimens in fluid (geological, biological)
- specimens in packets
- specimens or specimen parts on scanning electron microscope stubs
- specimens or specimen parts on microscope slides
- stomach contents
- taxidermy specimens
- thin sections
- tree rings and wood samples
- type specimens
- zymograms

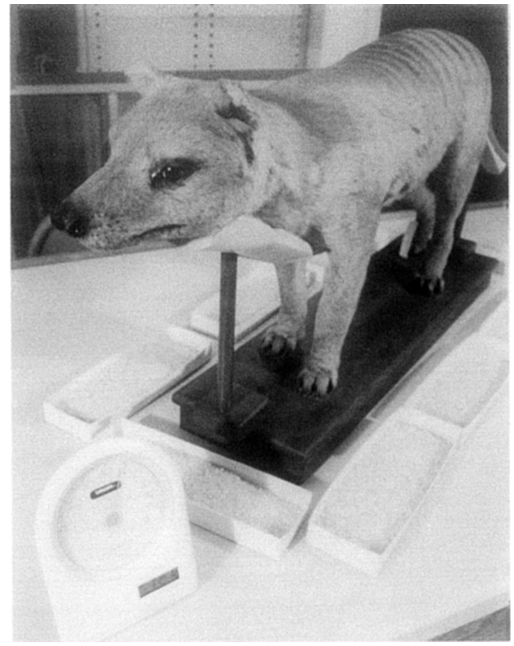


These geological survey drill cores are stored in individual containers. Drill core collections may include tens or hundreds of thousands of specimens, each several feet long. The cores vary in weight, ranging from very light, loosely compacted sediments to dense rock.

Figure 2-2

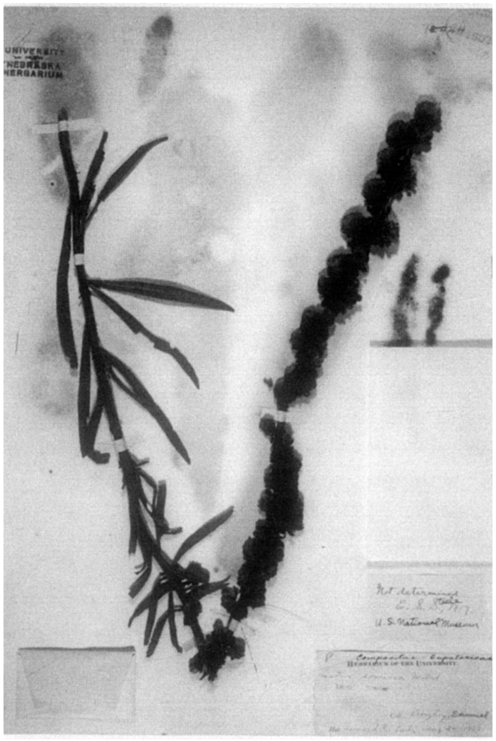
Examples of Materials Used in the Preparation and Care of Natural Science Specimens

abrasives (aluminum oxide, glass beads, powdered walnut shells)
acrolein (acrylic aldehyde)
acrylic polymers (dispersions, emulsions, molded products, paints, resins)
acrylonitrile-butadiene-styrene polymers
agar (polysaccharide extract from algae)
albumin (purified protein from egg white)
alcohols (butanol, ethanol, glycerol, isopropanol, methanol)
aluminum acetate
alums (ammonium aluminum and/or potassium aluminum sulfate, ammonium ferric sulfate)
ammonium hydroxide
amyl acetate
argon
arsenic compounds (trioxide, sulfide)
asbestos fibers and fabrics
barium compounds (chloride, hydroxide, sulfate)
butylated hydroxyanisole
butylated hydroxytoluene
calcium compounds (carbonate, chloride, hydroxide, sulfate)
carbamate insecticides (bendiocarb, propoxur)
carbon
carbon dioxide
carbon disulfide
cellulose acetate and triacetate films
cellulose ethers (ethyl cellulose, ethyl hydroxycellulose, methyl cellulose)
cellulose nitrate (adhesives, fillers, films)
cellulosic fibers and fabrics
ceramics
chloral hydrate
chloretone
chlorocresol
chloropicrin (trichloronitromethane)
chromotrope (sodium salt of p-nitrobenzeneazochromotropic acid)
copper sulfate
cork (natural, composite)
cornmeal and ground corn cobs
creosote
cyanoacrylates
dextrose
diatomaceous earth
diethyl ether
dioxane (1,4-dioxacyclohexane)



A fragile specimen of the Tasmanian wolf, a marsupial species believed to have become extinct in the 1930s, is stored with special supports in a case designed to provide a microclimate to ensure preservation. Microclimates can be effective approaches to special environmental requirements.

DMSO (dimethyl sulfoxide)
dolomite (calcium magnesium carbonate)
dyes and stains (natural, synthetic)
enzymes (amylase, papain, pepsin, trypsin)
epoxy resins
ethyl acetate
ethylene and polyethylene glycols
ethylene oxide
ethylene vinylacetate polymers
formaldehyde and paraformaldehyde (polymerized formaldehyde)
gelatin
glass fibers and fabrics
glassware (bimetallic alkaline, borosilicate)
glues (casein, fish, hide)
glutaraldehyde
glycerol monoacetate
gypsum cement (portland cement with raw gypsum)
hair products (commercial conditioners, dyes, setting lotions, sprays)
halogenated hydrocarbons (bromoform, carbon tetrachloride, chloroform, ethylene dichloride, methyl bromide, methylene chloride, perchloroethylene, trichloroethane, trichloroethylene, trichlorofluoroethane)
hexamethyleneamine
hydrocarbon solvents (benzene, cyclohexane, gasoline, heptanes, hexanes, kerosene, mineral spirits, naphtha, toluene, xylene)
hydrogen cyanide
hydrogen peroxide
inks (ballpoint, drafting, drawing, felt-tip, printing, roller-ball, stamp pad, typewriter, toner)
iodine
isinglass
kaolin (hydrated aluminum silicate)
ketone solvents (acetone, methyl ethyl ketone)
latexes (moulding compounds, paints)
lead chromate
magnesium compounds (carbonate, chloride, silicate)
mercuric chloride
metals (aluminum, copper and copper alloys, gold, iron and iron alloys, lead, mercury, tin, zinc)
mineral acids (boric, chromic, hydrochloric, hydrofluoric, nitric, osmic, phosphotungstic, picric, sulfuric, thyoglycolic)
monoterpenes (camphor, eucalyptol, thymol, turpentine)
morpholine
mosses (including peat)
mothproofing agents (textile industry treatments)
naphthalene
natural gums (acacia, arabic, tragacanth)



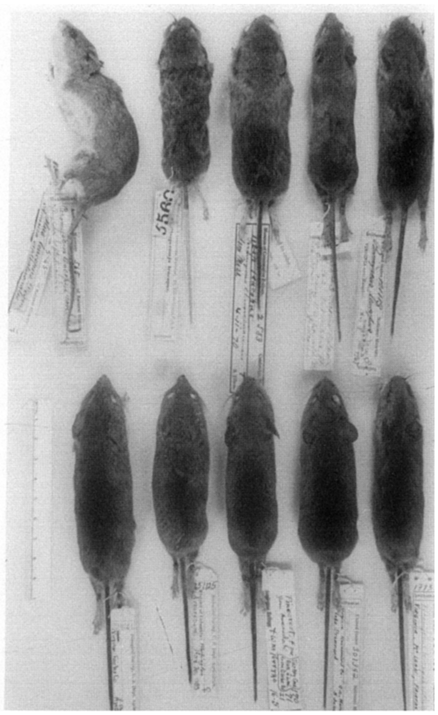
This herbarium specimen shows staining from mercury salts. Past treatments of specimens with toxic chemicals jeopardize the preservation and research integrity of the specimens and can pose health and safety problems for collections staff and users.

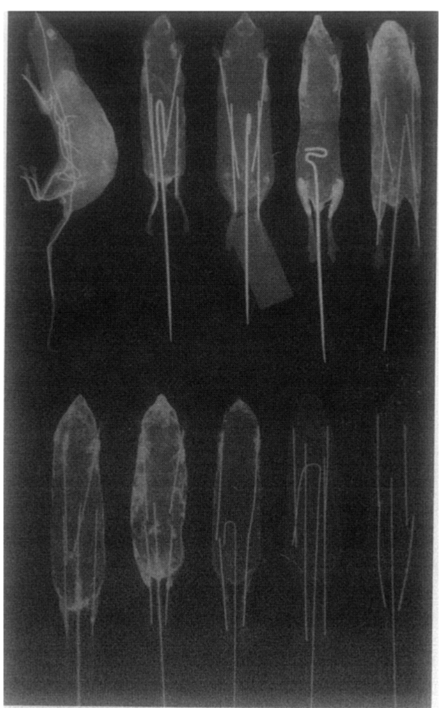
natural resins (Canada balsam, dammar, mastic, rosin, sandarac, shellac)
n-butyl acetate
nitrogen (gas, liquid)
oil-based paints (enamels and other alkyd resin coatings, artists' oils)
organic acids (acetic, carbolic, citric, ethylenediaminetetraacetic, formic, glacial acetic, lactic, oxalic, pyroligneous, salicylic, tannic, tartaric, trichloroacetic)
organochlorine insecticides (chlordane, DDT, lindane, heptachlor, paradichlorobenzene)
organophosphate insecticides (chlorpyrifos, dichlorvos, malathion)
paper (cellulose fiber, wood pulp, synthetic)
papier-mâché
pasteboards (bristol board, cardboard, chipboard)
pastes (rice starch, wheat starch)
pencil (colored, graphite, pastel, wax)
petroleum jelly
phenol-formaldehyde resin (Bakelite)
phenolic microballoons
pheromones
phosphine
pigments (mineral, organic)
plant alkaloids (nicotine, strychnine)
plant oils (cedarwood, linseed, olive)
polyamides (including soluble nylon)
polycarbonates (molded products, resins)
polydimethylsiloxane
polyester fibers and fabrics (batting, felt, thread)
polyester resins
polyester/polytetrafluoroethylene non-woven laminate
polyethylenes (films, foams, molded products, resins)
polyporus (fungus)
polypropylenes (films, molded products)
polystyrenes (foams, molded products, resins)
polysulfides
polytetrafluorethylenes
polyurethanes (coatings, foams)
polyvinyl acetates (emulsions, resins)
polyvinyl acetate/polyvinylchloride copolymers
polyvinyl resins (acetals, alcohols, butyrals)
polyvinylchlorides (films, molded products, resins)
polyvinylpyrrolidone
potassium compounds (acetate, carbonate, chloride, cyanide, dichromate, hydroxide, iodide, nitrate, nitrite, phosphate)
potato flour (freeze-dried)
powder paints
precipitated or fumed silica
pressure-sensitive adhesive tapes
propylene phenoxytol

The oral tradition emerged because the collector was the researcher in most instances, and the techniques and preferences that evolved were passed from teacher to student.... Because of this history, very few curators can at random select a specific specimen and say, "I know exactly how this specimen was treated from the time it was collected until today...." We cannot recapture such information, but we can begin recording it. Now.

—Mary H. Pritchard, 1992

putty (various formulations)
pyrethrins (natural, synthetic)
pyridine
rubber (natural, synthetic)
sal ammoniac (ammonium chloride)
sand
seaweed
silane (tetraethoyxsilane)
silica gel
silicones (elastomers, foams, oils, resins)
silk thread and fabrics
skin or gut (goldbeaters skin, leathers, parchment, pig and sheep bladders, vellum)
sodium compounds (acetate, alginate, arsenate, bicarbonate, borate or tetraborate, bromide, carbonate, chloride, cyanide, dithionate, hydroxide, hypochlorite, metasilicate, metasulfate, perborate, phosphates, silicofluoride, thiosulphate)
spices
stearin (glycerol tristearate)
strontium chloride
suet
sulfuryl fluoride
surfactants (detergents, soaps, wetting agents)
tetramethylthiuram disulfide
water
waxes (beeswax, Carnauba, paraffin, microcystalline)
wood products (excelsior, masonite, plywoods, sawdust)
woods (hardwoods and softwoods)
wool fibers and fabrics
zinc compounds (oxide, sulfate)





Above, these deer mice were prepared at various dates from the early 1800s to the 1970s (top left to bottom right). Except for the first specimen, which was prepared as a taxidermy mount, the preparation technique appears to be the same. Below, an X-radiograph of the same specimens shows variations on the standard preparation method, including the placement of support wires, location of bones remaining in the skins, and distribution of metal salts used in preparation.

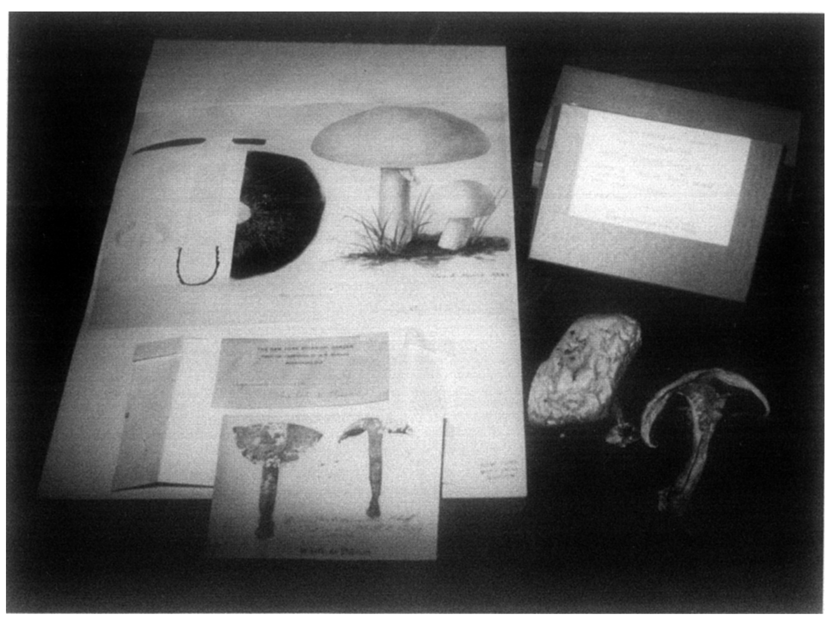
Figure 2-3

Forms of Documentation in Natural Science Collections

accession records and permit files
annotated maps
card files on various topics
cassette tapes
color slides
compact discs
computer printouts
computer tapes/disks
correspondence
files of detached specimen labels
historical artifacts and other memorabilia (early microscopes, collecting equipment, personal items from prominent collectors)
library resources (often including rare books and journals)
loan files
manuscript field notes and other manuscript research records
motion picture film
original catalogues
original sketches, watercolors and other artwork
phonographic records
photographic negatives and prints
plates or prints
radiographs
reel-to-reel tapes
reprint files
sampling/dissection records
specimen labels
videotapes

Because of the rapid proliferation of new [electronic] technologies for the capture and retrieval of information, the permanent retention of information residing in...inherently unstable formats will require archival intervention in decisions regarding the very creation of those records.

—Commission on Preservation and Access, Task Forces on Archival Selection, 1993



Documentation is a significant part of the value of this mycology specimen or any other research specimen.

To be credible and to elicit a positive, fruitful response from supporters of museums, expressions of financial need must not be crisis-oriented. They must come instead as part of a larger assertion that museums are essential national resources which not only merit but require a system of financial support in which all sectors of society participate.

—American Association of Museums,
Commission on Museums for a New Century, 1984

Chapter Three
Meeting the Challenge: Recommendations and Strategies

Stewardship of Collections

The foundation for meeting the multiple challenges posed by the conservation and preservation of natural science collections is responsible stewardship. Membership in an institution's governing authority carries with it an ethical obligation—and, increasingly, a legal obligation—for the prudent management and oversight of the institution's collections. Staff members, particularly top management, are partners in this obligation. With the leadership of board members and key staff, collections preservation and conservation can be valued throughout an institution as priorities central to the institution's mission.

> The crisis we are confronting is not just a crisis of funding. It is a crisis of consciousness. It is a crisis in understanding the purpose of our institutions and the meaning of the collections which have been entrusted to us... We must address the needs of these collections, not only for society today but, more important, for societies tomorrow.
>
> —Paul N. Perrot, 1987

Sound governance and management place the overall interests of the institution before those of any single organizational component. To ensure that all needs are met, plans must be made to address them in a strategic manner. When mission is the starting point for an institutional plan, the institution-wide approach to collections preservation and conservation is emphasized, and research and collections needs are integrated with educational programming and exhibition goals. The formulation of an institutional plan is an exercise in self-analysis that helps the institution define itself, its service to society, its strengths and weaknesses, its base of support and its funding and resource allocation strategies.

Responsible stewardship includes the duty to limit the size of collections. No institution can afford unrestrained collections growth. Specimens that cannot be cared for properly become liabilities rather than assets. No institution can responsibly allow or encourage growth that is not supported with adequate resources for collections care. Collections management policies, for the institution and for individual collections, provide mechanisms to define the appropriate scope of each collection, formulate acceptable approaches to accessioning and deaccessioning, and manage the use and care of collections. Such policies ensure that the growth of any collection is consistent with the mission and resources of the institution as a whole. They also assign responsibility and authority for policy implementation to appropriate staff.

Many conservation concerns can be addressed only on an institution-wide basis or are cost-effective only when coordinated throughout an institution. For this reason, it is important to adopt a phased plan and identify priorities among the concerns. A long-range conservation plan enables an institution to integrate collections care into an overall strategic plan. The Institute of Museum Services (IMS) has provided conservation assessment and planning grants to numerous natural science museums through its Conservation Project Support (CP) program and through the NIC-administered Conservation Assessment Program (CAP). Conservation Project Support grants have also helped many of these museums to implement various phases of their plans.

Storage designs based on preventive conservation principles promote specimen preservation and facilitate access to collections.

Recommendations:

Collecting institutions must make collections care a priority in their mission statements, management policies and resource allocations. This commitment should be commensurate with the inherent value of the information the collections contain.

Strategies

- Document at the highest organizational level the fiduciary obligations and liabilities inherent in the ownership of collections.
- Develop appropriate mission statements, policies, administrative frameworks and staffing to ensure that collections housed in university departments and other nonmuseum agencies are cared for according to professional museum standards.
- Keep collections growth compatible with the research goals of the institution and with the resources available for collections care to ensure present and future research utility.
- Require that collections care resources be part of any research proposal that will result in collections growth.
- Prepare cost estimates of what can be accomplished in collections care given a specific allocation of resources.
- Seek new resources by applying for private and public funding for preventive care, or reallocate existing resources to meet collections care needs.
- Computerize collections catalogues to facilitate management and use of collections.

Collecting institutions must develop strategic plans for improved collections care.

Strategies

- Conduct a thorough self-assessment of collections care policies and procedures, with emphasis on the adequacy of physical security, documentation and accessibility.

- Undertake conservation assessment and long-range planning projects, including periodic updates.

Individuals whose research results in collections must ensure the long-term preservation of collections by planning for their ongoing care.

Strategies

- Prepare a memorandum of understanding with a suitable repository prior to undertaking any research project that will result in collections.
- Include collections care resources in any research proposal that will result in collections.

Funding agencies must support collections care initiatives in natural science institutions.

Strategies

- Publicize to the natural science community the current sources of funding for improved collections care.
- Require that collections care resources be part of any research funding proposal that will result in collections growth.
- Require and support conservation assessments and long-range planning projects, including periodic updates.

Collections care and conservation organizations must support institutional collections care initiatives.

Strategies

- Provide staff and governing boards with information on the fiduciary nature of the responsibility for public trust collections.
- Prepare cost-benefit ratios to demonstrate that good collections care can be cost-effective if priorities are developed institution-wide rather than on the basis of individual collections.
- Publicize the current sources of funding for collections care, including regional and local sources.
- Develop, through collections organizations such as ASC and SPNHC, guidelines to help natural science collecting institutions prepare institutional plans, collections policies, memoranda of understanding and other documents relating to collections care and use.

Public Awareness of Collections and Conservation

The effort to cultivate increased support for collections-based research and collections conservation must include a broad-based attempt to improve public understanding of the importance of natural science collections and the relationship of collections conservation efforts to our ability to manage, preserve and interpret our natural heritage. Heightened awareness of the meaning and significance of materials conservation

Among our greatest threats are ourselves, and our persistence in the old ways: our wish to demonstrate our value by talking in highly technical language and our failure to really work to strengthen our image in the community.

—Des Griffin, 1993

is needed not only among those who work professionally with natural science collections but also among those who benefit in some way from the scientific, historical or esthetic value of these collections.

The significance of collections and the value of the information they contain go largely unnoticed outside the natural science professions. There is little recognition that collections are critical information resources that allow us to understand global change, evolution or biodiversity, although that recognition is growing. Specimen conservation, too, remains a largely hidden activity. The behind-the-scenes components of museums and other collecting institutions are rarely seen by or effectively explained to the public. Exhibits and educational programs in natural history museums are often based on research conducted in the collections, but they rarely explore this work or the effort required to create and maintain the collections. The problems are worse for university departmental collections because they are rarely seen by the public at all and are seldom central to the mission of the institution responsible for their care.

> Museums exist by virtue of their collections. In fact, a collection is the hallmark of a museum—the criterion distinguishing it from any other scientific, cultural or educational institution. Deprive a museum of its collections and that museum will cease to exist; allow the standard of collection care to decline and the status of the whole museum sinks with it.
>
> —C. K. Brain, 1990

Natural scientists need to bring their activities into public view. Public awareness efforts must be recognized as a legitimate and essential part of the work of these professionals. Convincing the public that collections are vital to environmental conservation, global change and biotechnology for agriculture and medicine will broaden the base of support for the collections and the institutions that house them.

The primary audiences for conservation awareness efforts include:

- decision makers in the private and public sectors, who as board members or chief executives control the policies and priorities of collecting institutions, businesses, foundations and government entities;
- environmental conservation organizations, which represent a different but complementary part of the conservation spectrum and make wide use of information derived from natural science collections;
- scientific disciplinary organizations, whose members should be informed proponents of collections care; and
- the general public, whose understanding, interest and commitment are essential to secure and sustain support of collections conservation.

Public awareness efforts can take a variety of forms: videos promoting conservation topics to be shown in schools and museums; special television series; exhibits in museums, schools and less traditional venues; newspaper and magazine articles; and special publications. But in addition to advertising and public relations, new ways must be found to create a public awareness effort that has lasting impact. Programs such as that recently established by the NSF to introduce high school and undergraduate college students to research collections are an excellent means of instilling a lifelong interest in science and fostering an understanding of collections.

A successful campaign must be supported by some fundamental information, including:

- data on the use of collections-based information by government, public interest and environmental conservation groups and by the private sector;
- descriptions of what the loss of a collection means to a region, particularly in regard to education; and
- cost projections for collections care, including estimates of what can be accomplished given a specific allocation of resources.

It is also time for systematic biologists, who traditionally go about their work quietly and unobtrusively, to invite others to their "secret garden" and explain clearly to us, their guests, what it is they offer that we need.

—Lord Dainton, 1993

Recommendations:

On the local or regional level, collecting institutions should create programs to enhance public awareness of the significance of their collections and the shared responsibilities of stewardship.

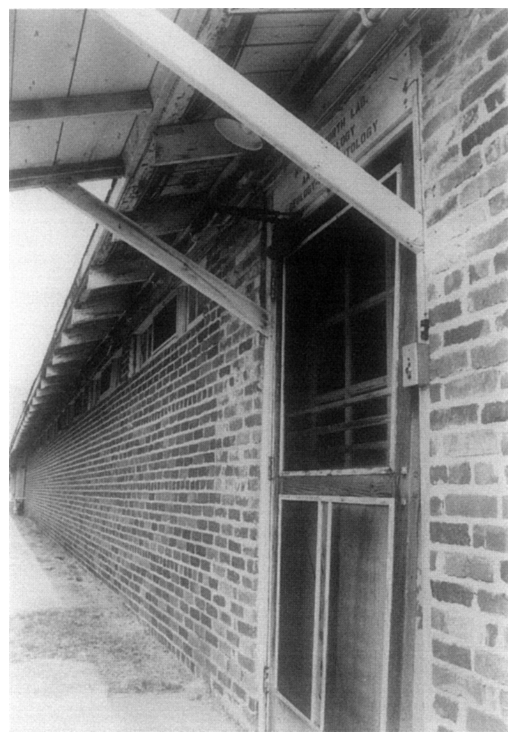
Strategies

- Create expanded science education initiatives that introduce high school students to specimen-based research.
- Offer behind-the-scenes tours or programs for policy makers, and present exhibits for the general museum audience that focus on the value of collections.
- Use television and other local media to publicize the value and use of collections.
- Develop cost projections for collections care, including estimates of what can be accomplished with a specific allocation of resources and the costs to society if collections are lost.

On the national level, public awareness initiatives must be developed to highlight the value of collections to society and the need for collections conservation.

Strategies

- Promote alliances among the diverse groups that create, maintain, use, fund and benefit from collections.
- Document the use of collections by government, business and nonprofit organizations.
- Develop publications, videos and television presentations on the value of collections, aimed at a variety of audiences.



For many years this building housed geology and paleontology collections. After a major public awareness initiative, two bond issues were passed that will contribute $20 million toward the construction of a new complex to house these and other collections.

Staffing, Education and Training

All professionals who work with natural science collections—whether in administration, research, collections management, exhibitions or educational programming—need access to basic, substantive, up-to-date education and training in collections care in order to carry out their responsibilities effectively. Improvements are needed in three areas:

- the level of knowledge among those now caring for and using natural science collections;
- the professional qualifications and status of collections managers; and
- the number of trained natural science conservators in North America.

Many natural science specimens are preserved in fluids; a typical collection uses a variety of jars and tanks for storage.

Education and training initiatives that would address these needs include formal in-service education, informal professional exchanges and pre-service education.

In-Service Education

Although there are some graduate programs in the management of natural science collections, most collections management staff do not have formal training in this field. Knowledge of collections management and care generally is acquired on the job. Workshops, short courses, seminars and symposia conducted by knowledgeable conservation professionals are an efficient means of disseminating information on a variety of conservation topics and increasing collections care expertise as new information becomes available. Similar in-service initiatives directed toward conservators who are not specialists in the conservation of natural science collections will enable them to understand the special requirements of these collections, particularly in preventive conservation.

A series of formal short courses in collections management could be developed through major natural history museums. Formal short courses on conservation topics can be arranged through major conservation laboratories, regional conservation centers, conservation and collections management academic training programs or the conservation departments of major museums. Symposia, workshops and seminars conducted at meetings sponsored by conservation and preservation organizations (e.g., SPNHC, American Institute for Conservation of Historic and Artistic Works), by disciplinary societies in the natural sciences and by umbrella organizations such as ASC also help to provide up-to-date information.

Professional Exchanges

Less formal than structured in-service training initiatives, professional exchanges—both national and international—encourage the dissemination of current and pertinent information among a variety of professionals working in areas relevant to natural science collections conservation. Dialogue among disciplines within institutions promotes a cost-effective exchange of information and ideas and a coordinated effort toward collections care.

Interdisciplinary dialogue can be initiated through:

- consolidation and dissemination of information on pertinent topics and existing technologies via resource databases, bibliographic databases, databases on supplies and equipment and lists of conservation research projects;

- participation in interdisciplinary collections care and management organizations;
- inclusion of collections care topics in major interdisciplinary forums, such as the meetings of ASC and the American Institute for Biological Sciences (AIBS);
- representation of collections care and management organizations at natural science professional society meetings through presentations and resource booths; and
- development of interdisciplinary collections committees within collecting institutions.

Present conservation training programs owe their origins to the needs of art galleries and history museums and are usually located in university faculties of fine art. They may draw on existing courses in other faculties for such subjects as chemistry, biology, and business administration, but course work that specifically addresses natural science collections would require a fundamental reorientation.

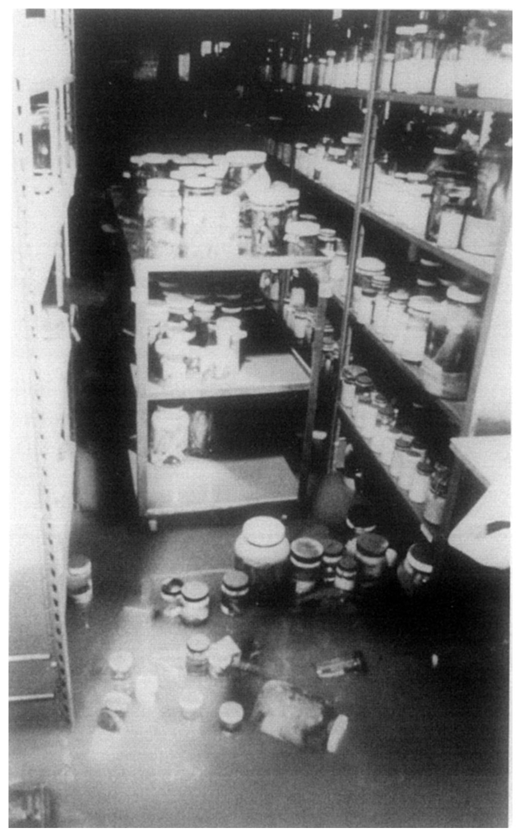
—Philip Ward, 1986

Intradisciplinary dialogue can be initiated through:

- establishment of collections committees in scientific disciplinary societies to help host workshops and compile information resources;
- disciplinary newsletters that advertise the availability of conservation information resources and provide new information in a timely manner; and
- symposia and workshops sponsored by conservation organizations that address natural science conservation issues for conservators in other specialty fields.

Pre-Service Education

All professionals who plan to work with collections should have some level of conservation training as part of their academic training. Graduate programs for both collections managers and conservators in the natural sciences should be located at institutions that have strong academic traditions in systematics and affiliations with conservation educators and with major natural history museums. The training would be accomplished through course work and hands-on experience in the collections. Ideally, accredited programs would be evenly distributed throughout the country.



Jars containing fluid-preserved specimens were swept off their shelves and broken during a flood. Restraining bars on shelves greatly reduce the potential for damage during a flood, earthquake or other disaster.

Research Scientists. For research scientists in collections-based disciplines, the graduate curriculum should include at least one course in research administration (including organizational management) and one course that covers the basic concepts of collections management and preventive conservation for scientific collections. This preparation will contribute to a productive partnership among researchers, collections managers and conservators.

Collections Managers. There is a growing need for collections managers who have both a sound knowledge of the scientific discipline in which they work and a background in collections management techniques. The movement to recognize collections management as a profession and as a distinct program element and organizational responsibility is a significant step in improving the care of scientific collections. Accredited master's-level graduate programs for students specializing in this field should incorporate one or more introductory courses in preventive conservation as part of the curriculum.

Conservators. Specialized graduate programs will be necessary to develop a cadre of conservators for the natural sciences. The proposed prerequisites and curriculum for a program to train bioscience and geoscience conservators are included in appendix A.

Natural science conservators should specialize in either the bio- or geosciences but must have a reasonable knowledge of both areas to enable them to serve the broad interests of natural history museums or regional conservation centers. The proposed curriculum is structured to cover the standard topics that are the core of any conservation training program, with adaptations for the special needs in the natural sciences.

To provide a shocking statistic, in all of continental Amazonia, there are no more than 300 well-trained natural scientists. Worse yet, there is not a single specialist on collections. Collection practices are based on "oral history" and visual remembrances of short visits to reputable institutions.

—Guilherme M. de La Penha, 1993

An alternate approach to natural science conservation training programs could be considered. A cooperative program with courses at established conservation programs and block courses through other universities affiliated with major natural history museums is one possibility.

Publications

Several types of publications are necessary to support education and training initiatives and disseminate collections care information throughout the natural sciences. These publications include textbooks, guidelines, methods manuals, annotated bibliographies, resource directories, critical reviews of available literature, statements of professional standards and conservation research reports.

Recommendations:

An intensive graduate program in the conservation of natural science collections must be established immediately to train a core group of conservators.

Strategies

- Modify the museum science and conservation curricula in an existing university program, in conjunction with a major natural history museum.
- Specify as prerequisites a master's degree in a scientific discipline, experience in natural science collections and extensive preventive conservation experience and training.
- Seek support for stipends, program costs and paid leave for participants.

An ongoing graduate program in the conservation of natural science collections must be established to train conservators for the future.

Strategies

- Combine the program with a training program for ethnographic and archaeological conservators.

- Locate the program at a university that is affiliated with a major natural history museum and has an established museum studies program.
- Seek support for stipends, fellowships and program costs.
- Work with international museum and conservation organizations to encourage participation by foreign students, particularly students from developing nations.
- Develop publications and other didactic materials necessary to support the curriculum.

Conservators from other fields should be made aware of the special needs of natural science collections and the areas in which their expertise is relevant.

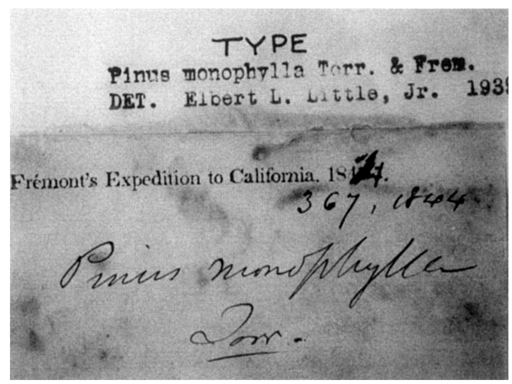
Strategy

- Sponsor workshops and symposia at meetings of conservation organizations on natural science collections conservation issues and opportunities.

Directors, research scientists and collections managers must gain a fuller understanding of their roles and responsibilities in collections care.

Strategies

- Incorporate preventive conservation courses in the curricula of graduate programs in the management of natural science collections.
- Incorporate a course in research administration and a course in collections management and preventive conservation in graduate programs for systematists.
- Encourage the inclusion of collections care training in academic internships and apprenticeships for collections managers.
- Sponsor presentations by experts from other fields (such as paper conservation and polymer chemistry) at scientific disciplinary society meetings and other professional meetings. Expand the audience for these presentations through teleconferencing or other communications technology.
- Improve the collections care skills of collections managers through in-service training and professional exchange.
- Develop publications on various aspects of preventive conservation in the natural sciences.



This label identifies a botanical type specimen collected by John Charles Frémont in 1844. The paper and the adhesive used to attach it to the herbarium sheet are inherently acidic. Information available from the field of paper conservation provides the means to preserve important documents and prevent future conservation problems in collections documentation.

Institutions must develop, support and encourage staff education and interdisciplinary professional exchange as investments in collections care.

Strategies

- Develop a comprehensive series of one-week courses on the basic principles of collections management to provide collections managers with appropriate in-service training.

- Support staff participation in interdisciplinary, international collections care organizations and attendance at symposia and workshops.
- Require appropriate professional education and continuing training for all staff.

Technology Transfer

I would ask that there be a greater willingness to accept change in collection care, in spite of the difficulties of change, and...that the problems of collection care be attacked with more imagination.

—Boyd W. Walker, 1963

Many of the conservation concerns expressed by those who use and care for natural science collections have been addressed in the bodies of knowledge that exist in closely allied disciplines such as chemistry, physics, engineering, materials science and various collections conservation fields. For example, concerns involving specimen label papers do not require additional research because extant paper conservation research can be applied to these questions. The literature in organic chemistry, medical research and forensic pathology has much to offer in regard to the chemistry of fixation and fluid preservation of specimens.

Organizing the widespread information base on the chemical and physical properties of materials and presenting it in a useful format for application to preservation problems has been a major effort on the part of the conservation community for more than 50 years. Incorporating additional research topics pertinent to the natural sciences and disseminating the information through networks that reach this constituency are feasible undertakings that would facilitate the transfer of technology and the development of focused conservation research investigations.

Appendix B contains detailed lists of technology transfer and research topics suggested by participants in this project's working groups, materials science panels and disciplinary organization meetings.

Recommendation:

The natural science community should seek the transfer of information and technology from other conservation fields, scientific disciplines and industry.

Strategies

- Establish an international information clearinghouse to coordinate existing information databases, disseminate publications and prepare new information tools, including didactic materials.
- Through existing organizations, prepare directories of laboratories, corporations and individuals willing to serve as research resources for natural science conservation.
- Prepare lists of current research investigations that can be applied to the conservation of natural science collections.
- Sponsor interdisciplinary and/or international meetings and workshops.

Conservation Research

The proliferation of biodiversity programs to sample disappearing ecosystems lends urgency to the need for scientific research, both applied and basic, to answer fundamental questions relating to the preparation, care, storage, exhibition and documentation of natural science collections. Analytical services to respond to straightforward inquiries, short-term projects to solve specific problems and long-term research on fundamental deterioration and preservation concerns are essential to protect the scientific integrity of collections and ensure their survival.

The nature of much of the conservation research needed depends on the type of investigation that will be conducted using the specimens. Categorizing specimens by their intended end use, defining the aspects that are important to preserve to support each use, and then determining the level of deterioration that is acceptable for each aspect will provide a framework for conservation research into new preparation methods. Although there is no way to predict what information in a specimen might be important to scientists a century or more in the future, reasonable projections can be based on the emerging techniques in biology, biochemistry and geochemistry. Preparing specimens in several formats and developing the least interventive methods for each format may be the only feasible approaches.

Two primary concerns cross all scientific disciplines:

- the impact of current and past practices and materials on long-term preservation and on the utility of the specimens for scientific studies, and
- the development of new methods and materials for the preservation and care of specimens collected in the future.

Addressing these concerns involves assessing materials interactions and developing appropriate specifications for both materials and methods.

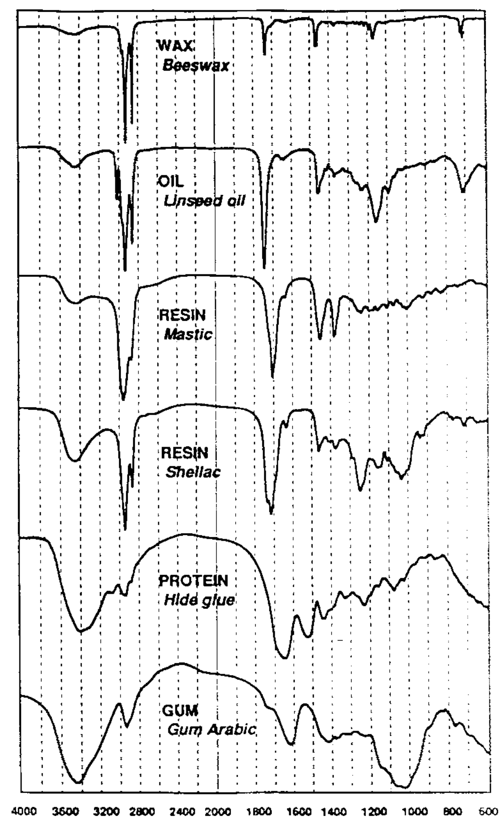
Within these two broad categories, the topics for which research, coupled with technology transfer, are needed can be grouped as follows (see appendix B for a detailed list of research and technology transfer topics):

Specimen Preparation

- field collecting and preparation methods and materials for use in a variety of climates
- laboratory preparation methods and materials for various uses of specimens

Post-Preparation Care

- methods and materials to control biodeterioration, especially control of insect pests and microorganisms
- techniques to monitor, assess and reduce observed deterioration, including diagnostic methods for early detection of specimen deterioration



Infrared spectra are used to identify types of natural organic materials that may have been used in the preparation of specimens. Laboratories that routinely provide this and other conservation-oriented analytical services are found in Canada but are not readily available to conservators and collections staff in the United States.

- methods and materials for specimen cleaning and restoration or repair

Storage and Exhibit Environments

- environmental conditions (e.g., light, temperature, relative humidity, inorganic and organic pollutant levels, and levels of shock and vibration)
- methods and materials for storage, exhibition, and shipping and packing

A researcher prepares ***Ganoderma sp.***, a bracket fungus, for storage in compact shelving. Specimens in mycology collections may range from microscopic to among the largest organisms on earth.

Specimen Documentation

- methods and materials for specimen labeling
- methods and materials for the creation and care of other collections documentation (databases, library and archival materials)
- methods to document preparation techniques and other specimen treatments

Recommendations:

A new interdisciplinary conservation research program should be established at one or more leading institutions.

Strategies

- Fund the program through existing agencies and coordinate it through existing laboratories.
- Develop the program in partnership with private and public funding agencies.
- Set priorities for conservation research based on the needs of multiple collections.
- Focus research on the materials that comprise collections to ensure that the results will be broadly applicable in the natural sciences.

Regional or centralized conservation analytical services should be made available.

Long-term research is sometimes mistakenly regarded as a luxury, but it is, in fact, the fuel of future knowledge.

—Philip Ward, 1986

Strategy

- Use existing conservation laboratories, regional conservation centers or university-affiliated major natural history museums as analytical service centers in order to minimize costs.

Agencies that fund collections care should expand the scope of their support to include conservation research.

Strategies

- Encourage private foundations to develop programs to support conservation research.
- Expand the NSF collections support program, or develop a new NSF research program to support interdisciplinary conservation research.
- Expand the IMS conservation programs, or develop a small IMS grants program to fund conservation research.

Guidelines and Standards of Practice

The development of guidelines and standards of practice—as well as specifications for materials and methods in specimen preparation, storage, exhibition and documentation—will maximize the future research utility of collections and help clarify conservation needs. Developing specifications and standards of practice will further efforts to assess the impact of preparation and post-preparation treatment over time and reduce future uncertainty about the treatment history of specimens.

New approaches to specimen care will require long-term multidisciplinary research. In the interim, modifying current practices could help improve specimen conservation. Ultimately, the widespread acceptance of modified practices and specified materials will depend on broad-based review and testing processes and close communication with the groups the changes are intended to benefit.

In addition, an understanding of the scope, state and status of collections is essential to the effort to quantify the conservation needs of natural science collections. Through the sponsorship of the NSF, the natural sciences have taken the first step toward identifying the scope of the collected resource through the development of computerized collections catalogues at many institutions. These catalogues also increase the accessibility of collections for research and are an important collections management tool. A major effort is now under way to define data standards in order to create a network of databases. Directories of collections developed by various disciplinary organizations also facilitate collections use and can be employed to track collections over time, allowing these groups to monitor threatened or endangered collections.

> There is ample opportunity for research in the field of collecting and preserving specimens in the tropics. Raw, fundamental investigations that start very basically with the environment of the collections themselves are needed to expand the boundaries of the standard techniques used in Europe, the U.S., Japan and Canada. Tropical conservation of collections is a wide-open field in all its disciplines, from microbiology to hard chemistry and physics.
>
> —Guilherme M. de La Penha, 1993

Recommendations:

The natural science community should establish guidelines or standards of practice in all aspects of collections care.

Strategy

- Develop, through ASC and SPNHC, a multidisciplinary task force to survey existing standards and draft preliminary guidelines for review by the natural science community.

Specifications for materials and methods used in preparing, storing, labeling and exhibiting natural science specimens should be developed and updated routinely.

Strategies

- Form multidisciplinary committees through the American Society of Testing Materials, the American National Standards Institute or other standards organizations.
- Develop methods to test materials supplied by vendors.
- Consider health and safety issues in all methods, materials and testing techniques.

Efficient methods to document specimen preparation, sampling, and other treatments or use should be developed to ensure the research integrity of the collections.

Strategies

- Adapt models used in other disciplines, particularly for computerized documentation of treatment histories.
- Develop standardized terminology for assessing the condition of specimens and collections.
- Urge that preparation protocols be included in proposals for field work and in publications on specimen-based research.

Databases and networks should be developed and maintained to provide the widest societal access to the information inherent in natural science collections.

Strategies

- Continue, through ASC, the effort to define standards to facilitate networking of collections databases.
- Develop a national, publicly supported program for computerized collections databases and networking to improve dissemination of information to the public, scientists, environmental conservationists, public officials, land and aquatic managers, industry managers and other users.

Bibliography

Care and Management of Specimen and Collections Documentation

Adelstein, P. Z. 1992. Status of permanence standards of imaging materials. *Journal of Imaging Science and Technology* 36(1):37–41.

Allen, N. S., M. Edge, T. S. Jewitt and C. V. Horie. 1992. Degradation and stabilization of cellulose triacetate base motion picture film. *Journal of Imaging Science and Technology* 36(1):4–12.

American Institute for Conservation of Historic and Artistic Works, Book and Paper Group. 1990. *Paper Conservation Catalog.* 7th edition. American Institute for Conservation of Historic and Artistic Works, Washington, D.C.

American National Standards Institute. 1986. *American National Standard for Photography (Processing)—Processed Films, Plates, and Papers—Filing Enclosures and Containers for Storage.* ANSI PH1.53–1986. American National Standards Institute, New York.

American National Standards Institute. 1984. *Permanence of Paper for Printed Library Materials.* ANSI Z39.48–1984. American National Standards Institute, New York.

Banks, P. N. 1981. *A Selective Bibliography on the Conservation of Research Library Materials.* Newberry Library, Chicago.

Bansa, H. 1991. The new media: Means for better preservation or special preservation problems? *Restaurator* 12(4):219–232.

Bellardo, L., and L. L. Bellardo. 1992. *A Glossary for Archivists, Manuscript Curators, and Records Managers.* Society of American Archivists, Chicago.

Browning, B. 1977. *Analysis of Paper.* 2nd edition. Marcel Dekker, New York.

Burgess, H., and C. Leckie. 1991. Evaluation of paper products: With special reference to use with photographic materials. Pp. 96–105 in *Topics in Photographic Preservation, Volume 4.* Postprints of the 1991 meeting of American Institute for Conservation, Photographic Materials Group. American Institute for Conservation of Historic and Artistic Works, Washington, D.C.

Calmes, A. 1992. Preservation of video images. *Journal of Imaging Science and Technology* 36(1):1–3.

Clapp, A. F. 1987. *Curatorial Care of Works of Art on Paper.* Nick Lyons Books, New York.

Daly, H. V., and C. L. Jordan. 1989. Computer generated collection labels: They are fast, but will they last? *Insect Collection News* 2(2):26–27.

Deiss, W. A. 1984. *Museum Archives: An Introduction.* Society of American Archivists, Chicago.

Eastman Kodak Company. 1985. *Conservation of Photographs.* Kodak Publication No. F–40. Eastman Kodak Company, Rochester.

Edge, M., M. Mohammadian, M. Hayes, N. S. Allen, K. Brems and K. Jones. 1992. Aspects of polyester degradation: Motion picture film and videotape material. *Journal of Imaging Science and Technology* 36(1):13–20.

Ehrenberg, R. E. 1982. *Archives and Manuscripts: Maps and Architectural Drawings.* Society of American Archivists, Chicago.

Grotke, R. 1991. Technical information: Proper tape maintenance. *The Library of Natural Sounds Bulletin* [Cornell Laboratory of Ornithology] (March):6–7.

Hawks, C. A., and S. L. Williams. 1986. The care of specimen labels in vertebrate research collections. Pp. 105–108 in *Proceedings of the 1985 Workshop on Care and Maintenance of Natural History Collections* (J. Waddington and D. Rudkin, eds.). Life Sciences Miscellaneous Publications. Royal Ontario Museum, Toronto, Ontario, Canada.

Hendriks, K. B., and A. Whitehurst. 1988. *Conservation of Photographic Materials: A Basic Reading List.* National Archives of Canada, Ottawa, Ontario, Canada.

Kenworthy, M. A., E. M. King, M. E. Ruwell and T. Van Houten. 1985. *Preserving Field Records.* University Museum, University of Pennsylvania, Philadelphia.

Kishinami, C. 1989. Archival storage of disintegrating labels from fluid-preserved specimens. *Collection Forum* 5:1–4.

Maounis, J. 1990. Curatorial care of cellulose nitrate negatives. Appendix M, pp. M:1–22 in *Museum Handbook, Part 1: Museum Collections.* National Park Service, Washington, D.C.

McLaren, S. B., H. H. Genoways and D. A. Schlitter. 1987. The computer as a collection management tool. Pp. 97–110 in *Mammal Collection Management* (H. Genoways, C. Jones and O. Rossolimo, eds.). Texas Tech University Press, Lubbock.

National Bureau of Standards. 1983. *Air Quality for Storage of Paper-Based Archival Records.* NBSIR 83-2795. National Bureau of Standards, Washington, D.C.

National Research Council, Committee on Preservation of Historical Records. 1986. *Preservation of Historical Records.* National Academy Press, Washington, D.C.

Newman, J., E. Banks and A. Jordan. 1990. Curatorial care of paper objects. Appendix J, pp. J:1–55 in *Museum Handbook, Part 1: Museum Collections.* National Park Service, Washington, D.C.

Ogden, S. (ed.). 1992. *Preservation of Library and Archival Materials: A Manual.* Northeast Document Conservation Center, Andover, Mass.

Ritzenthaler, M. L. 1983. *Archives and Manuscripts Conservation: A Manual on Physical Care and Management.* Society of American Archivists, Chicago.

Ritzenthaler, M. L., G. J. Munoff and M. S. Long. 1984. *Archives and Manuscripts: Administration of Photographic Collections.* Society of American Archivists, Chicago.

Rose, C. L., and A. R. de Torres (eds.). *Storage of Natural History Collections: Ideas and Practical Solutions.* Society for the Preservation of Natural History Collections, Pittsburgh.

Shahani, C. J., and W. K. Wilson. 1987. Preservation of libraries and archives. *American Scientist* 75(May–June):240–251.

Sims, L. L. 1989. How permanent are they? *Insect Collection News* 2(2):26.

Smith, L. E. 1991. Factors governing the long-term stability of polyester-based recording media. *Restaurator* 12(4):201–218.

Smith, R. D. (ed.). 1987. *Preservation Photocopying in Libraries and Archives.* Conference of U.S. National Archives and Records Administration, 9 December 1987. *Restaurator* 8(1):1–62.

Swartzburg, S. 1991. Basic preservation bibliography. *Conservation Administration News* (44):10–12.

Taylor, J. M., I. N. Wainwright, F. R. Livingstone, R. Rioux and P. Boulanger. 1987. Applications of a laser scanner to the recording and replication of museum objects. Pp. 93–97 in *Preprints of the ICOM Committee for Conservation 8th Triennial Meeting, Sydney, Australia, 6–11 September 1987.* Getty Conservation Institute, Marina del Rey, Calif.

Van Driel, D. 1990. Treasures in the Transvaal Museum library with reference to factors endangering their survival. Pp. 71–80 in *Natural History Collections: Their Management and Value* (E. Herholdt, ed.). Special Publication No. 1. Transvaal Museum, Pretoria, South Africa.

Weber, H. 1993. Opto-electronic storage—An alternative to filming? Translation of a chapter from a 1992 article, "Verfilmen oder Instandsetzen? Schutz- und Ersatzverfilmung im Dienste der Bestandserhaltung," in *Bestandserhaltung in Archiven und Bibliotheken* (H. Weber, ed.). Verlag W. Kohlhammer, Stuttgart, Germany. *Commission on Preservation and Access Newsletter* (53, Insert):1–6.

Williams, J. C. 1979. Paper permanence: A step in addition to alkalization. *Restaurator* 3:81–90.

Williams, J. C. 1981. A review of paper quality and paper chemistry. *Library Trends* (Fall):326–346.

Williams, S. L., and C. A. Hawks. 1986. Inks for documentation in vertebrate research collections. *Curator* 29(2):93–108.

Collections Care and Preventive Conservation

Adams, P. B. 1992. Predicting corrosion. Pp. 29–50 in *Corrosion of Glass, Ceramics and Ceramic Superconductors: Principles, Testing, Characterization and Applications* (D. E. Clark and B. K. Zoitos, eds.). Noyes Publications, Park Ridge, N.J.

Agnew, N. 1981. The corrosion of egg shells by acetic acid vapour. *ICCM Bulletin* [Institute for the Conservation of Cultural Material (Australia)] 7(4):39.

Appelbaum, B. 1991. *Guide to Environmental Protection of Collections.* Sound View Press, Madison, Conn.

Arni, C. P., G. Cochrane and J. Gray. 1965. The emission of corrosive vapors by wood. Part I. Survey of the acid-release properties of certain freshly felled hardwoods and softwoods. *Journal of Applied Chemistry* 15:305–313.

Arni, C. P., G. Cochrane and J. Gray. 1965. The emission of corrosive vapors by wood. Part II. The analysis of vapors emitted by certain freshly felled hardwoods and softwoods by gas chromatography and spectrophotometry. *Journal of Applied Chemistry* 15:463–468.

Art and Archaeology Technical Abstracts. 1966–present. Formerly *IIC Abstracts* (1955–1965). Getty Conservation Institute in association with International Institute for Conservation, Marina del Rey, Calif.

Bachman, K. (ed.). 1992. *Conservation Concerns: A Guide for Collectors and Curators.* Smithsonian Institution Press, Washington, D.C.

Baer, N., and P. Banks. 1985. Indoor air pollution: Effects on cultural and historic materials. *International Journal of Museum Management and Curatorship* 4(1):9–20.

Balkwill, G. 1990. Are diamonds really forever?—The preservation of geological samples. Pp. 61–69 in *Natural History Collections: Their Management and Value* (E. Herholdt, ed.). Special Publication No. 1. Transvaal Museum, Pretoria, South Africa.

Bandes, S. J. 1984. *Caring for Collections: Strategies for Conservation, Maintenance and Documentation.* American Association of Museums, Washington, D.C.

Bannister, F. A. 1937. The preservation of minerals and meteorites. *Museums Journal* 36(2):465–476.

Blackshaw, S. M., and V. D. Daniels. 1979. The testing of materials for use in storage and display in museums. *The Conservator* 3:16–19.

Bonte, W., J. Bleifuss and J. Volck. 1976. Experimental investigations in post-mortem protein degradation. *Forensic Science* 7:9–22.

British Leather Manufacturers' Research Association. 1948. *Progress in Leather Science 1920–1945.* British Leather Manufacturers' Research Association, Moulton Park, Northampton, England.

Budd, M. 1965. Corrosion of metal in association with wood. *Applied Materials Research* 4(2):124–125.

Burns, J. W. 1952. *Effects of Preservatives on the Fur Color of Mammal Specimens.* Master's thesis. University of Idaho, Moscow.

Calnan, C., and B. Haines (eds.). 1991. *Leather: Its Composition and Changes with Time.* Leather Conservation Centre, Northampton, England.

Canadian Conservation Institute. 1988. *A Light Damage Slide Rule.* CCI Notes 2/6. Canadian Conservation Institute, Ottawa, Ontario, Canada.

Chase, M. W., and H. H. Hills. 1991. Silica gel: An ideal material for field preservation of leaf samples for DNA studies. *Taxon* 40:215–220.

Clark, D. E., C. Pantano and L. L. Hench. 1979. *Corrosion of Glass.* Books for Industry and the Glass Industry, New York.

Clark, D. E., M. F. Dilmore, E. C. Ethridge and L. L. Hench. 1976. Aqueous corrosion of soda-silica and soda-lime-silica glass. *Journal of the American Ceramic Society* 59(1–2):62–65.

Clark, J. 1980. Ultraviolet filtering films for museum use: Properties and effectiveness. *ICOM Bulletin* 6(3–4):35–40.

Clark, S. H. 1986. Preservation of herbarium specimens: An archive conservator's approach. *Taxon* 35:675–682.

Coetzee, C. G. 1985. The influence of preservative on coat colour of small mammals. *Acta Zoologica Fennica* 170:67–68.

Conservation Sourcebook. 1991. Museums and Galleries Commission, Conservation Unit, London, England.

Coradin, L., and D. E. Giannosi. 1980. The effects of chemical preservatives on plant collections to be used in chemotaxonomic surveys. *Taxon* 29:33–40.

Croucher, P. R., and A. Woolley. 1982. *Fossils, Minerals and Rocks: Collection and Preservation*. British Museum (Natural History) and Cambridge University Press, London, England.

Crowther, P., and C. Collins (eds.). 1987. *The Conservation of Geological Material.* Geological Curators' Group, London, England. *Geological Curator* 4(7):375–474.

Demay, L., M. Dunnard and R. Julien. 1988. *Collections de Zoologie: Remarques sur leur Conservation*. Synthese du Seminaire OCIM de Novembre, 1987. Note Technique No. 12. Office de Cooperation et d'Information Museographiques, Montpellier, France.

Downing, S. C. 1945. Color changes in mammal skins during preparation. *Journal of Mammalogy* 26:128–132.

Douglass, D. L., Cichang Shing and Ge Wang. 1992. The light-induced alteration of realgar to pararealgar. *American Mineralogist* 77:1266–1274.

Egenberg, I. M., and D. Moe. 1991. A "stop-press" announcement: Damage caused by a widely used herbarium mounting technique. *Taxon* 40:601–604.

Entwistle, R., G. Kemp, J. Marsden and V. Todd. 1992. *Life After Death: The Practical Conservation of Natural History Collections.* Papers given at a conference held by the UKIC in conjunction with Ipswich Borough Council, 27 February 1992. United Kingdom Institute for Conservation, London, England.

Faber, D. J. (ed.). 1983. *Proceedings of 1981 Workshop on Care and Maintenance of Natural History Collections.* Syllogeus Series No. 44. National Museums of Canada, Ottawa, Ontario, Canada.

Feller, R. L., and M. Wilt. 1990. *Evaluation of Cellulose Ethers for Conservation.* Research in Conservation No. 3. Getty Conservation Institute, Marina del Rey, Calif.

FitzHugh, E. W., and R. J. Gettens. 1971. Calclacite and other efflorescent salts on objects stored in wooden museum cases. Pp. 91–102 in *Science and Archeology* (R. H. Brill, ed.). MIT Press, Cambridge, Mass.

Flessa, K. W., M. Kowaleswki and S. E. Walker. 1992. Post-collection taphonomy: Shell destruction and the Chevrolet. *Palaios*7(5):53–54.

Florian, M-L. 1986. Ideas on how to better preserve collections of natural history: We now need to do something. *Collection Forum* 2(2):6–7.

Florian, M-L., D. P. Kronkright and R. E. Norton. 1990. *The Conservation of Artifacts Made from Plant Materials.* J. Paul Getty Trust, Los Angeles.

Fogle, S., T. Raphael and K. Singley (eds.). 1985. *Recent Advances in Leather Conservation*. Foundation of the American Institute for Conservation of Historic and Artistic Works, Washington, D.C.

Forman, G. L., and C. J. Phillips. 1988. Preparation and fixation of tissues for histological, histochemical, immunohistochemical, and electron microscopical studies. Pp. 405–424 in *Ecological and Behavioral Methods for the Study of Bats* (T. Kunz, ed.). Smithsonian Institution Press, Washington, D.C.

Grattan, D. W. 1980. The oxidative degradation of organic materials and its importance in deterioration of artifacts. *Journal of the International Institute for Conservation–Canadian Group* 4(1):17–26.

Grattan, D. W., and M. Morris. 1991. The potential of parylene for consolidating natural history specimens. *Natural History Conservation* [newsletter of ICOM Committee for Conservation, Natural History Working Group] (6):4–7.

Greathouse, G. A., and C. J. Wessel (eds.). 1954. *Deterioration of Materials.* Reinhold Publishing, New York.

Green, S. W. (ed.). 1990. *The Conservation Assessment: A Tool for Planning, Implementing and Fundraising.* Getty Conservation Institute and National Institute for the Conservation of Cultural Property, Washington, D.C.

Harris, R. H. 1984. *A Selective Bibliography on Preservation, Macro- and Micro-Anatomical Techniques in Zoology.* Biology Curators' Group, London, England.

Haselkorn, R., and P. Doty. 1960. The reaction of formaldehyde with polynucleotides. *Journal of Biological Chemistry* 236:2738–2745.

Hawks, C. A. 1990. Recent advances in the conservation of natural science collections. Pp. 53–60 in *Natural History Collections: Their Management and Value* (E. Herholdt, ed.). Special Publication No.1. Transvaal Museum, Pretoria, South Africa.

Hawks, C. A. 1988. Conservation considerations in Recent mammal collections. Pp. 475–493 in *Management of Mammal*

Collection[s] in Tropical Environment[s] (B. Tikader, ed.). Proceedings of a Workshop on Management of Mammal Collections in Tropical Environments, Calcutta, 9–25 January 1984. Zoological Survey of India, Calcutta, India.

Hawks, C. A., and C. L. Rose. 1987. *A Preliminary List of Conservation Resources for the Care of Natural History Collections.* Conservation Committee, Society for the Preservation of Natural History Collections, Washington, D.C.

Hawks, C. A., and S. L. Williams. 1990. Deterioration of bone and ivory: An annotated bibliography. *Natural History Conservation* [newsletter of ICOM Committee for Conservation, Natural History Working Group] (5):25–27.

Hawks, C. A., S. L. Williams and J. S. Gardner. 1984. *The Care of Tanned Skins in Mammal Research Collections.* Museology No. 6. Texas Tech University Press, Lubbock.

Hollister, N. 1923. Museum preservation of incisor teeth of ruminantia. *Journal of Mammalogy* 4:123–125.

Hon, D., G. Ifju and W. Feist. 1980. Characteristics of free radicals in wood. *Wood and Fiber* 12(2):121–130.

Horie, C. V. 1987. Describing the condition of mounted animals. *Natural History Conservation* [newsletter of ICOM Committee for Conservation, Natural History Working Group] (2):4–5.

Horie, C. V. 1987. *Materials for Conservation.* Butterworth Publishers, London, England.

Horie, C. V. (ed.). 1989. *Conservation of Natural History Specimens—Spirit Collections.* Proceedings from a one-day course at Manchester University. Manchester Museum and Department of Environmental Biology, University of Manchester, Manchester, England.

Horie, C. V., and R. G. Murphy (eds.). 1988. *Conservation of Natural History Specimens—Vertebrates.* Proceedings of a short course at Manchester University. Manchester Museum and Department of Environmental Biology, University of Manchester, Manchester, England.

Howie, F. M. (ed.). 1992. *The Care and Conservation of Geological Material: Minerals, Rocks, Meteorites and Lunar Finds.* Butterworth-Heinemann, Oxford, England.

Howie, F. M. 1990. Pyritic specimens: Formation, deterioration and conservation [bibliography]. *Natural History Conservation* [newsletter of ICOM Committee for Conservation, Natural History Working Group] (5):20–25.

Howie, F. M. 1983. Fossil conservation and problems of mineral stability. Pp. 24–28 in *Geotechniques 83.* Proceedings of the

Symposium on Geological Laboratory Techniques. Institute of Science Technology, London, England.

Howie, F. M. 1979. Museum climatology and the conservation of palaeontological material. Pp. 103–125 in *Curation of Palaeontological Material* (M. Bassett, ed.). Special Papers in Palaeontology No. 22. The Palaeontological Association, London, England.

Howie, F. M. 1978. Storage environment and the conservation of geological material. *The Conservator* [journal of the United Kingdom Institute for Conservation] 2:13–19.

Jackson, H. H. 1926. The care of museum specimens of Recent mammals. *Journal of Mammalogy* 7:113–118.

Jones, E. M., and R. D. Owen. 1987. Fluid preservation of specimens. Pp. 51–63 in *Mammal Collection Management* (H. Genoways, C. Jones and O. Rossolimo, eds.). Texas Tech University Press, Lubbock.

Kalnins, M., C. Steelink and H. Tarkow. 1966. Light-induced free radicals in wood. *Research Papers of the U.S. Forest Service* FPL58:1–7.

Lafontaine, R. H. 1984. *Silica Gel.* Technical Bulletin No. 10. Canadian Conservation Institute, Ottawa, Ontario, Canada.

Lafontaine, R. H., and P. A. Wood. 1982. *Fluorescent Lamps.* Technical Bulletin No. 7. Canadian Conservation Institute, Ottawa, Ontario, Canada.

Lai, Ya-Ching. 1963. *Effects of Several Preservatives on Proportional Measurements of the Fatheaded Minnow,* Pimephales promelas. Master's thesis. University of Kansas, Lawrence.

Lavenberg, R. J., G. E. McGowen and R. E. Woodsum. 1983. Preservation and curation. Pp. 57–59 in *Ontogeny and Systematics of Fishes.* International symposium dedicated to the memory of Elbert Halvor Ahlstrom, La Jolla, Calif., 15–18 August 1983. Special Publication No. 1. American Society of Ichthyologists and Herpetologists, Lawrence, Kan.

Lennox, F. G., and R. J. Rowlands. 1969. Photochemical degradation of keratins. *Photochemistry and Photobiology* 9:359–367.

Lull, W. P. 1993. Selecting fluorescent lamps for UV output. *Abbey Newsletter* 16(4):54–55.

Marcon, P. J., and T. J. Strang. 1990. *Cushion Design Using the CCI Cushion Design Calculator and PadCAD.* CCI Notes (draft). Canadian Conservation Institute, Ottawa, Ontario, Canada.

Matienzo, L. J., and C. E. Snow. 1986. The chemical effects of hydrochloric acid and organic solvents on the surface of ivory. *Studies in Conservation* 31:133–139.

McKillop, W. B. 1986. Induced colour fading in entomological specimens. Pp. 101–104 in *Proceedings of the 1985 Workshop on Care and Maintenance of Natural History Collections* (J. Waddington and D. Rudkin, eds.). Life Sciences Miscellaneous Publications. Royal Ontario Museum, Toronto, Ontario, Canada.

Meurgues, G. 1986. The preservation of natural history specimens. *Museum* (150):92–97.

Michalski, S. 1992. *A Systematic Approach to the Conservation (Care) of Museum Collections, with Technical Appendices.* Canadian Conservation Institute, Ottawa, Ontario, Canada.

Miles, C. 1986. Wood coatings for display and storage cases. *Studies in Conservation* 31:114–124.

Mills, J. S., and R. White. 1987. *The Organic Chemistry of Museum Objects.* Butterworth Publishers, London, England.

Morse, E. 1992. Enzyme treatments for conserving artistic/historic works: A selected bibliography—1940–1990. *Technology & Conservation* 11(1):20–24.

Museums and Galleries Commission. 1987. *Science for Conservators, Volumes 1–3* [Introduction to Materials; Cleaning; Adhesives and Coatings]. Conservation Science Teaching Series. Conservation Unit, Museums and Galleries Commission, London, England.

National Committee to Save America's Cultural Collections. 1992. *Caring for Your Collections.* Harry N. Abrams, New York.

Newton, R. G. 1985. The durability of glass—A review. *Glass Technology* 26(1):21–38.

Nicholls, J. R. 1934. Deterioration of shells when stored in oak cabinets. *Journal of the Society of Chemical Industry* 53(51):1077–1078.

Packer, L., and E. W. Kellogg. 1980. Photooxidative damage to mammalian cells and proteins by visible light. Pp. 83–93 in *Chemical Deterioration of Proteins* (J. Whitaker and M. Fujimaki, eds.). ACS Symposium Series 123. American Chemical Society, Washington, D.C.

Packman, D. 1960. The acidity of wood. *Holzforschung* 14(6):178–183.

Padfield, T., D. Erhardt and W. Hopwood. 1982. Trouble in store. Pp. 24–27 in *Science and Technology in the Service of Conservation* (N. Brommelle and G. Thomson, eds.). Preprints of the contributions to the Washington Congress, 1982. International Institute for Conservation, London, England.

Peigler, R. S. 1992. Shipping of pinned insects. *Collection Forum* 8(2):73–77.

Phillips, C. J. 1985. Field fixation and storage of museum tissue collections suitable for electron microscopy. *Acta Zoologia Fennica* 170:87–90.

Pritchard, M. H., and G. O. Kruse. 1982. *The Collection and Preservation of Animal Parasites.* University of Nebraska Press, Lincoln.

Quay, W. B. 1974. Bird and mammal specimens in fluid—objectives and methods. *Curator* 17:91–104.

Raphael, T. J. 1991. Airtight, humidity stabilized display cases: The practical design and fabrication of sealed exhibit cases. Pp. 78–87 in *Objects Specialty Group Postprints, Volume 1* (P. Hatchfield, comp.). Objects Specialty Group, American Institute for Conservation of Historic and Artistic Works, Washington, D.C.

Reed, R. 1972. *Ancient Skins, Parchments and Leathers.* Seminar Press, London, England, and New York.

Rixon, A. E. 1976. *Fossil Animal Remains: Their Preparation and Conservation.* Athlone Press, University of London, London, England.

Rogers, S., M. Schmidt and T. Gutebier. 1989. *An Annotated Bibliography on Preparation, Taxidermy, and Collection Management of Vertebrates with Emphasis on Birds.* Special Publication No. 15. Carnegie Museum of Natural History, Pittsburgh.

Rose, C. L. 1991. The conservation of natural history collections: Addressing preservation concerns and maintaining the integrity of research specimens. Pp. 105–111 in *Natural History Museums: Directions for Growth* (P. Cato and C. Jones, eds.). Texas Tech University Press, Lubbock.

Rose, C. L., and A. R. de Torres (eds.). 1992. *Storage of Natural History Collections: Ideas and Practical Solutions.* Society for the Preservation of Natural History Collections, Pittsburgh.

Rose, C. L., and D. W. Von Endt (eds.). 1984. *Protein Chemistry for Conservators.* American Institute for Conservation of Historic and Artistic Works, Washington, D.C.

Scott, N. J., and A. L. Aquino-Shuster. 1989. The effects of freezing on formalin preservation of specimens of frogs and snakes. *Collection Forum* 5(2):41–46.

Sease, C. 1991. The development of the humidity control module at Field Museum. *Journal of the American Institute for Conservation* 30(2):187–196.

Selwitz, C. M. 1988. *Cellulose Nitrate in Conservation.* Research in Conservation No. 2. Getty Conservation Institute, Marina del Rey, Calif.

Shelton, S. Y. 1991. Forward into the past: A century of change in vertebrate paleontology collections. Pp. 105–111 in *Natural*

History Museums: Directions for Growth (P. Cato and C. Jones, eds.). Texas Tech University Press, Lubbock.

Simmons, J. E. 1991. Conservation problems of fluid-preserved collections. Pp. 69–89 in *Natural History Museums: Directions for Growth* (P. Cato and C. Jones, eds.). Texas Tech University Press, Lubbock.

Stambolov, T. 1969. *Manufacture, Deterioration and Preservation of Leather: A Literature Survey of Theoretical Aspects and Ancient Techniques.* Central Research Laboratory for Objects of Art and Science, Amsterdam, The Netherlands.

Steedman, H. F. (ed.). 1976. *Zooplankton Fixation and Preservation.* UNESCO Press, Paris, France.

Stroz, M. D., R. H. Glew, S. L. Williams and A. K. Saha. 1993. Comparisons of preservation treatments of collagen using the collagenase-SDS-PAGE technique. *Studies in Conservation* 38(1):35–54.

Suzumoto, A. Y. 1992. New materials for sealing old crocks. *Collection Forum* 8(2):68–72.

Tennant, N., and T. Baird. 1985. The deterioration of mollusca collections: Identification of shell efflorescence. *Studies in Conservation* 30:73–85.

Thomson, G. 1986. *The Museum Environment.* 2nd edition. Butterworth Publishers and International Institute for Conservation, London, England.

Thomson, G. 1985. Colour under some new fluorescent lamps. *National Gallery Technical Bulletin* [United Kingdom] 9:5–11.

Thomson, G. 1965. Air pollution—A review for conservation chemists. *Studies in Conservation* 10(4):147–167.

Toishi, K. 1959. Humidity control in a closed package. *Studies in Conservation* 4:81–87.

Torres, A. R. de (ed.). 1990. *Collections Care: A Basic Reference Shelflist.* National Institute for the Conservation of Cultural Property, Washington, D.C.

Torres, A. R. de (ed.). 1990. *Collections Care: A Selected Bibliography.* National Institute for the Conservation of Cultural Property, Washington, D.C.

Torres, A. R. de (ed.). 1990. *The Conservation Assessment: Bibliography.* National Institute for the Conservation of Cultural Property and Getty Conservation Institute, Washington, D.C.

Waddington, J., and J. Fenn. 1988. Preventive conservation of amber: Some preliminary investigations. *Collection Forum* 4(2):25–35.

Wainwright, I. N., and J. L. Down. 1985–86. Slatechuck Creek argillite: Its structure, composition and dimensional stability. *Journal of the International Institute for Conservation–Canadian Group* 10/11:8–19.

Waller, R. R. 1987. An experimental ammonia gas treatment method for oxidized pyritic mineral specimens. Pp. 623–629 in *Preprints of the ICOM Committee for Conservation 8th Triennial Meeting, Sydney, Australia, 6–11 September 1987.* Getty Conservation Institute, Marina del Rey, Calif.

Waller, R. R. 1984. The prevention of deliquescence, efflorescence and hydration in mineral specimens. Pp. 84.13.8–10 in *Preprints of the ICOM Committee for Conservation 7th Triennial Meeting, 10–14 September 1984.* International Council of Museums, Committee for Conservation, Paris, France.

Waller, R. R. 1980. The preservation of mineral specimens. Pp. 116–128 in *Preprints of the AIC Annual Meeting, San Francisco, Calif., 1980.* American Institute for Conservation of Historic and Artistic Works, Washington, D.C.

Waller, R. R., R. A. Stairs and T. Miller. 1992. Improving the selectivity of a selective dissolution process: A solution for removing calcite from fluorapatite. *Collection Forum* 8(1):22–34.

Weintraub, S., and G. O. Anson. 1990. Technics: Natural light in museums: An asset or a threat? *Progressive Architecture* 5:49–54.

Werner, G. 1987. Corrosion of metal caused by wood in closed spaces. Pp. 185–187 in *Recent Advances in the Conservation and Analysis of Artifacts* (J. Black, comp.). University of London, Institute of Archaeology Summer School Press, London, England.

Williams, R. S., J. B. Waddington and J. Fenn. 1990. Infrared spectroscopic analysis of Central and South American amber exposed to air pollutants, biocides, light and moisture. *Collection Forum* 6(2):65–75.

Williams, S. L. 1991. Investigation of the causes of structural damage to teeth in natural history collections. *Collection Forum* 7(1):13–25.

Conservation Research

Allsopp, D., and A. D. Baynes-Cope. 1991. Small world or one large world: The relationship between conservators, curators and scientists. Pp. 19–27 in *Biodeterioration of Cultural Property* (O. Agrawal and S. Dhawan, eds.). Proceedings of the International Conference on Biodeterioration of Cultural Property, 20–25 February 1989. National Research Laboratory for Conservation of Cultural Property, in collaboration with ICCROM and INTACH, New Delhi, India.

Bishop, M. H. 1992. Literature sources for conservation research. *Western Association for Art Conservation Newsletter* 14(1):23–27.

Brill, R. H. (ed.). 1971. *Science and Archeology*. MIT Press, Cambridge, Mass.

Brommelle, N. S., and G. Thomson. 1982. *Science and Technology in the Service of Conservation*. Preprints of the contributions to the Washington Congress, 3–9 September 1982. International Institute for Conservation, London, England.

Burgess, H., and N. Binnie. 1990. The development of a research approach to the scientific study of cellulosic and ligneous materials. *Journal of the American Institute for Conservation* 29(2):132–152.

Cordaro, M. 1990. Use ed abuso delle indagini scientifiche. *Materiali e Strutture* 1(1):32–34.

Hallebeek, P. B. 1989. Chemie, restaureren, conserveren, het meten en de interpretatie toegelicht met voorbeelden. Pp. 34–46 in *Mogelijkheden en Genrnzen van Natuurwetenschappelijk onderaoek aan en ten behoeve van voorwerpen van kunst en wetenschap* (W. Roelofs and J. Mosk, eds.). CL Themadag No. 16. Central Research Laboratory, Amsterdam, The Netherlands.

Hansen, E. F., and C. L. Reedy. In press. *Art Conservation Research Priorities: A Report of the Results of an AIC Membership Survey*. American Institute for Conservation of Historic and Artistic Works, Washington, D.C.

Hofenk de Grafff, J. H. 1989. Natuurwetenschappelijk onderzoek ten behoeve van conservering en restauratie. Pp. 50–64 in *Mogelijkheden en Genrnzen van Natuurwetenschappelijk onderaoek aan en ten behoeve van voorwerpen van kunst en wetenschap* (W. Roelofs and J. Mosk, eds.). CL Themadag No. 16. Central Research Laboratory, Amsterdam, The Netherlands.

Museums and Galleries Commission. 1991. *Directory of Conservation Research in the United Kingdom*. Conservation Unit, Museums and Galleries Commission, London, England.

Nainis, L. 1992. LC [Library of Congress] round table on preservation research and development. *Abbey Newsletter* 6(6):88–89.

National Conservation Advisory Council. 1979. *Report of the Study Committee on Scientific Support*. National Conservation Advisory Council, Washington, D.C.

National Institute for the Conservation of Cultural Property. 1984. *Ethnographic and Archaeological Conservation in the United*

States. National Institute for the Conservation of Cultural Property, Washington, D.C.

Education and Training

American Association of Museums, Committee on Museum Studies. 1987. *Museum Studies Programs: Guide to Evaluation*. Technical Information Resource Report No. 3. American Association of Museums, Washington, D.C.

Association of Graduate Training Programs in Conservation. 1988. *Conservation Management*. Papers presented at the 1987 Graduate Training Programs Conference, Queens University, 8 May 1987. Getty Conservation Institute, Marina del Rey, Calif.

Baer, N. (ed.). 1989. *Training in Conservation*. Symposium on the Occasion of the Dedication of the Stephen Chan House, 1 October 1983. Institute of Fine Arts, New York University, New York.

Cato, P. S. 1991. Summary of a study to evaluate collection manager-type positions. *Collection Forum* 7(2):72–94.

Cato, P. S. 1990. Collection management and preservation. *ASC Newsletter* 18(1):12–13.

Collins, C. 1992. *Training Course on the Conservation and Care of Geological Materials* [curriculum]. Geological Conservation Unit, Department of Earth Sciences, University of Cambridge, Cambridge, England.

Genoways, H. H. 1989. Museum studies in collection management. *ASC Newsletter* 17(6):77–71.

Malaro, M. C. 1991. *Collections Management: Legal and Ethical Issues* [course outline]. George Washington University Graduate Program in Museum Studies, Washington, D.C.

National Conservation Advisory Council. 1979. *Report of the Study Committee on Education and Training*. National Conservation Advisory Council, Washington, D.C.

National Institute for the Conservation of Cultural Property. 1991. *Training for Collection Care and Maintenance: A Suggested Curriculum. Volume III: Natural Sciences*. Bay Foundation and National Institute for the Conservation of Cultural Property, Washington, D.C.

National Institute for the Conservation of Cultural Property. 1990. *Training for Collections Care and Maintenance: A Suggested Curriculum. Volume I: Archaeology and Ethnology*. National Institute for the Conservation of Cultural Property, Washington, D.C.

National Institute for the Conservation of Cultural Property. 1984. *A Suggested Curriculum for Training in Ethnographic and Archaeological Conservation*. National Institute for the Conservation of Cultural Property, Washington, D.C.

Office of Museum Programs. 1988. *Museum Studies International.* Office of Museum Programs, Smithsonian Institution and International Council of Museums, Committee on Training of Personnel, Washington, D.C.

Pearson, C., and P. Winsor (eds.). 1988. *The Role of Science in Conservation Training.* Proceedings of the interim meeting of the ICOM Committee for Conservation Working Group on Training in Conservation and Restoration, 6–10 October 1986, British Museum. International Council of Museums, Committee for Conservation, Working Group on Training in Conservation and Restoration, Belconnen, Australia.

Queen's University. N.d. *Master of Art Conservation* [curriculum] Queen's University, Kingston, Ontario, Canada.

Rockwell, C., M. Garcia, G. de Guichen and J. Todd (eds.). 1987. *International Index on Training in Conservation of Cultural Property.* International Centre for the Study of the Preservation and Restoration of Cultural Property and Getty Conservation Institute, Rome, Italy, and Marina del Rey, Calif.

United Kingdom Institute for Conservation, Conservation Unit. 1988. *Training in Conservation: A Guide to Full-Time Courses in the United Kingdom.* United Kingdom Institute for Conservation, London, England.

University of Delaware and Henry Francis Du Pont Winterthur Museum. 1991. *Art Conservation Department, Conservation Program* [curriculum]. University of Delaware and Henry Francis Du Pont Winterthur Museum, Newark, Del.

University of Kansas Museum of Natural History. 1992. *Plans for Development of Courses on Collection Management and Museum Research Administration: Outline for Course in Collections Care & Management for Systematics and Ecology Graduate Students.* University of Kansas Museum of Natural History, Lawrence.

Waller, R. R., and G. R. Fitzgerald. 1989. *Course Notes on the Conservation of Earth Sciences Collections.* 1989. Canadian Museum of Nature and Conservation Analytical Laboratory, Smithsonian Institution, Ottawa, Ontario, Canada, and Washington, D.C.

Emergency Preparedness and Response

Advisory Council on Historic Preservation. 1989. *Fire Safety Retrofitting in Historic Buildings.* Advisory Council on Historic Preservation and General Services Administration, Washington, D.C.

Agbabian, M. S., W. S. Ginell, S. F. Masri and R. L. Nigbor. 1991. Evaluation of earthquake damage mitigation methods for museum objects. *Studies in Conservation* 36:111–120.

Agbabian, M. S., S. F. Masri and R. L. Nigbor. 1990. *Evaluation of Seismic Mitigation Measures for Art Objects.* Getty Conservation Institute Scientific Program Report. J. Paul Getty Museum, Santa Monica, Calif.

American Society for Industrial Security, Standing Committee on Museum, Library and Archive Security. 1990. *Suggested Guidelines in Museum Security.* American Society for Industrial Security, Arlington, Va.

Babcock, P. 1990. Ready for the worst. *Museum News.* 69(3):50–54.

Barton, J. P., and J. G. Wellheiser (eds.). 1985. *An Ounce of Prevention: A Handbook on Disaster Contingency Planning for Archives, Libraries and Record Centres.* Toronto Area Archivists Group Education Foundation, Toronto, Ontario, Canada.

Burke, R. B., and S. Adeloye. 1986. *A Manual of Basic Museum Security.* International Council of Museums, International Committtee on Museum Security, Paris, France.

Cornu, E., and L. Bone. 1991. Seismic disaster planning: Preventive measures make a difference. *Newsletter of the Western Association for Art Conservation* 13(3):13–19.

Faulk, W. 1993. Are you ready when disaster strikes? *History News* 48(1):4–11.

Fennelly, L. J. (ed.). 1983. *Museum, Archive and Library Security.* Butterworth Publishers, London, England.

Fortson, J. 1992. *Disaster Planning and Recovery: A How-to-Do-It Manual for Librarians and Archivists.* Neal-Schuman Publishers, New York.

Hendriks, K. B., and B. Lesser. 1983. Disaster preparedness and recovery: Photographic materials. *American Archivist* 46(1):52–68.

Holland, M., and L. Lawrence. 1991. Records recovery and terrorism. *Conservation Administration News* (47):1–3, 15, 22.

Hunter, J. 1990. Museum collections: Emergency planning. Pp. 10:1–10:29 in *Museum Handbook, Part 1: Museum Collections.* National Park Service, Washington, D.C.

Hunter, K. 1984. Survival of packaging materials in a fire. *UKIC News* [United Kingdom Institute for Conservation] 23:15–16.

Jacob, K. H., and C. J. Turkstra (eds.). 1989. *Earthquake Hazards and the Design of Constructed Facilities in the Eastern United States.* Annals of New York Academy of Sciences, Volume 558. New York Academy of Sciences, New York.

Jones, B. G. 1990. Litany of losses. *Museum News* 69(3):56–58.

Jones, B. G. 1986. *Protecting Historic Architecture and Museum Collections from Natural Disasters.* Butterworth Publishers, London, England.

Knapp, T., and J. Hunter. 1990. Museum collections protection: Security and fire protection. Pp. 9:1–34 in *Museum Handbook, Part 1: Museum Collections.* National Park Service, Washington, D.C.

Lindblom, B. C., and K. Motylewski. 1993. Disaster planning for cultural institutions. *History News,* 48(1,Supplement):1–8. Nashville, Tenn.

Mathieson, D. F. 1983. Hurricane preparedness: Establishing workable policies for dealing with storm threats. *Technology and Conservation* 8(2):28–29.

Morris, J. 1986. *The Library Disaster Preparedness Handbook.* American Library Association, Chicago.

Musson, M., and H. L. Crook. 1991. Earthquake preparedness planning. *Disaster Recovery Journal* 4(3):30–33.

National Fire Protection Association, Technical Committee on Protection of Cultural Resources. 1991. *Recommended Practice for the Protection of Libraries and Library Collections.* ANSI/NFPA 910. National Fire Protection Association, Quincy, Mass.

National Fire Protection Association, Technical Committee on Protection of Cultural Resources. 1991. *Recommended Practice for the Protection of Museums and Museum Collections.* ANSI/NFPA 911. National Fire Protection Association, Quincy, Mass.

National Institute for the Conservation of Cultural Property. 1991. *Emergency Preparedness and Response.* Materials developed from the NIC seminar, 17 October 1990, Washington, D.C. National Institute for the Conservation of Cultural Property, Washington, D.C.

Nelson, C. L. 1991. *Protecting the Past from Natural Disasters.* Preservation Press, National Trust for Historic Preservation, Washington, D.C.

O'Connell, M. 1983. Disaster planning: Writing and implementing plans for collections-holding institutions. *Technology and Conservation* 8(2):18–24.

Solley, T. T., J. Williams and L. Baden (eds.). 1987. *Planning for Emergencies: A Guide for Museums.* Association of Art Museum Directors, Washington, D.C.

Tillotson, R. G. 1977. *Museum Security/La Securité dans les Musées.* International Council of Museums, International Committee on Museum Security, Paris, France.

Upton, M. S., and C. Pearson. 1978. *Disaster Planning and Emergency Treatments in Museums, Art Galleries, Libraries, Archives and Allied Institutions.* Institute for the Conservation of Cultural Material, Canberra, Australia.

Waters, P. 1979. *Procedures for Salvage of Water-Damaged Library Materials.* 2nd edition. Library of Congress, Washington, D.C.

Ethics, Standards and Guidelines

American Association of Museums. 1991. *Code of Ethics for Museums.* American Association of Museums, Washington, D.C.

American Institute for Conservation of Historic and Artistic Works, Committee on Ethics and Standards. 1979. *Code of Ethics and Standards of Practice.* American Institute for Conservation of Historic and Artistic Works, Washington, D.C.

American Ornithologists' Union. 1975. Report of the Ad Hoc Committee on Scientific and Educational Use of Wild Birds. *Auk* 92(3, Supplement):1A–27A.

Association of Systematics Collections. 1992. Report from the ASC Workshop on Data Sharing and Database Ethics. *ASC Newsletter* 20(6):157, 159–165.

Association of Systematics Collections. 1975. *Report of the Council on Standards, Subcommittee on Preservation.* Association of Systematics Collections, Lawrence, Kan.

Bassett, M. (ed.). 1979. *Curation of Palaeontological Material.* Special Papers in Palaeontology No. 22. The Palaeontological Association, London, England.

Billington, J. H. 1987. *The Moral Imperative of Conservation.* Address presented at "Invest in the American Collection," a regional forum on conservation of cultural property. National Committee to Save America's Cultural Collections, Washington, D.C.

Cannell, P. F., M. R. Bakst and C. S. Asa. 1988. Suggestions regarding alcoholic bird collections. *The Condor* 90:500–503.

Cato, P. S. 1986. *Guidelines for Managing Bird Collections.* Museology No. 7. Texas Tech University Press, Lubbock.

Cato, P. S., and D. J. Schmidly. 1991. Policies concerning the use and management of ancillary preparations in vertebrate systematics collections. Pp. 91–104 in *Natural History Museums: Directions for Growth* (P. Cato and C. Jones, eds.). Texas Tech University Press, Lubbock.

Choate, J. R. 1978. Revised minimal standards for systematic collections of mammals. *Journal of Mammalogy* 59(4):911–914.

Cooper, J. A. 1987. Conservation documentation. Pp. 407–412 in *The Conservation of Geological Material* (P. Crowther and C. Collins, eds.). *Geological Curator* 4(7):375–474.

Dunn, P. J. 1992. The discreditation of mineral species: Guidelines endorsed by the Commission on New Minerals and Mineral Names. *Mineralogical Record* 22(2):91–94.

Dunn, P. J., and J. A. Mandarino. 1988. Guest editorial: The preservation of type mineral specimens. *Mineralogical Record* 19(July–August):226–227.

Fitzgerald, G. 1988. Documentation guidelines for the preparation and conservation of paleontological and geological specimens. *Collection Forum* 4(2):38–45.

Forman, L., and D. Bridson (eds.). 1989. *The Herbarium Handbook.* Royal Botanic Gardens, Kew, England.

Frey, J. K., T. L. Yates, D. W. Duszynski, W. L. Gannon and S. L. Gardner. 1992. Designation and curatorial management of type host specimens (symbiotypes) for new parasite species. *Journal of Parasitology* 78(5):930–932.

Garrett, K. L. 1989. Documentation guidelines for the preparation and conservation of biological specimens. *Collection Forum* 5(2):47–51.

Genoways, H. H. 1988. Philosophy and ethics of museum collection management. Pp. 5–26 in *Management of Mammal Collection[s] in Tropical Envrionment[s]* (B. Tikader, ed.). Proceedings of the Workshop on Management of Mammal Collections in Tropical Environments, Calcutta, 19–25 January 1984. Zoological Survey of India, Calcutta, India.

Geological Curators' Group. 1982. Recommendations for the preservation of research collections. *The Geological Curator* 3(5):290–291.

Hawksworth, D. L. (ed.). 1990. *Guidelines for the Establishment and Operation of Collections of Cultures of Microorganisms.* World Federation for Culture Collections, Richmond, Surrey, England.

Hoagland, K. E. 1990. Natural history museums and the public trust: Meeting the challenge of the biological diversity crisis. *Environment West* (Spring):4–5.

Hoagland, K. E. 1989. Socially responsible. *Museum News* 68(5):50–52.

International Commission on Zoological Nomenclature. 1985. *International Code of Zoological Nomenclature.* 3rd edition. International Trust for Zoological Nomenclature and the British Museum (Natural History), London, England.

International Council of Museums. 1990. *ICOM Statutes and Code of Professional Ethics.* International Council of Museums, Paris, France.

International Institute for Conservation–Canadian Group and Canadian Association of Professional Conservators. 1989. *Code of Ethics and Guidance for Practice for Those Involved in the Conservation of Cultural Property in Canada.* 2nd edition. International Institute for Conservation–Canadian Group and Canadian Association of Professional Conservators, Ottawa, Ontario, Canada.

Kushel, D. 1980. *Photodocumentation for Conservation: Procedural Guidelines and Photographic Concepts and Techniques.* American Institute for Conservation of Historic and Artistic Works, Washington, D.C.

Lee, W. L., B. Bell and J. Sutton (eds.). 1982. *Guidelines for Acquisition and Management of Biological Specimens.* Report of the Conference on Voucher Specimen Management. Association of Systematics Collections, Lawrence, Kan.

Leifer, J. C., and M. B. Glomb. 1992. *The Legal Obligations of Nonprofit Boards: A Guidebook for Board Members.* National Center for Nonprofit Boards, Washington, D.C.

Malaro, M. C. 1989. Collections care and accountability: Legal and ethical standards. Pp. 379–400 in *Legal Problems of Museum Administration, ALI–ABA Course of Study Materials, 20–22 March 1989, Washington.* American Law Institute, Philadelphia.

Malaro, M. C. 1985. *A Legal Primer on Managing Museum Collections.* Smithsonian Institution Press, Washington, D.C.

McGuire, P. E., L. S. Kimsey and S. L. Gardner (eds.). 1993. *Management of University Biological Collections: A Framework for Policy and Practice.* Task Force Report No. 11. Genetic Resources Conservation Program, Division of Agriculture and Natural Resources, University of California, Davis.

McLaren, S. B. 1992. On database accessibility. *ASC Newsletter* 20(6):158–159.

Meester, J. 1990. The importance of retaining voucher specimens. Pp. 123–127 in *Natural History Collections: Their Management and Value* (E. Herholdt, ed.). Special Publication No. 1. Transvaal Museum, Pretoria, South Africa.

Merritt, E. 1992. Conditions of outgoing research loans. *Collection Forum* 8(2):78–82.

Museums and Galleries Commission. 1991. *Standards in the Museum Care of Biological Collections: Final Draft.* Museums and Galleries Commission, London, England.

Nakamura, L. K. 1989. Culture collection guidelines. *U.S. Federation for Culture Collections Newsletter* 19(2):1,4–6.

Perry, L. G., M. A. Jawer, J. T. Murdoch and J. C. Dinegar. 1991. *ADA Compliance Guidebook: A Checklist for Your Building.* Building Owners and Managers Association International, Washington, D.C.

Peterson, G. M., and T. H. Peterson. 1985. *Archives and Manuscripts: Law.* Society of American Archivists, Chicago.

Pogeta, J. 1993. Paleontological collecting. *Geotimes* 38(2):11.

Reynolds, D., and J. Taylor. 1991. DNA specimens and the "International Code of Botanical Nomenclature." *Taxon* 40:311–315.

Ride, W. D. 1973. Conservation from the viewpoint of the responsibilities of a museum director. Pp. 9–13, in *Proceedings of the National Seminar on Conservation of Cultural Material, Perth, August 1973* (C. Pearson and G. L. Pretty, eds.). Institute for Conservation of Cultural Material, Canberra, Australia.

Saito, K. 1992. *A Primer on Endangered Species Law: Obtaining Federal Permits for Specimens Protected by Endangered Species Laws.* Office of the Registrar, Smithsonian Institution, Washington, D.C.

Simmons, J. E. 1987. *Herpetological Collecting and Collections Management.* Herpetological Circular 16. Society for the Study of Amphibians and Reptiles, St. Louis.

Society for the Preservation of Natural History Collections, Conservation Committee—Assessment Subcommittee. 1990. Defining Standard Procedures for Assessing the Condition of a Fluid-Preserved Collection. Pp. 437–440 in *Preprints of the ICOM Committee for Conservation 9th Triennial Meeting, Dresden, Germany, 26–31 August 1990* (K. Grimstad, ed.). International Council of Museums, Committee for Conservation, Los Angeles.

Solem, A., W. K. Emerson, B. Roth and F. G. Thompson. 1981. Standards for malacological collections. *Curator* 24(1):77–86.

Swinton, W. E. 1955. *Type Specimens in Botany and Zoology: Recommendations for their Conservation in Natural History Museums and General Museums.* International Council of Museums, Paris, France.

Thompson, J. M. (ed.). 1992. *Manual of Curatorship: A Guide to Museum Practice.* Butterworth-Heinemann, Oxford, England.

Ullberg, A. D., and R. C. Lind. 1989. Consider the potential liability of failing to conserve collections. *Museum News* 68(1):32–33.

Ullberg, A. D., and P. Ullberg. 1981. *Museum Trusteeship.* American Association of Museums, Washington, D.C.

Waller, R. R. 1987. A view of ethical conservation and mineral specimen falsification. Pp. 433–437 in *The Conservation of Geological*

Material (P. Crowther and C. Collins, eds.). *Geological Curator* 4(7):375–474.

Ward, P. 1986. *The Nature of Conservation: A Race Against Time.* Getty Conservation Institute, Marina del Rey, Calif.

White, J. S. 1991. Some aspects of modern mineral specimen curation. *Mineralogical Record* 22(4):251–254.

Williams, S. L., R. Laubach and H. H. Genoways. 1977. *A Guide to the Management of Recent Mammal Collections.* Special Publication No. 4. Carnegie Museum of Natural History, Pittsburgh.

Health and Safety

American Geological Institute. 1992. *Planning for Field Safety.* American Geological Institute, Alexandria, Va.

Blount, A. M. 1990. A low-cost radioactivity test for geologic specimens. *Collection Forum* 6(1):8–11.

Bretherick, L. 1990. *Handbook of Reactive Chemical Hazards.* 4th edition. Butterworth-Heinemann, Oxford, England.

Briggs, D., P. Sell, M. Block and R. I'Ons. 1983. Mercury vapor: A health hazard in herbaria. *New Phytologist* 94:453–457.

Carman, M. R., and J. D. Carman. 1989. Health considerations of radon source fossil vertebrate specimens. *Collection Forum* 5(1):5–10.

Clark, N., T. Cutter and J-A. McGrane. 1984. *Ventilation: A Practical Guide.* Center for Occupational Hazards [now Center for Safety in the Arts], New York.

Cosgrove, J. A., D. F. Donaldson, G. W. Hughes and W. W. Maloff. 1992. Plague at the museum: Disease transmission potential and biosafety precautions. *Collection Forum* 8(1):1–8.

Hawks, C. A., and D. W. Von Endt. 1990. Mercury and mercury compounds in natural history collections: An annotated bibliography. *Natural History Conservation* [newsletter of ICOM Committee for Conservation, Natural History Working Group] (5):4–19.

Hawks, C. A., and S. L. Williams. 1986. Arsenic in natural history collections. *Leather Conservation News* 2:(2):1–4.

Howie, F. M. 1992. Hazards for the mineral collector, conservator and curator. Pp. 114–121 in *The Care and Conservation of Geological Material: Minerals, Rocks, Meteorites and Lunar Finds* (F. M. Howie, ed.). Butterworth-Heinemann, Oxford, England.

Howie, F. M. 1987. Safety considerations for the geological conservator. Pp. 379–401 in *The Conservation of Geological Material* (P. Crowther, C. Collins, eds.). *Geological Curator* 4(7):375–474.

Howie, F. M. (ed.). 1987. *Safety in Museums and Galleries.* Butterworth Publishers, London, England.

Irvin, A. D., J. E. Cooper and S. R. Hedges. 1972. Possible health hazards associated with the collection and handling of post-mortem zoological material. *Mammal Review* 2(2):43–54.

Knapp, T., W. Meuse and B. Rogers. 1990. Introduction to curatorial health and safety. Pp. 11:1–11:27 in *Museum Handbook, Part 1: Museum Collections.* National Park Service, Washington, D.C.

Muir, D., M. Lovell and C. P. Peace. 1981. Health hazards in natural history museum work. *Museums Journal* 80:205–206.

National Research Council, Committee on Hazardous Substances in the Laboratory. 1983. *Prudent Practices for Disposal of Chemicals from Laboratories.* National Academy Press, Washington, D.C.

National Research Council, Committee on Hazardous Substances in the Laboratory. 1981. *Prudent Practices for Handling Hazardous Chemicals in Laboratories.* National Academy Press, Washington, D.C.

Pabst, R. 1987. Exposure to formaldehyde in anatomy: An occupational health hazard? *Anatomical Record* 219:109–112.

Puffer, J. H. 1980. Toxic minerals. *The Mineralogical Record* (Jan.–Feb.):5–11.

Richardson, J. H., and W. E. Barkley (eds.). 1988. *Biosafety in Microbiological and Biomedical Laboratories.* 2nd edition. HHS Publication No. (NIH) 88-8395. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and National Institutes of Health,Washington, D.C.

Riedmiller, A., P. L. Hauff and R. W. Mathias. 1984. *The Dangers and Handling of Hazardous Chemicals in the Geologic Laboratory.* Geological Survey Circular 924. United States Geological Survey, Washington, D.C.

Rossol, M. 1993. Using TLVs for common-sense risk assessment for solvents. *AIC News* [American Institute for Conservation] 18(1):1–5.

Technology and Conservation. 1988. Occupational health and safety organizations: A directory of government and professional associations. *Technology and Conservation* 9(3–4):31–39.

Thorn, A. 1992. Safer solubility. *Studies in Conservation* 37(1):12–21.

Waddington, J., and J. Fenn. 1986. Health and safety in natural history museums: An annotated reading list. Pp. 117–121 in *Proceedings of the 1985 Workshop on Care and Maintenance of Natural History Collections* (J. Waddington and D. Rudkin, eds.). Life Sciences Miscellaneous Publications. Royal Ontario Museum, Toronto, Ontario, Canada.

Waller, R. R., and D. E. McAllister. 1986. A spot test for distinguishing formalin from alcohol solutions. Pp. 93–99 in *Proceedings of the 1985 Workshop on Care and Maintenance of Natural History Collections* (J. Waddington and D. Rudkin, eds.). Life Sciences Miscellaneous Publications. Royal Ontario Museum, Toronto, Ontario, Canada.

Historical Perspective

Alderson, W. T. (ed.). 1992. *Mermaids, Mummies, and Mastodons: The Emergence of the American Museum*. Baltimore City Life Museums and American Association of Museums, Washington, D.C.

Barber, L. 1980. *The Heyday of Natural History: 1820–1870.* Doubleday, Garden City, N.Y.

Barclay, B. 1992. CCI [Canadian Conservation Institute]: The first twenty years. *CCI Newsletter* (10):1–4.

Edwards, W. 1976. *The Early History of Palaeontology.* British Museum (Natural History), London, England.

Faber, P. L. 1982. The development of taxidermy and the history of ornithology. *Isis* 68(244):550–566.

Faber, P. L. 1977. The type-concept in zoology during the first half of the nineteenth century. *Journal of the History of Biology* 9(1):93–119.

Goode, G. B. 1991. *The Origins of Natural Science in America: Essays of George Brown Goode* (S. G. Kohlstedt, ed.). Smithsonian Institution Press, Washington, D.C., and London, England.

Howie, F. M. 1986. Conserving and mounting fossils: A historical review. *Curator* 29(1):5–24.

Howie, F. M. 1984. Materials used for conserving fossil specimens since 1930. Pp. 92–97 in *Adhesives and Consolidants* (N. Bromelle, E. Pye, P. Smith and G. Thomson, eds.). International Institute for Conservation, London, England.

Porter, C. 1991. Natural history in the 20th century: An oxymoron? Pp. 221–237 in *Natural History Museums: Directions for Growth* (P. Cato and C. Jones, eds.). Texas Tech University Press, Lubbock.

Ripley, S. D. 1975. Cabinets, lost and found. *Transactions of the Connecticut Academy of Arts and Sciences* 46:1–12.

Ritterbush, P. 1969. Art and science as influences on the early development of natural history collections. *Proceedings of the Biological Society of Washington* 82:561–578.

Sheets-Pyenson, S. 1988. *Cathedrals of Science: The Development of Colonial Natural History Museums During the Late Nineteenth*

Century. McGill-Queen's University Press, Kingston, Ontario, and Montreal, Quebec, Canada.

Viola, H. J., and C. Margolis (eds.). 1985. *Magnificent Voyagers: The U.S. Exploring Expedition, 1838–1842*. Smithsonian Institution Press, Washington, D.C.

Wagstaffe, R., and J. H. Fidler. 1955 and 1968. *The Preservation of Natural History Specimens, Volumes I and II*. Witherby Ltd., London, England.

Whybrow, P. 1985. A history of fossil collecting and preparation techniques. *Curator* 28(1):5–26.

Williams, S. L., and C. A. Hawks. 1987. History of preparation materials used for Recent mammal specimens. Pp. 21–49 in *Mammal Collection Management* (H. Genoways, C. Jones and O. Rossolimo, eds.). Texas Tech University Press, Lubbock.

Pest Control

Bloomcamp, L. 1987. Pest control and pesticide usage in museums and systematics collections. *ASC Newsletter* 15(4):40–41.

Caneva, G., M. P. Nugari and O. Salvadori. 1991. *Biology in the Conservation of Works of Art*. International Centre for the Study of the Preservation and Restoration of Cultural Property, Rome, Italy.

Dawson, J. E., revised by T. J. Strang. 1991. *Solving Museum Insect Problems: Chemical Control*. Technical Bulletin No. 15. Canadian Conservation Institute, Ottawa, Ontario, Canada.

Ebeling, W., and C. F. Forbes. 1988. Sand barriers for subterranean termite control. *IPM Practitioner* 10(5):1–5.

Ebeling, W., C. F. Forbes and S. Ebeling. 1989. Heat treatment for powderpost beetles. *IPM Practitioner* 11(9):1–4.

Florian, M-L. 1990. Freezing for museum insect pest eradication. *Collection Forum* 6(1):1–7.

Florian, M-L. 1990. The effects of freezing and freeze-drying on natural history specimens. *Collection Forum* 6(2):45–52.

Florian, M-L. 1987. The effect on artifact materials of the fumigant ethylene oxide and freezing used in insect control. Pp. 199–208 in *Preprints of the ICOM Committee for Conservation 8th Triennial Meeting, Sydney, Australia, 6–11 September 1987*. Getty Conservation Institute, Marina del Rey, Calif.

Florian, M-L. 1986. The freezing process—effects on insects and artifact materials. *Leather Conservation News* 3(1):1–13, 17.

Gilberg, M. 1992. Pheromone traps for monitoring insect pest in museums. *Bulletin of the IIC–CG* [International Institute for Conservation–Canadian Group] 17(2):9–11.

Gilberg, M. 1991. The effects of low oxygen atmospheres on museum pests. *Studies in Conservation* 36(2):93–98.

Gilberg, M. 1989. Inert atmosphere fumigation of museum objects. *Studies in Conservation* 34(2):80–84.

Gilberg, M., and A. Brokerhof. 1991. The control of insect pests in museum collections: The effects of low temperature on *Stegobium paniceum* (Linnaeus), the drugstore beetle. *Journal of the American Institute for Conservation* 30(2):197–201.

Gilberg, M., and A. Roach. 1991. The use of a commercial pheromone trap for monitoring *Lasioderma serricorne* (F.) infestations in museum collections. *Studies in Conservation* 36(4):243–247.

Hall, A. V. 1988. Pest control in herbaria. *Taxon* 37(4):885–907.

Hawks, C. A., and W. F. Rowe. 1988. Deterioration of hair by airborne microorganisms: Implications for museum biological collections. Pp. 461–465 in *Biodeterioration 7* (D. Houghton, R. Smith and H. Eggins, eds.). International Biodeterioration Society and Elsevier Applied Science Publishers, Essex, England.

Hill, S. R. 1983. Microwave and the herbarium specimen: Potential dangers. *Taxon* 32(4):614–615.

Horie, C. V., and R. G. Murphy (eds.). 1988. *Conservation of Natural History Specimens—Vertebrates.* Proceedings of the short course at Manchester University. Manchester Museum and Department of Environmental Biology, University of Manchester, Manchester, England.

Hugo, W. B. 1991. The degradation of preservatives by microorganisms. *International Biodeterioration* 27:185–194.

Jessup. W. C. 1990. Biological infestations. Pp. 5:1–5:44 in *Museum Handbook, Part 1: Museum Collections.* National Park Service, Washington, D.C.

Koestler, R. J., and J. Vedral. 1991. Biodeterioration of cultural property: A bibliography. *International Biodeterioration* 28:299–340.

Lee, M. W. 1989. *Prevention and Treatment of Mold in Library Collections with an Emphasis on Tropical Climates.* UNESCO Press, Paris, France.

Olkowski, W., and H. Olkowski. 1987. Pests that damage paper: Silverfish, firebrats and booklice. *Common Sense Pest Control Quarterly* [Bio-Integral Resource Center, Berkeley] 3(1):9–13.

Olkowski, W., H. Olkowski and S. Daar. 1988. What is IPM? *Common Sense Pest Control Quarterly* [Bio–Integral Resource Center, Berkeley] 4(3):9–16.

Peltz, P., and M. Rossol. 1983. *Safe Pest Control Procedures for Museum Collections.* Data Sheet. Center for Safety in the Arts, New York.

Pinniger, D. 1989. *Insect Pests in Museums.* Institute of Archaeology Publications, London, England.

Strang, T. J. 1992. A review of published temperatures for the control of pest insects in museums. *Collection Forum* 8(2):41–67.

Strang, T. J. 1992. Museum pest management. Technical Appendix, in *A Systematic Approach to the Conservation (Care) of Museum Collections* (S. Michalski, ed.). Canadian Conservation Institute, Ottawa, Ontario, Canada.

Strang, T. J., and J. E. Dawson. 1991. *Controlling Museum Fungal Problems.* Technical Bulletin No. 12. Canadian Conservation Institute, Ottawa, Ontario, Canada.

Strang, T. J., and J. E. Dawson. 1991. *Controlling Vertebrate Pests in Museums.* Technical Bulletin No. 13. Canadian Conservation Institute, Ottawa, Ontario, Canada.

Stansfield, G. 1985. Pest control—A collections management problem. *Museums Journal* 85(2):97–99.

Story, K. O. 1985. *Approaches to Pest Management in Museums.* Conservation Analytical Laboratory, Smithsonian Institution, Washington, D.C.

Valentin, N., M. Lidstrom and F. P. Preusser. 1990. Microbial control by low oxygen and low relative humidity environment. *Studies in Conservation* 35(4):222–230.

Valentin, N., and F. P. Preusser. 1990. Insect control by inert gases in museums, archives and libraries. *Restaurator* 11:22–23.

Von Endt, D. W., and W. C. Jessup. 1986. The deterioration of protein materials in museums. Pp. 332–337 in *Biodeterioration 6* (S. Barry and D. Houghton, eds.). CAB International Mycological Institute and The Biodeterioration Society, London, England.

Williams, S. L., C. A. Hawks and S. Weber. 1986. Considerations in the use of DDVP resin strips for insect pest control in biological research collections. Pp. 344–350 in *Biodeterioration 6* (S. Barry and D. Houghton, eds.). CAB International Mycological Institute and The Biodeterioration Society, London, England.

Williams, S. L., and S. B. McLaren. 1990. Modification of storage design to mitigate insect problems. *Collection Forum* 6(1):27–32.

Williams, S. L., and E. A. Walsh. 1989. The effects of DDVP on the life stages of a museum insect pest. *Curator* 32(1):34–41.

Williams, S. L., and E. A. Walsh. 1989. Behavior of DDVP in storage cases. *Curator* 32(1):41–49.

Williams, S. L., E. A. Walsh and S. Weber. 1989. Effect of DDVP on museum materials. *Curator* 32(1):49–69.

Zycherman, L. A., and J. R. Schrock (eds.). 1988. *A Guide to Museum Pest Control.* Foundation of the American Institute for Conservation of Historic and Artistic Works and Association of Systematics Collections, Washington, D.C.

State and Status of Collections

Agrawal, V. C., and S. Chakraborty. 1987. India: Maintenance problems in developing nations. Pp. 185–193 in *Mammal Collection Management* (H. Genoways, C. Jones and O. Rossolimo, eds.). Texas Tech University Press, Lubbock.

American Association of Museums. 1992. Forum: Toward working with university natural history museums. *Curator* 35(2):93–94.

American Association of Museums. 1992. *Data Report from the 1989 National Museums Survey.* American Association of Museums, Washington, D.C.

American Association of Museums. 1985. *Collections Management, Maintenance and Conservation: A Study of America's Collections.* American Association of Museums and Institute of Museum Services, Washington, D.C.

American Association of Museums. 1984. *Museums for a New Century: A Report of the Commission on Museums for a New Century.* American Association of Museums, Washington, D.C.

American Association of Museums. 1968. *America's Museums: The Belmont Report.* American Association of Museums, Washington, D.C.

Anderson, S., and J. R. Choate (Co-Chairmen). 1974. *Report and Recommendations of the Advisory Committee for Systematic Resources in Mammalogy.* American Society of Mammalogists.

Biology Curators Group. 1991. *The Sunflower Campaign: Biology Collections in Crisis.* Biology Curators' Group, London, England.

Bryant, J. M. 1983. Biological collections—legacy or liability? *Curator* 26(3):203–218.

Cato, P. S. In press. The effect of governance structure on the characteristics of a sample of natural history-oriented museums. *International Journal of Museum Management and Curatorship* 11(4).

Cato, P. S. 1992. The relationship between type of institution and institutional characteristics. *International Journal of Museum Management and Curatorship* 11(2):153–170.

Cato, P. S., and C. Jones (eds.). 1991. *Natural History Museums: Directions for Growth.* Texas Tech University Press, Lubbock.

Cleevely, R. J. 1983. *World Palaeontological Collections.* British Museum (Natural History), London, England.

Cohen, D. M., and R. F. Cressey (eds.). 1969. *Natural History Collections: Past, Present and Future.* Biological Society of Washington, Washington, D.C. *Proceedings of the Biological Society of Washington* 22:559–762.

Conference of Directors of Systematic Collections. 1971. *The Systematic Biology Collections of the United States: An Essential Resource. Parts I and II. The Great Collections: Their Nature, Importance, Condition and Future.* Report to National Science Foundation. New York Botanical Garden, Bronx, N.Y.

Croat, T. 1978. Survey of herbarium problems. *Taxon* 27:203–218.

Culotta, E. 1992. News and comment: Museums cut research in hard times. *Science* 256(5061):1268–1271.

Danks, H. V. 1991. Museum collections: Fundamental values and modern problems. *Collection Forum* 7(2):95–11.

Davis, G. M., W. D. Duckworth, P. H. Raven, E. O. Wilson, K. E. Hoagland and B. Chernoff (eds.). 1989. *Systematics Collections Resources for the 1990s: A Report to the National Science Foundation.* Association of Systematics Collections and National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Dessauer, H. C., and M. S. Hafner (eds.). 1984. *Collections of Frozen Tissues: Value, Management, Field and Laboratory Procedures, and Directory of Existing Collections.* Association of Systematics Collections, Lawrence, Kan.

Diamond, J. 1992. Forum: Issues confronting university natural history museums. *Curator* 35(2):91–93.

Doughty, P. S. 1981. *The State and Status of Geology in U.K. Museums.* Miscellaneous Paper No. 13. Geological Society of London, London, England.

Fink, W. L., K. E. Hartel, W. G. Saul, E. M. Koon and E. O. Wiley. 1979. *A Report On Current Supplies and Practices Used in Curation of Ichthyological Collections.* American Society of Ichthyologists and Herpetologists, Washington, D.C.

Foster, M. S. 1982. The research natural history museum: Pertinent or passé. *The Biologist* 64(1):1–12.

Glenister, B. F., T. E. Bolton, T. W. Broadhead, N. Eldredge, N. Silberling, W. C. Sweet and T. R. Waller. 1977. *Fossil Invertebrates—Collections in North American Repositories 1976.* Report of the Paleontological Society Ad Hoc Committee on

North American Resources in Invertebrate Paleontology (CONARIP). Paleontological Society and University of Iowa, Iowa City.

Hoagland, K. E. 1992. Forum: University natural history museums and public service. *Curator* 35(2):89–90.

Hoagland, K. E., and P. M. Mabee. 1988. ASC Workshop on Collections Resources for the 1990s. *ASC Newsletter* 16(6):1, 3–8.

House of Lords Select Committee on Science and Technology. 1991. *Systematic Biology Research, Volume I–Report.* House of Lords Session 1991–91, 1st Report, HL Paper 22-1. HMSO, London, England.

Howie, F. M. 1986. Conserving natural history collections: Some present problems and strategies for the future. Pp. 1–6 in *Proceedings of the 1985 Workshop on Care and Maintenance of Natural History Collections* (J. Waddington and D. Rudkin, eds.). Life Sciences Miscellaneous Publications. Royal Ontario Museum, Toronto, Ontario, Canada.

Humphrey, P. S. 1992. University natural history museum systems. *Curator* 35(1):49–70.

Humphrey, P. S. 1992. Forum: More on university natural history museum systems. *Curator* 35(3):174–179.

Humphrey, P. S. 1991. The nature of university natural history museums. Pp. 5–11 in *Natural History Museums: Directions for Growth* (P. Cato and C. Jones, eds.). Texas Tech University Press, Lubbock.

International Mineralogical Association, Commission on Museums. 1977. *World Directory of Mineral Collections.* 2nd edition. International Mineralogical Association, Copenhagen, Denmark.

International Symposium and First World Congress on the Preservation and Conservation of Natural History Collections, Congress Resolutions Commission. 1992. Resolutions. Pp. 14–20 in *Resolutions, Awards and Directory* (M. Ali Gago, ed.). Comité de Organización del Simposio Internacional y Primer Congreso Munidal sobre Preservación y Conservación de Colecciones de Historia Natural and Sociedad para el Desarrollo de la Historial Natural, Madrid, Spain.

Irwin, H. S., W. W. Payne, D. M. Bates and P. S. Humphrey. 1973. *America's Systematics Collections: A National Plan.* Association of Systematics Collections, Lawrence, Kan.

Jeffrey, C. 1991. The condition of the Leningrad Herbarium. *Taxon* 40:459–460.

Knell, S., and M. Taylor. 1991. Museums on the rocks. *Museums Journal* 91(1):23–25.

King, J. R., and W. J. Bock. 1978. *Workshop on a National Plan for Ornithology.* Final report submitted to National Science Foundation and Council of the American Ornithologists' Union. American Ornithologists' Union.

Lachner, E. A., J. W. Atz, G. W. Barlow, B. B. Collette, R. J. Lavenberg, C. Richard Robins and R. J. Schultz. 1976. *A National Plan for Ichthyology.* Report to American Society of Ichthyologists and Herpetologists by ASIH Advisory Committee. American Society of Ichthyologists and Herpetologists.

Langston, W., R. L. Carroll, C. L. Gazin, J. A. Lillegraven, T. H. Patton, A. S. Romer and R. W. Wilson. 1972. *Fossil Vertebrates in the United States, 1972.* Report of an Ad Hoc Committee of the Society of Vertebrate Paleontology on the Status of Fossil Vertebrate Conservation in the United States. Society of Vertebrate Paleontology.

Mabee, P. M., and K. E. Hoagland. 1988. Progress and needs of systematics collections. *ASC Newsletter* 16(6):1, 8–9.

Mares, M. A. 1988. *Heritage at Risk: Oklahoma's Hidden Treasure.* Oklahoma Museum of Natural History, Norman.

McAlpine, D. 1986. Curators and natural history collections: Have we become islands in science? Pp. 7–14 in *Proceedings of the 1985 Workshop on Care and Maintenance of Natural History Collections* (J. Waddington and D. Rudkin, eds.). Life Sciences Miscellaneous Publications. Royal Ontario Museum, Toronto, Ontario, Canada.

McGinley, R. J. 1990. Entomological collection management—Are we really managing? *ASC Newsletter* 18(2):30–31.

McGuire, P. E., M. L. Warburton, L. S. Kimsey and S. L. Garner (eds.). 1992. *Biological Collections at the University of Calif, Davis: Scope, Status, and Needs.* Report No. 9. Genetic Resources Conservation Program, Division of Agriculture and Natural Resources, University of California, Davis.

Miller, D. R. 1989. Some thoughts on collections in the 1990s. *ASC Newsletter* 17(1):4.

Miller, S. E. 1991. Biological diversity and the need to nurture systematics collections. *American Entomologist* 37(2):76.

Miller, S. E. 1991. Entomological collections in the United States and Canada: Current status and growing needs. *American Entomologist* 37(2):77–84.

Morgan, P. 1986. Natural science collection resources: A report on the working party's survey. *Museums Journal* 86:145–146.

Morgan, P. (ed.). 1986. *A National Plan for Systematics Collections?* Proceedings of a conference held at the National Museum of Wales, Cardiff, 6–9 July 1982. National Museum of Wales, Cardiff, Wales.

Museums Association. 1988. *Biological Collections UK.* Museums Association, London, England.

Payne, W. W., T. B. Croat, M. E. Hale, P. K. Holmgren, R. McVaugh, R. Ornduff, A. E. Schuyler and R. F. Thorne. 1974. *Systematic Botany Resources in America, Part 1, Survey and Preliminary Ranking.* Report to National Science Foundation and to the botanical systematics collections community by the Advisory Committee for Systematic Resources in Botany, Section for American Systematics Collections, American Society of Plant Taxonomists. New York Botanical Garden, New York.

Pefaur, J. E. 1987. Latin America: Status of collections and management concerns. Pp. 195–214 in *Mammal Collection Management* (H. Genoways, C. Jones and O. Rossolimo, eds.). Texas Tech University Press, Lubbock.

Raath, M. A. 1990. Cinderellas of academe: The plight of university museum collections. Pp. 153–157 in *Natural History Collections: Their Management and Value* (E. Herholdt, ed.). Special Publication No.1. Transvaal Museum, Pretoria, South Africa.

Ramer, B. 1989. *A Conservation Survey of Museum Collections in Scotland.* Scottish Museums Council, Edinburgh, Scotland.

Rose, C. L., S. L. Williams and J. Gisbert (eds.). In press. *Current Issues, Initiatives, and Future Directions for the Preservation and Conservation of Natural History Collections.* International Symposium and First World Congress on the Preservation and Conservation of Natural History Collections, Madrid, Spain, 10–15 May 1992, Volume 3. Consejería de Educacíon y Cultura, Madrid, Spain.

Shetler, S. G. 1969. The herbarium: Past, present, and future. Pp. 687–758 in *Natural History Collections: Past, Present, and Future* (D. Cohen and R. Cressey, eds.). *Proceedings of Biological Society of Washington* 82:559–762.

Simmons, J. E. 1993. Natural history collections management in North America. *Journal of Biological Curation* 1(3–4):1–17.

Solem, A. 1975. The Recent mollusk collection resources of North America. *Veliger* 18:222–236.

Tikader, B. K. (ed.). 1988. *Management of Mammal Collection[s] in Tropical Environment[s].* Proceeding of the Workshop on Management of Mammal Collections in Tropical Environments, Calcutta, 9–25 January 1984. Zoological Survey of India, Calcutta, India.

Wake, D. B., R. G. Zweifel, H. C. Dessauer, G. W. Nace, E. R. Pianka, G. B. Rabb, R. Ruibal, J. W. Wright and G. R. Zug. 1975. Report of the Committee on Resources in Herpetology. *Copeia* (2):391–404.

West, R. M. 1988. Endangered and orphaned natural history and anthropology collections in United States and Canada. *Collection Forum* 4(2):65–74.

Wiktor, J., and R. Wladyslaw. 1991. *Bibliography of Catalogues of Type Specimens in World's Zoological and Palaeozoological Collections.* Wroclaw University Press, Wroclaw, Poland.

Williams, S. L., and C. A. Hawks. 1992. The condition of type specimens of the genus *Peromyscus. Journal of Mammalogy* 73(4):731–743.

Wonders, K. 1992. Sweden's biological museums. *Curator* 35(3):190–205.

Terminology

American Society for Testing Materials. 1990. *Compilation of ASTM Standard Definitions.* 7th edition. American Society for Testing Materials, Philadelphia.

Horie, C. V. 1990. Industrial standards of terminology for conservation. Pp. 473–486 in *Terminology for Museums* (D. A. Roberts, ed.). Museum Documentation Association, Cambridge, England.

Horie, C. V. 1989. Industrial standards of terminology for conservation of museum objects. *ASTM Standardization News* 17(4):40–43.

Schur, S. E. 1985–1992. Conservation terminology: A review of past and current nomenclature of materials. Parts 1–5. *Technology and Conservation* 9(1,1985):34–40; 9(2,1985):35–38; 9(3-4,1988):40–41; 10(1,1989):29–32; 11(1,1992):25–36.

Value and Use of Collections

Arnold, N. 1991. Biological messages in a bottle. *New Scientist* (24 Aug 91):25–27.

Banks, R. (ed.) 1979. *Museum Studies and Wildlife Management: Selected Papers.* Smithsonian Institution Press and U.S. Fish and Wildlife Service, Washington, D.C.

Bates, M. F. 1990. The hidden value of a reptile wet collection with special reference to the National Museum, Bloemfontein. Pp. 139–143 in *Natural History Collections: Their Management and Value* (E. Herholdt, ed.). Special Publication No. 1. Transvaal Museum, Pretoria, South Africa.

Becklund, W. W. 1969. The role of the national parasite collection in veterinary parasitology. Pp. 603–609 in *Natural History Collections: Past, Present and Future* (D. Cohen and R. Cressey, eds.). *Proceedings of the Biological Society of Washington* 82:559–762.

Cambray, J. A. 1990. The role of natural history museums in aquatic conservation. Pp. 127–137 in *Natural History Collections: Their Management and Value* (E. Herholdt, ed.). Special Publication No. 1. Transvaal Museum, Pretoria, South Africa.

Carter Shropshire, C., and R. T. Shropshire. 1991. Natural history museums as a function of wildlife management. Pp. 41–47 in *Natural History Museums: Directions for Growth* (P. Cato and C. Jones, eds.). Texas Tech University Press, Lubbock.

Cato, P. S. 1991. The value of natural history collections in Latin American conservation. Pp. 416–430 in *Latin American Mammalogy: History, Biodiversity and Conservation* (M. Mares and D. Schmidly, eds.). University of Oklahoma Press, Norman.

Challinor, D. 1983. Preservation for all posterity. *New Scientist* 99:959.

Challinor, D., and C. Kerby. 1984. Natural science collections as a global data bank. Pp. 84.13.4–7 in *Preprints of the 7th Triennial Meeting of the ICOM Committee for Conservation, Copenhagen, 1984.* International Council of Museums and J. Paul Getty Trust, Paris, France.

Committee on Science and Technology. 1986. *The Role of the Research Museums.* Science Policy Study Hearings, Volume 2. Hearing before the Task Force on Science Policy of the Committee on Science and Technology, House of Representatives, 99th Congress, First Session, April 17, 1985, No. 56. Washington, D.C.

Conference of Directors of Systematic Collections. 1971. *The Systematic Biology Collections of the United States: An Essential Resource. Parts I and II. The Great Collections—Their Nature, Importance, Condition and Future.* Report to National Science Foundation. New York Botanical Garden, Bronx, N.Y.

Corbitt G., A. S. Bailey and G. Williams. 1990. HIV infection in Manchester, 1959. *Lancet* 336:51.

Cowan, R. 1969. The national collections as biological standards. Pp. 611–617 in *Natural History Collections: Past, Present and Future* (D. Cohen and R. Cressey, eds.). *Proceedings of the Biological Society of Washington* 82:559–762.

Delibes, J., and A. Garcia-Valdecasas. 1987. Museo Nacional de Ciencias Naturales: Specimens of historical significance. Pp. 179–184 in *Mammal Collection Management* (H. Genoways, C. Jones and O. Rossolimo, eds.). Texas Tech University Press, Lubbock.

Diamond, J. M. 1990. Old dead rats are valuable. *Nature* 347:334–335.

Dubeau, L., L. Chandler, J. Gralow, P. Nichols and P. Jones. 1986. Southern blot analysis of DNA extracted from formalin-fixed pathology specimens. *Cancer Research* 46:2964–2969.

Finley, R. B. 1987. The value of research collections. *BioScience* 37(2):92.

Genoways, H. H., J. R. Choate, E. F. Pembelton, I. F. Greenbaum and J. W. Bickham. 1976. *Systematists, Other Users, and Uses of North American Collections of Recent Mammals.* Museology No. 3. Texas Tech University Press, Lubbock.

George, S. B. 1987. Specimens as bioindicators of environmental disturbance. Pp. 63–73 in *Mammal Collection Management* (H. Genoways, C. Jones and O. Rossolimo, eds.). Texas Tech University Press, Lubbock.

Gibbon, A. 1991. Systematics goes molecular. *Science* 251(22 February):6.

Goldman, K. J. (ed.). 1970. *Opportunities for Extending Museum Contributions to Pre-College Science Education.* Summary report of a conference supported by National Science Foundation, Belmont Conference Center, 26–27 January 1970. Smithsonian Institution, Washington, D.C.

Gottfried, J., R. Smith and J. Dacus. 1991. The role of natural history museums in improving science education in rural schools. Pp. 171–198 in *Natural History Museums: Directions for Growth* (P. Cato and C. Jones, eds.). Texas Tech University Press, Lubbock.

Hauschka, P. 1980. Osteocalcin: A specific protein of bone with potential for fossil dating. Pp. 75–82 in *Biogeochemistry of Amino Acids* (E. Hare, ed.). John Wiley and Sons, New York.

Hill, J. (ed.). 1991. *Conserving the World's Biological Diversity: How Can Britain Contribute?* Proceedings of a seminar presented by the Department of the Environment in Association with The Natural History Museum, 13–14 June 1991. Department of the Environment, London, England.

Holland, P. G. 1975. The use of herbarium records in biogeography. *Professional Geographer* 27(4):475–479.

Hounsome, M. V. 1992. Research: Natural science collections. Pp. 536–541 in *A Manual of Curatorship: A Guide to Museum Practice* (J. M Thompson, ed.). 2nd edition. Butterworth-Heinemann, Oxford, England.

House of Lords Select Committee on Science and Technology. 1991. *Systematic Biology Research, Volume 1-Report.* House of Lords Session 1991–91, 1st Report, HL Paper 22-1. HMSO, London, England.

Huilun, Hua, Zhou Manzhang and P. Dooley. 1992. Natural history museums and their role in conservation: A Chinese perspective. *Curator* 35(3):206–214.

Kiff, L. 1991. The egg came first. *Terra* 30(2):5–19.

Knutson, L., and W. L. Murphy. 1988. *Systematics: Relevance, Resources, Services and Management: A Bibliography.* Special Publications No. 1. Association of Systematics Collections, Washington, D.C.

Lee, G. K. 1991. Analytical chemistry tracks poachers. *Analytical Chemistry* 63(9):513A–515A.

May, R. M. 1992. How many species inhabit the earth? *Scientific American* 267 (October):42–48.

Miller, E. H. (ed.). 1985. *Museum Collections: Their Roles and Future in Biological Research.* Occasional Papers No. 25. Royal British Columbia Provincial Museum, Victoria, British Columbia, Canada.

Miller, S. E. 1991. Biological diversity and the need to nurture systematics collections. *American Entomologist* 37(2):76.

Nicholson, T. D. 1991. Preserving the earth's biological diversity: The role of museums. *Curator* 34(2):85–108.

Olson, S. 1979. The museum tradition in ornithology—A response to Ricklefs. *Auk* 98:193–195.

Patton, E. 1991. Natural history loan materials for the classroom. Pp. 149–158 in *Natural History Museums: Directions for Growth* (P. Cato and C. Jones, eds.). Texas Tech University Press, Lubbock.

Pettitt, C. 1991. Putting "bloody mice" to good use. *Museums Journal* 91(8):25–28.

Radetsky, P. The first case. *Discover* 12:74–75.

Rautenbach, I. L., and E. M. Herholdt. 1990. Curators and the research collections of natural history museums—Their contribution to nature conservation in South Africa. Pp. 145–151 in *Natural History Collections: Their Management and Value* (E. Herholdt, ed.). Special Publication No. 1. Transvaal Museum, Pretoria, South Africa.

Rick, A. M. 1975. *Use of Museum Collections in Toxic Chemical Research.* Occasional Paper No. 21. Canadian Wildlife Service, Ottawa, Ontario, Canada.

Ricklefs, R. E. 1980. Old specimens and new directions: The museum tradition in contemporary ornithology. *Auk* 97:206–208.

Sibley, C. S., and J. E. Ahlquist. 1981. Instructions for specimen preservation for DNA extraction: A valuable source of data for systematics. *ASC Newsletter* 9(3):44–45.

Smith, K. G. 1986. *A Manual of Forensic Entomology.* British Museum (Natural History) and Comstock Publishing Association Division, Cornell University Press, Ithaca, N.Y.

Tirrell, P. B. 1991. Traveling exhibits as a strategy for university-state museums of natural history. Pp. 159–170 in *Natural History Museums: Directions for Growth* (P. Cato and C. Jones, eds.). Texas Tech University Press, Lubbock.

Wiggins, G. B., S. A. Marshall and J. A. Downes. 1991. The importance of research collections of terrestrial arthropods: A brief prepared by Biological Survey of Canada (Terrestrial Arthropods). *Bulletin of the Entomological Society of Canada* 23(2,Supplement):1–16.

Williams G., T. B. Stretton and J. C. Leonard. 1983. AIDS in 1959? *Lancet* 2:1136.

Yates. T. 1987. Value and potential of the collection resource. Pp. 9–17 in *Mammal Collection Management* (H. Genoways, C. Jones and O. Rossolimo, eds.). Texas Tech University Press, Lubbock.

Zusi, R. L. 1969. The role of museum collections in ornithological research. Pp. 651–661 in *Natural History Collections: Past, Present and Future* (D. Cohen and R. Cressey, eds.). *Proceedings of the Biological Society of Washington* 82:559–762.

Glossary of Selected Terms

accession: an object acquired by a museum as part of its permanent collection; the act of recording and processing an addition to the permanent collection.

acidic: having a pH less than 7.0.

albumen: printing paper with egg whites added to the white base to enhance the highlights of the photographic prints.

ambrotype: an early type of photograph consisting of a glass negative backed by a dark surface so as to appear positive, made by the collodion process invented in the mid-19th century by Frederick Scott Archer (1813–57), an English photographer.

archival: term applied to records preserved because they are deemed to be of continuing value; term loosely used to imply that products, particularly paper products, are suitable for preservation purposes.

baculi: plural of baculum, a bone in the penises of certain mammals.

bar code: variable-width stripes on packaging or tags that identify the item and provide other data when read by an optical scanner.

bimetallic alkaline glassware: containers produced from glass composed of silica, sodium oxide and calcium oxide.

biochemistry: the study of the chemistry of living organisms, especially the structure and function of their chemical components.

biodeterioration: degradation resulting from the activity of organisms.

biodiversity (or biological diversity): terms used to describe the sum of the variety of life on earth; diversity of ecosystems, of species and of genes.

biogeographers: scientists who study the geographical distributions of organisms, their habitats (ecological biogeography) and the historical and biological factors that produce them (historical biogeography).

biomechanics: study of the mechanics of living things; scientists who study the mechanics of living things.

bioscience: contraction of the term "biological science."

biota: the combined flora, fauna and microorganisms of a given region.

biotechnology: the development of techniques for the application of biological processes to the production of materials of use in medicine and industry.

blood components: the plasma, platelets, cells, etc., that compose the fluid that circulates in the principal vascular system of vertebrates.

botany: the study of plants.

buffer: solution containing both a weak acid and its conjugal weak base whose pH changes only slightly on the addition of acid or alkali; used to maintain pH.

Byne's disease: a reaction between calcareous specimens (including shell and eggshell) and the acetic and formic acids outgassed by some storage and exhibit materials, resulting in the formation of water-soluble calcium acetate-formate double salts as replacements for calcium carbonate.

calendered: term used to describe paper with a smooth, glossy surface that is produced by passing the paper stock between rollers.

carbohydrates: compounds of carbon, oxygen and hydrogen, of general formula $C_x(H_20)_y$, including sugars (monosaccharides and disaccharides) and their derivatives, and polysaccharides such as starch and cellulose.

casts/molds/peels: impressions taken of an object with a liquid or plastic substance. A cast may also be a reproduction of an object produced from such an impression.

cell suspension: individual cells or small groups of cells from microorganisms or from disrupted tissues or organs that are suspended in a fluid.

chitin: long chain polymer of N-acetylglucosamine units, the chief polysaccharide in fungal cell walls, also found in the exoskeletons of arthropods.

cleared and stained specimen: biological specimen or specimen sample in which some parts have been rendered transparent by treatment with a clearing agent, while others have been treated with pigments and dyes to enhance detail and increase visibility.

clearing agent: chemical used to change the refractive index of biological materials so that they become transparent to light.

climatologist: scientist who studies the annual composite or general prevailing weather conditions of a region, averaged over a series of years, or the way these conditions are related to ecological phenomena.

cloned probe: a population of identical DNA molecules, or portions of molecules, used to select or identify complementary DNA from a heterogeneous population of molecules; e.g., a sequence of DNA can be prepared from the DNA of a microorganism, numerous copies prepared (cloned), and this material (probe) can then be used to identify the presence of the microorganism.

code of ethics: formal statement of the body of moral precepts or rules of conduct considered to be the standards for a profession.

collagen: a fibrous protein found in vertebrate connective tissues and also among invertebrates, such as worms and sponges.

collections documentation: preparation and maintenance of a permanent record of the history and description of collections and all transactions related to them.

collections care: a holistic approach to the preservation and conservation of collections that involves all aspects of the collecting institution, from the facilities in which collections are housed and used to basic policies and practices and the education and training of staff; collections care is the responsibility of all staff, administrators and trustees, and many collections care activities do not require professional conservators for implementation.

collections management: policies and procedures involved in the development, processing, documentation, organization, maintenance and use of collections, particularly natural science collections; activities related to collections management may be the responsibility of one or more staff members depending upon the organizational structure of the collecting institution.

conservation: the application of science to the examination and treatment of museum objects and to the study of the environments in which they are placed.

conservation assessment: a broad study of the policies, practices and conditions that have an impact on the care and preservation of collections.

conservation awareness: an understanding of the value of collections and the need for their care.

conservation research: science employed to the benefit of any of the functions of conservation; may involve basic research, developmental and applied research, or analytical and technical services.

conservation scientist: a researcher specializing in science employed to the benefit of any of aspect of conservation.

conservator: one who applies science to the technical study, preservation and treatment of collection objects; in North America, professional conservators must carry out their work in accordance with formal codes of ethics and standards of practice.

consolidant: a material that can impregnate an object and impart strength by binding it together.

contaminants: impurities or other undesirable components in a material.

Cretaceous: geological period from 136 to 65 million years ago, at the end of the Mesozoic era.

cryopreservation: the storage of organisms and tissue samples at extremely cold temperatures, usually in liquid nitrogen.

crystallography: the study of crystals, including their growth, structure, physical properties and classification by form.

cuticular hydrocarbons: compounds composed of carbon and hydrogen that are found in the noncellular materials covering and are secreted by the epidermis of many invertebrates.

daguerreotype: an early photographic process, developed in 1837 by Frenchman Louis Daguerre, in which an image is created on a light-sensitive, silver-coated metal plate.

database: a collection of data (information) transported by a medium, a data carrier such as magnetic tape, and stored and processed in an electronic device such as a computer.

deaccession: an object that has been removed permanently from a museum collection, through sale, exchange, donation to another institution or deliberate destruction; the process of removing an object permanently from the collection.

dendrochronologist: scientist who determines dates and chronological order of past events by study of the growth rings of trees.

desiccate: to dry

disciplinary organizations: societies, associations and other groups of professionals who share a common specialty field (e.g., mammalogy; plant taxonomy).

dissection: the act of cutting apart a specimen in order to examine the structure or relation of the parts, or to conduct detailed examination or analysis of a part or parts.

DNA/RNA (including sequence gels): deoxyriboneucleic acid; the primary genetic material of a cell; the fundamental hereditary material of all living organisms.

drill core: cylindrical sample of earth, mineral or rock extracted from the ground by means of a hollow drill tube so that the strata are undisturbed in the sample.

dry shell: the exoskeleton of a marine or freshwater mollusk, preserved in a dry state.

echinoderm: a member of the phylum Echinodermata, such as a starfish or a sea urchin.

ecology: the study of the relationships between organisms and their environment, which includes other organisms as well as physical factors such as climate and soil type.

ectoparasite: a parasite that does not completely invade the body but which feeds superficially on the skin, hair or feathers, or sucks blood.

educational collection: a group of specimens designated for use in educational programming.

electronic media: machine-readable records that are stored, manipulated and disseminated by electronic means, such as computer networks, earth satellite relays and television broadcasting.

embryo/larvae: an organism in the earliest stages of its development.

emergency preparedness: the advance effort by a collecting institution to ensure the safety of personnel, facilities and collections in the event of a natural disaster (flood, earthquake) or institution-specific emergency (fire, broken water pipe, bomb threat).

endangered/orphaned collection: systematic collection that, for any reason, is or soon may be no longer regarded as of value to its present ownership and thus in danger of becoming lost to the systematics research and education community.

endoparasite: a parasite that completely invades the body, i.e., the dermal or subdermal tissues, head cavities or inner organs.

enzyme: a protein that acts as a catalyst in biochemical reactions.

epidemiology: the study of factors affecting the spread of diseases in populations.

ethylene glycol: a thick, liquid dihydric alcohol composed of carbon, hydrogen and oxygen.

evolutionary biologists: scientists in any number of disciplines that have in common a focus on the process of change in the genetic composition of a population of organisms and any factors that induce changes in the genetic composition of a population.

exsiccati(ae): dried specimens; i.e., herbarium specimens, usually used to indicate early bound volumes of pressed plants.

fiduciary: relating to or involving a trust.

field notes: documentation, often in the form of a journal, made concerning specimens, their habitat or environment, field conditions, etc., at the time the specimens were originally collected.

fixation: process of hardening and preserving biological material, particularly proteins.

fluid-preservation: the fixation and/or preservation of specimens in a fluid such as formalin or alcohol.

forensic pathology: knowledge concerning the origin, nature and cause of disease and any other deviations from normal, healthy or efficient condition of organisms, applied to the elucidation of questions in a court of law.

forensic scientist: one who applies science to the elucidation of questions in a court of law.

formaldehyde: gas composed of carbon, hydrogen and oxygen; mixed with water or other liquids and used to fix tissues; in water solution it is a reducing agent, and in the presence of air it oxidizes to formic acid.

fossil: an organism or a fragment, impression or trace of an organism preserved in rock through geological time, by which is usually meant a time span of 10,000 years or longer; may be either a body fossil (such as a bone or shell) or a trace fossil (such as a burrow, track or imprint)

freeze-drying: freezing in a high vacuum to remove moisture by sublimation (direct change from ice to water vapor, without melting); lyophilization.

fumigant: a chemical smoke or vapor used to treat an object, group of objects or structure for elimination of pests or mold.

fungi: members of a large group of nonvascular organisms that obtain nourishment either as saprophytes or parasites; may be unicellular or make up a multicellular body called a mycelium consisting of filaments known as hyphae.

gaseous pollutants: vapor-phase atmospheric contaminants that may be harmful to collections, e.g., sulfur and nitrogen oxides, ozone and organic acid vapors.

gaskets: packing used to make the space between two surfaces air- or fluid-tight.

genome: the minimum set of nonhomologous chromosomes required for the proper functioning of a cell; the basic (monoploid) set of chromosomes of a particular species; the gametic chromosome number.

geo-biochemistry or bio-geochemistry: the study of mineral cycling and of organism-substrate relationships; also the study of the process of lithification of organic material.

geochemistry: the study of the distribution and amounts of the chemical elements in minerals, ores, rocks, soils, water and the atmosphere and their circulation in nature, on the basis of the properties of their atoms and ions; also, the study of the distribution and abundance of isotopes, including problems of nuclear frequency and stability in the universe. A major concern of geochemistry is the synoptic evaluation of the abundance of the elements in the earth's crust and in the major classes of rocks and minerals.

geology: the study of the structure, processes and chronology of the earth.

geophysicists: scientists who apply the principals of mathematics and physics to the study of the earth's crust and interior.

geoscience: contraction of the term "geological science."

germ plasm scientists: scientists who study the protoplasm of germ cells that contain the units of heredity, the chromosomes and genes; scientists who use these cells in the regeneration of plants and animals, especially plant seeds in seed banks.

glacial acetic acid: 99.9 percent pure acetic (ethanoic) acid ; the impurity is mostly water.

glaciologists: scientists who study snow or ice accumulation; the formation and movement of glaciers; the glacial features of a region, or the geological period when glaciers covered more of the earth than at present.

glassine: lightweight, highly calendered, translucent paper. For stability, transparency should be obtained from mechanical processing rather than chemical treatments or additives and pH should be close to neutral.

glycerin: a synonym for glycerol, a trihydric alcohol.

halogenated hydrocarbons: compounds composed of carbon, hydrogen and one or more halogens (fluorine, chlorine, bromine, iodine).

heavy metals: metals that have a high specific gravity; used here to indicate metals, such as mercury, or mercury compounds, such as mercury chlorides used in various specimen treatments, particularly pest control treatments.

herbaria sheet: the support, usually paper, on which a pressed plant specimen is mounted for storage and use; the support with the attached pressed plant specimen.

herbarium: a collection of dried plant specimens, usually mounted and systematically arranged for reference; a place that houses such a collection.

herpetology: the study of amphibians and reptiles.

histological analysis: analysis of the minute structure of living things, especially the structure of tissues.

holographic imaging: the use of coherent light (laser) in conjunction with ordinary photo plates to produce images that can be viewed in three dimensions without special optical equipment.

Hoyer's mounting medium: a mixture of gum arabic, chloral hydrate and glycerin (glycerol) used to mount specimens on slides for microscope examination.

HVAC: acronym for heating, ventilation, air conditioning.

hygroscopic: having the ability to attract or absorb moisture from the air.

inorganic: pertaining to or derived from nonbiological material; used of compounds that do not contain carbon as the principal element, except carbonates, cyanides and cyanates.

iron sulfides: any mineral, such as marcasite or pyrite, having the chemical composition FeS_2.

isolated proteins: any purified or separated protein.

karyotype: morphological characteristics of the chromosomes of a cell; an arrangement of chromosomes of a cell according to shape, centromere position and number.

keratin: a chemically complex material (scleroprotein) of which horns, nails, claws, hoofs and the scales of reptiles, birds and mammals are formed. Hair and feathers also contain much keratin; it is present in the external layers of the skin, where it develops by the transformation of clear granules of keratohyalin of lower levels.

lapidary: the art of cutting gems; a cutter, polisher or engraver of precious stones, usually other than diamonds.

LEV: acronym for local exhaust ventilation.

Linnaean classification: the system of hierarchical classification and binomial nomenclature established by Linnaeus.

loaded paper: paper in which finely divided, relatively insoluble white mineral powders have been added to improve finish, ink absorption, dimensional stability or opacity.

magnetic media: machine-readable records in the form of disks and tapes on which the information or image is carried as magnetic grains or particles suspended in a binder on a rigid or flexible substrate.

mass spectrometry: a technique used to determine relative atomic masses and the relative abundance of isotopes, as well as for chemical analysis and the study of ion reactions.

materials science: study of nature, behavior and use of materials applied to science and technology.

matrix, matrices: 1) the ground mass of an igneous rock; the finer-grained materials enclosing the larger grains in a sediment or sedimentary rock; the rock or sediment in which a fossil is embedded; a gemstone cut from a mineral and the surrounding rock mineral, e.g., opal matrix; 2) the intercellular substance in which tissue cultures are embedded; 3) something within which something else originates or develops.

mercury salts: usually mercury chlorides, used in the past to fix biological tissues or used on specimens as a prophylactic against or as treatment for infestations of insects or microorganisms.

mercury vapor: gaseous form of elemental mercury.

microbiology: the scientific study of microscopic organisms.

microchemical test: analysis that involves the use of minute quantities of chemical reagents on microscopic amounts of sample; typically conducted under a microscope.

micromount: a crystallized mineral specimen that is mounted on a small pedestal inside a container; the container must have a volume equal to or less than one cubic inch, and magnification (normally microscopy) is required to see the specimen; also a microscope slide with a small enclosure in which a specimen or sample is contained.

microscopy: use of, or investigation with, a microscope.

mineralogy: the branch of geology concerned with the study of minerals.

morphological: of, or pertaining to, the form and structure of organisms, rocks and sediments, with special emphasis on external features.

mounting media: substances used to hold specimens or samples on microscope slides; a mounting medium may enhance some aspect of a specimen or sample for microscopy.

mummified: pertaining to a specimen that has been preserved by natural dehydration.

museology: the systematic study of the organization, management and function of a museum.

nanometer: one billionth of a meter.

natural science: any science, such as botany, zoology, etc., dealing with the study of objects in nature.

nomenclature: a system of terms used in a particular science or discipline, e.g., an international system of standardized New Latin names used in biology for kinds and groups of animals and plants.

non-Recent: not of the present, or post-Pleistocene, geological epoch.

organic: of or relating to chemical compounds based on carbon chains or rings and containing hydrogen with or without oxygen, nitrogen or other elements; derived from living organisms; compounds containing carbon as an essential component.

organic chemistry: the branch of chemistry concerned with carbon compounds of living things and most other carbon compounds.

oxidation: change in a compound by combination with oxygen or by an increase in the electronegative part, or the change of an ion or element from a lower to a higher positive valance; removal of one or more electrons from an atom, ion or molecule.

paleobotanical: of or relating to ancient plants that are known today only through fossil remains.

paleoecologists: scientists who study the relationships of fossil organisms to each other and to their environments, including study of both the fossils and the rocks in which they are found.

paleogeologists: scientists who study the geologic conditions of the earth as it was at some given time in the past.

paleontology: the study of extinct organisms, including their structure, environment, evolution and distribution, as revealed by their fossil remains.

paraffin block: specimen or specimen part embedded in paraffin wax.

parasitology: the study of parasites and parasitism.

parasite: an organism able to live on and cause damage to another organism.

particulate pollutants: atmospheric pollutants that are solid particles, such as soot and dust.

parylene consolidation: impregnation of the structure of an object or specimen using a gas phase, organic monomer—paraxylene—that polymerizes inside the structure.

pasteboard: stiff, firm board made up of layers of paper or paper pulp pressed together.

pathology: the study of disease, particularly by laboratory methods, including the bacteriology of pathogenic organisms.

petrology: that branch of geology dealing with the origin, occurrence, structure and history of rocks, especially igneous and metamorphic rocks.

pH: an expression indicating the hydrogen-ion concentration of a solution; the negative logarithm of the hydrogen-ion concentration.

phage (bacteriophage): a virus that is parasitic within a bacterium; each phage is specific to only one type of bacterium.

phalli: plural of phallus; penis, the male reproductive organ of mammals.

phase transitions: transitions between homogenous states—e.g., ice to water (melting), mercury metal to elemental mercury vapor (volatilization), diamond to graphite (polymorphic transition);

dissolution of some salts by atmospheric moisture to yield other minerals (decomposition during deliquescence).

phylogeny: the ordering of species into higher taxa; the evolutionary history of an organism or groups of related organisms.

physical chemistry: branch of chemistry dealing with the relations between the physical properties of substances and their chemical composition and transformations.

physiognomy: the characteristic features or appearance of a plant community or vegetation; the outward appearance of anything, taken as offering some insight into its character.

planetary geologists: scientists who study the physical features and history of planets other than the earth, the materials of which they are composed, and the physical changes or processes they have undergone.

plant pathologists: scientists who study of the origin, nature and courses of diseases that afflict plants.

plasmid: a structure in cells consisting of DNA that can exist and replicate independently of the chromosomes. Bacterial plasmids are used to produce recombinant DNA for gene cloning.

plaster field jackets: bandages made of Plaster of Paris and strong woven fabric that are used to encapsulate blocks of matrix rock that contain fossils; used during field collecting in paleontology to protect specimens until they can be excavated from the rock in a laboratory.

pointing materials, or points: materials used to make supports for small, dried insect specimens; points, rather than the specimens themselves, are then pinned into the base of a storage drawer or tray.

polarized light: light waves confined to vibration in only one plane through the line of propagation.

polished sections: cross sections cut from specimens of teeth, bone, shell, rock, minerals, etc., and then surface polished to improve the study of their structure and optical properties; may be thin sections, i.e., sections sliced from a specimen mounted on glass and ground to a thickness of three microns to render them transparent to light for polarized light microscopy.

polymer: a macromolecule formed by the chemical union of five or more combining units called monomers. In most cases, the number of monomers is quite large (3,500 for pure cellulose) and is often not precisely known.

powder diffraction mount: a sample containing many small crystals that is analyzed by X-ray diffraction in order to identify crystals of different compounds.

practicum: the part of an academic course consisting of practical work in a particular field.

preservation: actions taken to retard or prevent deterioration or damage to collections materials by control of their environment and/or treatment of their structure in order to maintain them as nearly as possible in an unchanging state.

preventive conservation: the methodology by which the rate of deterioration of collections is reduced by controlling the causes of the deterioration.

public trust repository: an institution in which material is deposited, held and maintained for the benefit of the common good.

pyrite oxidation: chemical reaction in which ferrous sulfide minerals (particularly those in which the grain size is microcrystalline) react with oxygen to form hydrated sulfates and sulfuric acid; the amount of water vapor in the atmosphere around the specimen is a critical factor in the rate at which the reaction will occur; below 30 percent RH, the rate is negligible.

radioactive: the property possessed by some elements (as uranium) of spontaneously emitting alpha or beta rays and sometimes also gamma rays by the disintegration of the nuclei of atoms.

radiograph: photographic image formed by the use of ionizing radiation to produce a transmission image of an object on photosensitive material (usually a film).

rag papers: high-quality, durable papers made from cotton or other textile fiber or rags. The rag content is indicated by a percentage.

reference sample collection: a group of specimens or specimen parts that are identified and can be used for comparative purposes.

refractive index or index of refraction: a number indicating the speed of light in a given medium, either as a ratio of the speed of light in a vacuum to that in the given medium, or as the ratio of the speed of light in a specified medium to that in the given medium.

relative humidity (RH): the ratio of the actual vapor pressure of air to its saturation vapor pressure at that temperature.

research: the search, conducted primarily but not exclusively in the laboratory, for facts, conclusions and applications that were previously unknown to or untried by the scientific community.

sampling: the act or process of selecting and removing some part of an object or specimen for testing, analysis or other use.

sampling records: documentation of the sampling of specimen or object, including date of sample; nature of sample taken; purpose of sampling; results of tests, analysis or other research using samples; amount of sample remaining, etc.

scanning electron microscope stub: the mount on which a specimen or sample is placed for examination or analysis by scanning electron microscopy.

scat: excrement; fecal material.

serial propagation: maintaining a culture of living cells by continuous subculturing of a portion of the population to fresh growth medium.

shell ultrastructures: samples from mollusk shells that permit researchers to study the submicroscopic structure of the shell, usually by electron microscopy.

silver gelatin: particles of light-sensitive silver salts suspended in a complex protein (gelatin) emulsion on paper or film as a photographic medium.

single crystal mount: a single crystal mounted on a small support for use in X-ray diffraction analysis.

solvent: that which has the power to dissolve; a substance that dissolves another to form a solution.

speciation: the process of species formation: the full sequence of events leading to the splitting of one population of organisms into two or more populations reproductively isolated from one another.

specimen: any animal or plant, or any part, product, egg, seed or root of any animal or plant or geological sample.

spectroscopy: the study of materials through the use of radiant energy to produce spectra for chemical analysis; the science of producing and analyzing spectra using spectroscopes.

stratigraphers: scientists who study the origin, composition, distribution and succession of rock strata.

sub-fossil: a post-Pleistocene fossil; used of plant and animal remains not strictly Recent but which are not old enough to be regarded as fossil.

synthetic polymer: human-made polymer, as opposed to cellulose, or others that occur in nature.

systematics: the science of classifying all organisms, both living and extinct, and of investigating the relationships between them; the field of science concerned with taxonomy and phylogeny.

taxidermy: the process of preparing animal skins and stuffing them in a lifelike form.

taxonomists: scientists who identify, name and classify organisms.

taxonomy: the science or technique of classification; the discipline devoted to the identification, naming and classification of organisms.

technology transfer: the passage of scientific or industrial knowledge from one field or discipline to another.

Tertiary: of or relating to the first period of the Cenozoic era, beginning with the end of the Mesozoic era (Age of Reptiles) 66 million years ago and closing with the start of the Pleistocene epoch about 2.5 million years ago; succeeded by the Quaternary period (Pleistocene plus Recent epochs).

thin section: see polished section.

tintypes and ferrotypes: photographs taken directly as positive prints on sensitized plates of enameled tin or iron.

toxicologists: scientists who study poisons, their detection and counter-action.

tree ring and wood sample: cross sections, radial sections or other samples from the trunks of trees or the stems of woody plants.

type (holotype) specimen: the single specimen designated as the name bearer for a taxon when it was established; or the single specimen on which such a taxon was based when no type was specified.

ultraviolet radiation: radiation of wavelengths shorter than 400nm; UV radiation from the sun, sky and most artificial light sources is in the range of 300–400nm. It is invisible and has a strongly damaging effect on many collection materials. The proportion of UV emitted from a light source may be expressed as milliwatts of UV radiation per 100 lumens (mW/100lm).

visible light: that portion of the electromagnetic spectrum that is perceptible to the human eye, roughly the range from 700nm to 400nm.

voucher specimen: any specimen identified by a recognized authority for the purposes of forming a reference collection; a specimen that physically and permanently documents data in an archival report by verifying the identity of the organism(s) used in the study and by so doing ensures that a study which otherwise could not be repeated can be accurately reviewed or reassessed.

wood pulp: the mechanically or chemically prepared mixtures of wood fibers that are used in the manufacture of some paper and board.

X-radiography: see radiograph.

X-ray diffraction: the diffraction of a beam of X-rays, usually by the three-dimensional periodic array of atoms in a crystal that has periodic repeat distances (lattice dimensions) of the same order of magnitude as the wavelength of the X-rays.

zoology: the study of animals

zymogram: a visible pattern of mobility of isozymes for cells from different species.

Sources of Glossary Definitions

The definitions provided in this glossary have been culled largely from the sources listed in the Bibliography and the publications listed below. Many terms, however, were not easily defined in relation to the natural sciences and required the expertise of many project contributors, especially David Von Endt and Frank Simione.

Bates, R. L., and J. A. Jackson (eds.). 1984. *Dictionary of Geological Terms.* 3rd edition. Prepared under the direction of the American Geological Institute. Anchor Press/Doubleday, Garden City, N.Y.

Brady, G. S., and H. R. Clauser. 1991. *Materials Handbook.* 13th edition. McGraw Hill, New York.

Brock, T. D. 1979. *Biology of Microorganisms.* Prentice-Hall, Englewood Cliffs, N.J.

Concise Science Dictionary. 1992. 2nd edition. Oxford University Press, Oxford, England.

Considine, D. M., and G. D. Considine (eds.). 1984. *Van Nostrand Reinhold Encyclopedia of Chemistry.* 4th edition. Van Nostrand Reinhold, New York.

DeBlase, A. F., and R. E. Martin. 1981. *A Manual of Mammalogy with Keys to Families of the World.* Wm. C. Brown Company, Dubuque, Iowa.

Nauert, P. 1979. Glossary. Pp 409–416 in *Museum Registration Methods* (Dudley, D. H., I. B. Wilkinson and others). 3rd edition. American Association of Museums, Washington, D.C.

Eastman Kodak Company. 1980. *Fundamentals of Radiography.* 12th edition. Eastman Kodak Company, Rochester, N.Y.

Illuminating Engineering Society. 1970. *Lighting of Art Galleries and Museums.* IES Technical Report No. 14. Illuminating Engineering Society, London, England.

Lawrence, E., and S. Holmes. 1989. *Henderson's Dictionary of Biological Terms.* 10th edition. John Wiley & Sons, New York.

Lewis, R. J. (ed.). 1993. *Hawley's Condensed Chemical Dictionary.* 12th edition. Van Nostrand Reinhold, New York.

Lincoln, R. J., and G. A. Boxshall. 1990. *Cambridge Illustrated Dictionary of Natural History.* Cambridge University Press, Cambridge, England.

Lord, G. D., and B. Lord, (eds.). 1991. *Manual of Museum Planning.* Manchester Museum of Science and Industry. HMSO, London, England.

McGraw Hill Dictionary of Scientific Terms. 1978. 2nd edition. McGraw Hill, New York.

The Merck Index. 1983. 10th edition. Merck & Co., Inc., Rahway, N.J.

Phillips, W. R. 1971. *Mineral Optics: Principles and Techniques.* W. H. Freeman & Company, San Francisco.

Roberts, M. T., and D. Etherington. 1982. *Bookbinding and the Conservation of Books: A Dictionary of Descriptive Terminology.* Library of Congress, Washington, D.C.

Weiner, R. 1990. *Webster's New World Dictionary of Media and Communications.* Simon & Schuster, New York.

Wilson, E. O. 1992. *The Diversity of Life.* Harvard University Press, Cambridge, Mass.

Appendix A
Natural Science Conservation Training Program

Prerequisites and Curriculum

Completion of this three-year program will fulfill the requirements of a master of science degree in conservation of natural science collections.

Prerequisites

Eligible applicants must have completed a bachelor of science degree in a biological or geological scientific discipline. Coursework in biochemistry (minimum of three credit hours), microbiology (minimum of three credit hours) and organic chemistry (minimum of six credit hours), with requisite laboratory courses, are required for students in all disciplines.

Curriculum

Courses outside specialty. All students will be required to have knowledge of natural science collections outside their specialty fields. To this end, students with a background in one of the geosciences will be required to take survey courses in one botany discipline and one zoology discipline; students with a degree in botany will take survey courses in zoology and geology; and so on. Summer field work (see below) may be in any natural science discipline that is not the student's specialty.

Summer field work. Participation in a collecting trip will give students experience in field preparation techniques and an opportunity to understand the special preservation problems occasioned by field conditions. Students will be expected to summarize their observations in a written report.

Directed research projects. Directed research projects will permit students to develop solutions for problems in the conservation of natural science materials. Team projects that foster an interdisciplinary approach to research design will be encouraged. Students will be expected to prepare their research results in a format suitable for publication in a refereed journal.

Internship and practicums. The final internship will be an opportunity for each student to complete a specific project of mutual interest to the student and an institution that houses natural science collections. The internship will also permit the student to work with a variety of professionals on collections conservation issues. Many courses will include practicums to give students experience in working with systematics collections in a museum setting.

Natural Science Conservation Training Program Suggested Curriculum

First Year

First Semester	*Credit Hours*
Introduction to Conservation Theory	3
Introduction to Museum Studies and Administration	3
Systematics	3
Disciplinary Survey Course	3
Second Semester	
Documentation in Conservation	3
Management of Scientific Collections	3
Materials Science	3
Disciplinary Survey Course	3
Summer	
Field work in a scientific discipline	0

Second Year

Third Semester	
Conservation Practice	3
Plant Materials Block Course	6
Preservation of Library and Archival Materials	3
Fourth Semester	
Research Methods in Conservation	3
Animal Materials Block Course	6
Preservation of Photographic Materials and Magnetic Media	3
Summer	
Research project	3

Third Year

Fifth Semester	
Geological Materials Block Course	6
Fluid-Preserved Materials Block Course	6
Sixth Semester	
Internship	9

Total Credit Hours 72

Suggested Course Topics

Introduction to Conservation Theory

- History of conservation
- Conservation disciplines; differing goals and approaches
- Conservation ethics and standards of practice: formal codes of ethics and standards of practice, ethics in natural science conservation, legal issues related to conservation
- Conservation information resources: organizations, training programs and other training opportunities, literature
- Preventive conservation: philosophical basis; conservation assessments (methodology, environmental monitoring, agents of deterioration, assessment of risks, practicum); facilities management (HVAC, LEV systems, lighting design); storage designs and control of deterioration of storage systems; pest management (prevention, monitoring, treatment of infestations); emergency preparedness; conservation policies, procedures and guidelines (accessions and deaccessions, handling, packing and shipping); collections use for research (including dissection/sampling), exhibition and educational programming
- Long-range planning
- Sources of funding
- Public relations; fostering awareness of conservation

Introduction to Museum Studies and Administration (with practicum)

- What is a museum? American Association of Museums and other definitions; types of museums
- Brief history of museums
- Legal viewpoint: concept of a public trust (duty of care, accountability, loyalty); formation (incorporation, bylaws, tax-exempt status, comparisons among university museums, free-standing and hybrid structures); governance and role of board (effect of structure on role, set policy, oversee implementation of policy, assure fiscal health, link with community); role of director (day-to-day management, hire and oversee staff, present policy suggestions to board); special situations
- Functions performed: collections management and conservation; research; public programming (exhibitions, lectures, outreach)
- Basic policies: mission statement, collections management policy, code of ethics, strategic plan, budget as management tool
- Funding sources and preparation of grant proposals
- Resources: professional organizations, codes of ethics, bibliographies
- Practicum in a museum

Systematics

- What is systematics? Folk taxonomies; common vs. scientific names; Linnaeus and modern systematics
- History of systematics; growth of disciplines relative to collections use; development of taxonomic principles and nomenclatural rules

- How systematics is used; law, agriculture, medicine, biological control, environmental conservation
- Role of collections relative to systematics and other disciplines; value of specimens for research
- Systematics literature
- Nomenclature
- Identification (keys, diagnoses, descriptions, vocabulary)
- Classifications, species concepts, speciation
- Phylogeny
- Systematics problem-solving techniques; use of equipment
- Special considerations of different biological disciplines
- Systematics in mineralogy

Disciplinary Survey Courses (Botany, Zoology, Geology)

Two survey courses in scientific disciplines (e.g., mineralogy and plant physiognomy, paleontology and entomology). Each course should include:

- Taxonomy
- Terminology
- Collecting techniques
- Current areas of research, including techniques

Documentation in Conservation (lecture/lab)

- Need for documentation; ethics, standards
- Documentation techniques: technical drawing, X-radiography, photography, digital imaging, video imaging, holographic imaging
- Forms and formats
- Condition reports, treatment proposals
- Record keeping (including computerization of conservation records)

Management of Scientific Collections (with lab)

- Institutional context: mission statement for institution; place of collections within the institution; line of authority for overall responsibility
- Philosophy of collections: external parameters set by disciplines, intrinsic value of specimens (as vouchers), kinds of uses
- Process for developing collections management policy
- Content of collections management policy:

  scope of collection

  standards of conduct, ethics

  acquisitions: national and international laws; legal and ethical issues such as titles/permits; documentation; designation of authority, responsibility; criteria and procedures for evaluation, appraisals, authentication

  use of specimens: access; education, exhibit and research; loans; reproductions; destructive sampling or testing

  specimen and collections documentation: data management, data systems and data policies *disposal:* reasons to deaccession; methods for disposal; laws; ethics; documentation; designation of authority; criteria for evaluation; procedures

care and management: standards of care; designation of authority, responsibility; treatment; disaster/emergency preparedness; pest management; risk management; insurance; security

health and safety: staff, collections

- Procedures at departmental level: resource management; policy implementation; development of procedural manuals relative to discipline; standard techniques and variations, staffing considerations; discussion of responsibilities

Materials Science

- Chemistry and structure of the solid state

  atomic and electronic structure: atomic order in solids, crystallinity; atomic disorder in solids, the imperfect solid state (impurities, defects); the glassy state

  intermolecular forces and molecular solids and liquids: solvents and solubility, wetting and surface tension, surfactants and detergency, adhesion and types of adhesives

  structure, composition and their relationship to the properties of materials: mechanical properties of materials, chemical properties, degradation
- Deterioration processes (general phenomena); types of deterioration (physical, chemical, biological); major factors influencing deterioration processes in museums (physical forces, temperature, moisture, atmospheric pollutants and particulate matter, light, organisms)
- Specific materials: glass, metals, cellulosic materials, synthetic polymers

Conservation Practice (with lab)

- Health and safety in conservation practice
- Treatment: philosophical/ethical basis, examination techniques, documentation requirements and media, treatment proposals and justifications, types of treatments (cleaning, consolidation, pest control treatments, repair and restoration)
- Research integrity of collections: impact of conservation activities on specimen-based research, such as systematics research and nontraditional research use of collections
- Materials identification
- Treatment research: evaluating past treatments, developing new methods

Plant Materials Block Course (lab/practicum/lecture)

- Terminology
- Chemistry and structure
- Identification of specimen materials

- History of preparation techniques and other treatments (e.g., pest control treatments)
- Identification and evaluation of past and current techniques and materials
- Specimen treatment: field preparation, lab preparation, post-preparation treatment, research treatments
- Special considerations: moulding and casting, ancillary collections, specimen labels, applications of documentation
- Storage, exhibition, shipping and packing

Animal Materials Block Course (lab/practicum/lecture)

- Terminology
- Chemistry and structure
- Identification of specimen materials
- History of preparation techniques and other treatments (e.g., pest control treatments)
- Identification and evaluation of past and current techniques and materials
- Specimen treatment: field preparation, lab preparation, post-preparation treatment, research treatments
- Special considerations: moulding and casting, ancillary collections, specimen labels, applications of documentation
- Storage, exhibition, shipping and packing

Geological Materials Block Course (lab/practicum/lecture)

- Terminology
- Chemistry and structure
- Identification of specimen materials
- History of preparation techniques and other treatments (e.g., pest control treatments)
- Identification and evaluation of past and current techniques and materials
- Specimen treatment: field preparation, lab preparation, post-preparation treatment, research treatments
- Special considerations: moulding and casting, ancillary collections, specimen labels, applications of documentation
- Storage, exhibition, shipping and packing

Fluid-Preserved Materials Block Course (lab/practicum/lecture)

- Terminology
- Solvent chemistry
- Fixation chemistry
- Chemistry of clearing agents, stains and mounting media
- Reactions between plant/animal/geological materials and fluids
- Research implications of different preservation techniques
- Monitoring and testing methods
- Assessment of collections and specimens
- Labels
- Chemistry and deterioration processes of storage containers
- Storage, exhibition, shipping and packing

Preservation of Library and Archival Materials

- Paper chemistry and manufacturing processes for traditional western papers: rag, calendered, tracing, wood pulp, glassine, loaded varieties, coated stocks and pulpboards
- Chemistry of inks and toners
- Media of works of art on paper
- Printing and photocopy processes
- Bookbinding processes and materials
- Methods of testing inks, toners, adhesives, paper and boards
- Handling, storage and exhibit of paper-based archival materials
- Handling, storage and exhibit of bound materials
- Shipping and packing library and archival materials
- Deacidification technology
- Minor cleaning and repair techniques: dry cleaning; washing and relaxation of paper, drying methods; mends and hinges; hinge, tape and adhesive removal; lining and backing damaged specimen labels
- Literature and other resources in book and paper conservation

Research Methods in Conservation

- Scientific research: experimental and research design, statistical analysis, literature searches, publication and presentation of results
- Examination techniques: measurement techniques; illumination techniques; microscopy method and theory; transmitted and reflected light; stereo binocular, polarized light; X-radiography
- Chemical techniques: method and theory; microchemical tests
- Instrumental analysis: method and theory (spectroscopy); emission and absorption (IR, UV, XRD, XRF, SEM-EDS); mass spectrometry; separation techniques
- Laboratory projects (particularly microscopy and microchemical tests)

Preservation of Photographic Materials and Magnetic Media

- Historic and contemporary photographic processes: daguerreotypes, ambrotypes, tintypes; silver gelatin, platinum or albumen; color processing
- Chemistry, structure and identification of materials
- Deterioration of historic and contemporary photographic materials
- Handling, storage and exhibit of photographic materials
- Treatments and techniques to mend tears, flatten creases
- Information and imaging storage systems and materials
- Handling and storage of magnetic tape, optical discs, videotape, motion picture film
- Emerging technologies in information storage and retrieval
- Emerging technologies in imaging systems
- Shipping and packing techniques for photographic materials and magnetic media
- Literature and other resources on preservation of photographic materials and magnetic media

Appendix B
Recommended Topics for Research and Technology Transfer

Representatives from natural science disciplines, gathered at their annual meetings, identified concerns to be addressed through technology transfer or research. These issues were supplemented by those raised at the materials science panel meetings held in Washington, D.C., in February 1992.

The topics of concern are grouped according to their material properties: fluid-preserved, inorganic/organic, plant or animal materials. Within these four divisions the concerns are further subdivided into specimen preparation, specimen environments, pest control and post-preparation care. In addition, the common concerns about specimen and collections documentation are covered in a separate section.

Fluid-Preserved Specimens

Specimens fixed or otherwise preserved in fluids are found in all natural science collections, including paleontological and mineralogical collections.

Specimen Preparation

- substitute(s) for formalin in the fixation of plant and animal material
- appropriate buffers for fixatives
- methods of determining when fixation is complete
- preservation of color in biological specimens
- mounting media for microscope slide preparations of various specimens and specimen parts
- methods of ringing microscope slides to prevent deterioration of the mounting media
- clearing and staining agents for use in microscopic and macroscopic preparations
- impact of fixatives and clearing and staining agents on histological and biochemical analyses of specimens

Specimen Environments

- type and concentration of storage fluids for use as long-term storage media
- effects on specimens of glycerin, buffers and other additives to storage fluids
- effects of alcohol and other storage fluids on histological and biochemical analyses of specimens
- hydration and biodeterioration of glycerin used as a long-term storage medium
- appropriate mixtures of glycerin/water or glycerin/alcohol for long-term storage of cleared and stained specimens and alternative fluids for storage of these specimens
- optimum temperature and relative humidity for storage of fluid-preserved collections
- optimum temperature and relative humidity for storage of microscope preparations
- effects of visible light and ultraviolet radiation on specimens stored in fluid
- design of storage furniture for fluid-preserved collections
- safety concerns in the storage of fluid-preserved collections (flammable/toxic vapors, floor-loading capacity, etc.)
- materials specifications for jars, bottles and tanks in fluid-preserved collections (plastics, metals, glass)
- materials specifications for gaskets, lids and liners for use with fluid-preserved collections
- impact of the deterioration of current storage containers and gaskets, etc., on specimens preserved in fluid
- specifications for cases to store microscope slides

Post-Preparation Care

- effects on specimens of adding alcohol, etc., to replenish fluids that have evaporated
- impact of periodic changes of storage fluids (e.g., to replace acidified or discolored fluids) on specimens
- impact of changing to different fluids (e.g., changing from isopropanol to ethanol) on specimens
- identification of the materials extracted from specimens by fluid preservatives
- methods to assess the deterioration of specimens

Inorganic/Organic Matrices

The specimen materials in natural science collections that contain inorganic/organic composites include bone, antler, teeth, shell, egg-shell, the exoskeletons of many invertebrates, corals, lichens on substrate rocks and many vertebrate and invertebrate paleontological specimens. In addition, materials traditionally viewed as inorganic are increasingly shown to contain organic inclusions. Comprehending the nature of many inorganic/organic specimens also depends on an understanding of mineralogy. Consequently, concerns related to mineralogical specimens and lithified paleontological specimens are included here.

Specimen Preparation

- impact of methods of removing flesh, fats and oils from bone on the long-term stability of skeletal material
- effects of clearing and staining on the stability of bone
- impact of preparation chemicals such as formaldehyde, glacial acetic acid and other acidic preparation chemicals, and various insecticides on the development of soluble efflorescent salts on calcareous specimens
- impact of acid preparation on long-term stability and on biochemical analyses of paleontological bone and shell
- impact of various consolidants and adhesives on the chemical and physical stability of specimens
- impact of molding and casting materials on specimen preservation and specimen-based research

Pest Control

- impact of pest control chemicals on specimen preservation and specimen-based research
- impact of oxygen deprivation and non-chemical methods of pest control (low temperatures, heat) on biochemical and mechanical properties of teeth and bone
- new methods of pest control

Post-Preparation Specimen Care

- mechanisms of oxidation reactions
- techniques to clean greasy bone and specimens stained by particulate pollutants

Specimen Environments

- proper relative humidity for general storage or exhibit environments
- particular relative humidity and temperature requirements for specific mineral species, whether as specimens themselves or inclusions in other specimens
- cost-effective methods to create microclimates for humidity- or temperature-sensitive materials
- impact of storage environment and storage materials on pyrite oxidation and on the development of soluble efflorescent salts on calcareous specimens
- standards for storage materials to mitigate the development of soluble efflorescent salts on calcareous specimens
- interactions between mineral species in storage/exhibit environments
- visible light and ultraviolet radiation sensitivity of various specimen materials
- storage and monitoring of radioactive material
- storage designs to mitigate shock, vibration and abrasion
- methods for storing SEM stubs, casts, molds and peels
- specifications for storage furniture

Plant Materials

Plant materials are the basic specimens in herbaria, although these collections often contain nonvascular organisms such as algae and fungi, whose chemistry and structure differs greatly from those of vascular plants. Culture collections usually preserve viable plant tissues by serial propagation; however, some are preserved by cryopreservation techniques. Culture collections also preserve living strains of fungi and other nonvascular organisms that traditionally have been associated with botanical collections.

Specimen Preparation

- methods of drying plant specimens in the field
- materials for temporary storage of specimens awaiting processing
- specifications for herbarium mounting and packet paper (chemical and other properties of the paper, including appropriate weights for particular applications)
- methods of testing the alkalinity, acidity and general composition of the papers used in herbaria collections
- information on paper substitutes and their potential utility in botanical collections
- preservation of color in herbarium specimens, when desired; or standardized means/language by which color can be documented
- optimum methods of attaching specimens to herbaria sheets (adhesives, thread, cloth and paper tapes)
- impact of current supports and adhesives on the long-term preservation and biochemical integrity of botanical specimens
- cryopreservation methods for algae and slime molds
- methods of preserving plant tissue cultures that do not remain viable with current cryopreservation techniques
- effects of freeze-drying on plant materials

Pest Control

- impact of pest control chemicals (metallic poisons, halogenated hydrocarbons, fumigants containing sulfur, commercial sprays, etc.) on botanical specimens
- impact of oxygen deprivation and non-chemical methods of pest control (freezing, freeze-drying, heat, radiation) on biochemical and mechanical properties of botanical specimens
- new methods of pest control
- identification of groups of specimens that are vulnerable to pests and groups that are not, and investigations into the differences between the two
- methods to identify pest control chemical residues on specimens

Post-Preparation Specimen Care

- techniques to clean herbaria sheets stained by pest control chemicals, mold, acidic adhesives and particulate pollutants
- methods to mitigate the need to remount herbaria specimens
- methods to assess the condition of herbaria specimens
- mechanisms by which the fragility of botanical specimens increases over time
- methods to deacidify herbaria sheets
- role of mechanical damage in the deterioration of botanical collections
- design of fragment packets

- storage for herbaria sheets that minimize handling and stacking
- effects of synthetic resins and polymers on the preservation of plant materials

Specimen Environments

- proper temperature, relative humidity, lighting designs and air quality for general storage/exhibition of plant collections and other specimens traditionally found in these collections
- specifications for materials used in specimen storage trays and boxes (pasteboards, especially 100-pt. board; papers and adhesives)
- specifications for genus covers in herbaria collections (design, colors, materials)
- impact of acids and alkalis on botanical specimens
- specifications for storage furniture

Animal Materials

Animal materials are here considered to be those specimens that are preserved in dry form in natural science collections, *excluding* bone, teeth, shell, eggshell and the materials traditionally found in botanical collections. The components of interest include materials such as chitin, keratins, collagens, enzymes, carbohydrates, fats, oils, waxes and noncollagenous proteins.

Specimen Preparation

- methods of assessing the impact of past and current preparation techniques on both long-term preservation and biochemical analyses of specimens (e.g., effects of ethylene glycol used in pitfall traps on the analysis of cuticular hydrocarbons in insect specimens, as well as on the preservation of the specimens over time)
- new methods of field capture/killing
- specifications for materials used in specimen preparation (e.g., metal insect pins, support wires in mammal specimens, fibrous materials for filling bird and mammal study skins)
- specifications for adhesives and pointing materials for use in mounting insect specimens
- methods of drying specimens in the field, particularly in tropical environments
- methods of packing and shipping field-prepared specimens
- methods of preparing specimens for specialized uses, such as educational programming (e.g., parylene consolidation, freeze-drying)
- preparation of tissue samples for histological and biochemical analyses

Pest Control

- impact of pest control chemicals, including fungicides (metallic poisons, halogenated hydrocarbons, carbon dioxide, fumigants containing sulfur, etc.), on specimens and labels
- impact of various oxygen deprivation and non-chemical pest control methods (low temperatures, heat) on the preservation

and on the research potential of specimens (i.e., effects on color, amino acids, DNA/RNA, cuticular hydrocarbons, fats and oils, etc.)

- impact of various chemical and non-chemical pest control methods on the materials used in the preparation and storage of specimens
- effects of naturally present microorganisms on specimen preservation

Post-Preparation Specimen Care

- methods of monitoring specimen condition over time
- methods for repair/restoration of damaged specimens and the impact of interactive conservation treatments on the scientific utility of the specimens

Specimen Environments

- methods of assessing the impact of currently used storage materials (wood, wood products, acidic paper and boards, paints and varnishes, various plastics) on the preservation and scientific utility of specimens (e.g., impact of the organic acids, peroxides and other materials released by various woods and wood products on aging, color and biochemical information)
- specifications for storage case designs
- specifications for storage containers for dry proteinaceous materials (paper products, metals, plastics, glass) in various climates
- optimum environments (temperature, relative humidity, air quality) for the storage/exhibit of dry proteinaceous materials
- effects of visible light and ultraviolet radiation on color, aging, biochemical information, etc. in dry proteinaceous materials
- methods of storing: SEM stubs; casts, molds and peels; and paraffin blocks, micromounts and other ancillary materials

Specimen and Collections Documentation

The estimated 2.5 billion natural science specimens worldwide are documented in a variety of ways, including labels, catalogues, electronic databases, maps, field records, correspondence, film and photographic media, sound recordings and art works. Much of the research value of the collections is vested in this documentation.

General Concerns

- information on paper substitutes and their potential utility for specimen labeling and other specimen or collections documentation
- clarification of terminology used in paper chemistry and in the description of paper stocks
- methods to test pH, and other testing methods to verify the quality of paper stock

Collections Documentation

- general guidelines for the care and handling of a variety of field records and other manuscripts, photographs, negatives, color slides, maps, original catalogues, radiographs, motion picture films, videotapes, sound recordings, electronic media databases, original artworks, etc.
- proper environments for the storage and display of archival and library materials

Specimen Labels and Labeling

- specifications for materials used in specimen labeling, including durable red inks for use in designating type specimens and materials for use in labeling fluid-preserved specimens
- standards for equipment and materials used to produce laser-printed labels or to produce labels via photocopy processes
- use of bar codes to label specimens (nature of support and adhesive, and potential for technological obsolescence)
- appropriate adhesives to attach labels to a variety of substrates including paper, glass and plastics
- impact of current labeling materials (inks, toners, plastics, metals, pigmented labels, bar code labels) on specimens
- deterioration of labeling materials, including pigmented labels, and inks and toners
- effects of fats, oils, and preparation and pest control chemicals on the preservation of specimen labels
- impact of storage environment on specimen labels
- techniques to clean specimen labels stained by pest control chemicals, mold, fats and oils, acidic adhesives and particulate pollutants
- conservation treatments to deacidify or repair specimen labels

Appendix C
Project Chronology

20 May 1989	Preliminary discussion with museum directors and representatives of selected organizations, in conjunction with ASC meeting, Lincoln, Neb.
16 Oct 1989	Preliminary meeting with conservators and collections managers, Washington, D.C.
06 Feb 1991	Submission of project proposal to National Science Foundation
12 Feb 1991	Mineral Museums Advisory Council discussion group, Tucson, Ariz.
14 Mar 1991	Meeting with U.S. Federation of Culture Collections board, Washington, D.C.
19 Mar 1991	Meeting and tour, American Type Culture Collection, Rockville, Md.
17 Jun 1991	American Society of Mammalogists discussion group, Manhattan, Kan.
19 Jun 1991	American Society of Ichthyologists and Herpetologists discussion group, New York
01 Jul 1991	Council of Systematics Malacologists/American Malacological Union discussion group, Berkeley, Calif.
03 Aug 1991	American Institute of Biological Sciences discussion group, San Antonio, Tex.
05 Aug 1991	Mycological Society of America/Bryological and Lichenological Society/American Fern Society discussion group, San Antonio, Tex.

07 Aug 1991	American Society of Parasitologists/Society of Nematologists discussion group, Madison, Wisc.
16 Aug 1991	American Ornithologists' Union discussion group, Montreal, Quebec, Canada
20 Oct 1991	Paleontological Society/Society of Vertebrate Paleontologists discussion group, San Diego, Calif.
22 Oct 1991	Mineralogical Society of America discussion group, San Diego, Calif.
07 Dec 1991	Entomology Collections Network/Entomological Society of America discussion group, Reno, Nev.
14–16 Feb 1992	Materials Science panel meetings, Washington, D.C.
10 Mar 1992	Grant awarded by National Science Foundation (DEB-9112855)
21–22 Mar 1992	Working Group 1 meeting, Washington, D.C.
25 Mar 1992	Meeting with US Federation of Culture Collections board, Washington, D.C.
4–5 Apr 1992	Working Group 2 meeting, Washington, D.C.
13 Mar 1992	Presentation of preliminary findings to the International Symposium and World Congress on the Conservation and Preservation of Natural Science Collections, Madrid, Spain
04 Jun 1992	Presentation of preliminary findings to the Society for Preservation of Natural History Collections meeting, Lincoln, Neb.
24 Jul 1992	Advisory Panel meeting, Washington, D.C.
05 Dec 1992	Meeting with members of Entomology Collections Network, Beltsville, Md.
14 Dec 1992	Editorial meeting to review draft report, Washington, D.C.
12 Apr 1993	Editorial meeting to review final report, Washington, D.C.
Jul 1993	Submission of project report to National Science Foundation and distribution of report to participants and other interested parties

Appendix D

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Appendix E
Resolutions from the International Symposium and First World Congress on the Preservation and Conservation of Natural History Collections

Preamble

We cannot even estimate the number of species of organisms on earth to an order of magnitude, an appalling situation in terms of knowledge and our ability to affect the human prospect positively. There are clearly few areas of science about which so little is known, and none of such direct relevance to human beings. —*Peter H. Raven, 1992*

The following issues and recommended actions are made understanding full well that burgeoning world population growth and the associated exponential increase of industrial exploitation of natural resources and energy use is causing an ever-increasing destruction of the world's biodiversity. Knowledge and understanding of biodiversity is essential for the conservation, management, and sustained use of ecosystems. Recent research demonstrates that our catalogues of biodiversity are seriously inadequate (as much as 90 percent of species diversity is unknown to science) and urgently need to be improved, so that science can place proper value on our natural resources and provide models to predict the consequences of lowered biodiversity. Thus, natural history collections are important for the study of biodiversity.

Issue 1

The Central Purposes of Collections: Recommendations to Aid and Monitor Worldwide Collections Concerns

The central purposes of natural history collections are to record through specimens and related data the existence of species on the earth along with their supporting geological structures, to carry out research on the interrelationships of plants, animals, and minerals, and to communicate this knowledge to serve the needs of society.

The preservation and conservation of natural history collections transcend local or national concerns. Natural history specimens and associated data, housed in museums, document the existence of species in time and space. Museums, then, are libraries of life and supporting geological structures. These resources are essential for expanding knowledge through research and education. Each biological species is an encyclopedia of genetic information; specimens in museums represent volumes of each different encyclopedia. Reference and type specimens within these collections are essential for precise identification of species and strains. Voucher specimens serve to validate biological research by ensuring that it can be replicated or compared with future research. Museum holdings cannot be replaced, they are priceless archives. Contributions emanating from natural history collections contribute significantly to diverse fields such as conservation, agriculture, medicine, toxicology, epidemiology, biochemistry, archeology, ethnology, economics, commerce, food and mineral resources, and law enforcement. Modern biotechnology is dependent on biological collections.

Action:

1-1 — The Congress, first and foremost, recognizes that the biological species of each country should be considered and respected as cultural resources of inestimable value for the entire world.

1-2 — As this first World Congress on the Conservation and Preservation of Natural History Collections, convened in Madrid, Spain, in 1992, clearly demonstrated the need for international coordination on numerous issues, a World Council on Collections Resources (WCCR) should be formed by the Organizing Committee of the 1992 Congress. The WCCR should consist of representatives from those world-wide organizations that are concerned about the preservation and conservation of natural history collections. The WCCR would be established for the following purposes:

(1) to monitor the activities and results of initiatives arising from this conference;
(2) to promote exchange of information and technology relating to the preservation and conservation of natural history collections;
(3) to work internationally to establish treaties so that in times of conflict, collections of natural history specimens are accorded equal protection with cultural artifacts. They must not be taken for trophy or ransom; and
(4) to collect documentation on the uses and benefits derived from natural history collections, and to update this documentation on a regular basis.

1-3 — The WCCR is to promote international standards established by the International Commission on Zoological Nomenclature (ICZN), International Commission on Botanical Nomenclature (ICBN), Association of Systematics Collections (ASC), Society for the Preservation of Natural History Collections (SPNHC), American Society for Microbiology (ASM), etc., and similar organizations to ensure placement and long-term preservation of type and other voucher natural history specimens in appropriate institutions.

1-4 — The WCCR will work with international organizations such as the International Council of Museums (ICOM) to promote high professional standards and establish educational programs for collection managers and conservators. This process will be aided by:

(1) providing museums and similar institutions with qualified consultants;
(2) helping with development of proposals for programs and funding;
(3) arbitrating conflicting opinions; and
(4) providing recommendations.

1-5 — The WCCR, working with established organizations such as ASC and the Biology Curators' Group of the United Kingdom, will establish a network to monitor, assess, and assist collections at risk.

1-6 — The WCCR will work with national organizations to help society understand the mission and value of natural history collections and the needs for professional care of collections, large and small, in perpetuity.

1-7 — The WCCR will organize a meeting every four years for the purpose of:

(1) reviewing progression of the WCCR toward implementing the mandates of its mission;
(2) reviewing international progress toward preservation and conservation of natural history collections;
(3) providing a forum for presenting and discussing new conservation and storage techniques, and common problems, and making strategies to solve international problems; and
(4) giving a prestigious award, a medal, under the patronage of the Fundación Cultural Banesto, to recognize outstanding contributions of individuals or organizations to the preservation and conservation of natural history collections and related issues.

Issue 2

Facility and Resource Needs for Conserving Collections

As only approximately 10 percent of biological diversity is known to science of the 10 plus million species estimated to live on earth, and as efforts intensify to inventory earth's biological diversity due to the rapidly increasing species extinctions caused by man, collections are growing, and will continue to grow in size at a considerable rate. The tasks of conserving these collections in perpetuity likewise will increase. Currently there are insufficient collection spaces or facilities with appropriate environmental controls.

Action:

2-1 — The Congress calls for rapid and focused surveys and inventories of the earth's biota realizing that the rate of man-related extinctions significantly decreases the diversity each year, and knowledge of the biota is the first step in understanding the function of biodiversity in ecosystems and its value to the human species.

2-2 — This Congress and the WCCR encourage institutional and societal policies that promote selective collecting of organisms, recognizing legitimate research needs and both the problems of the impact of collecting on species survival, and the problems of appropriate space for storage of specimens in perpetuity. The WCCR working with organizations such as the Sociedad para el Desarrollo de la Historia Natural will encourage the development of mechanisms to facilitate interactions between natural history collectors and those striving for the conservation of nature. The WCCR advocates salvaging of carcasses as a source of collection materials, selecting specimens where they are abundant, and establishing breeding stations (in situ or ex situ) as examples.

2-3 — The WCCR will contact and interact with appropriate international bodies (ICOM, the United Nations (UN), the World Bank, non-governmental organizations (NGOs), the European Community (EC), multinational corporations) to gain support to build, enlarge, and recondition natural history museums, and to provide appropriate facilities and resources based on a professional assessment of needs and long-range plans. Help is especially needed in developing countries.

2-4 — The Congress recommends that a pan-tropical conference be convened to define a strategic plan for small tropical museums and equivalent institutions, recognizing that such museums face extremely difficult physical and financial conditions as well as a growing need and responsibility to care for the rapidly increasing tropical natural history collections.

2-5 — As national museums of natural history provide leadership for each country's efforts to understand its biological diversity and the sustainable use of its natural resources for their cultural and economic value, this Congress encourages countries without such institutions to form them. Furthermore, the Congress resolves that the WCCR will assist in providing models of organization and mission statements for new national museums.

2-6 — The WCCR will aid regional and national collections care organizations to make national governmental agencies, NGOs, foundations, and the public aware of the need for new and/or enlarged/ upgraded buildings, facilities, and resources for maintaining and preserving natural history collections in perpetuity.

Issue 3

Museums and Educational Needs in Developing Countries

The largest and longest established museums with collections housing millions of biological specimens from throughout the world are situated in northern industrialized countries. The greatest proportion of biological diversity is found in developing countries with tropical rain forests. Also, there are other great centers of biological diversity and rich historic-cultural materials in developing countries. There are special needs to develop and maintain museums in developing countries. Scientists, scholars, and collection managers in developing countries require access to the large established collections. Considerable international cooperation is needed with regard to collections access, training, data exchange, and technology transfer.

Action:

3-1 — The WCCR will promote efforts to establish regional training centers in one or more developing countries, particularly in tropical regions, to train natural history museum collection managers and conservators to properly maintain collections in tropical regions. Support for such programs should be solicited from international organizations such as the UN, the World Bank, NGOs, and multinational corporations.

3-2 — Aid is needed to provide scholarships and fellowships for students of developing countries to gain education in systematics, collection management and conservation in advanced centers in developed countries. Courses must be taught with recognition of the tools and technology that will be available to students when they return.

3-3 — Industrialized and developing countries should be encouraged to form partnerships to build programs in collection management, and research on materials and methods for preservation. All countries should share information and improve access to scientific and world-wide cultural and natural resources.

3-4 — International support should be sought to fund research on problems particular to specimen deterioration in tropical humid regions and to develop appropriate control measures.

3-5 — In establishing partnerships between institutions of industrialized and developing countries, this Congress calls for bilateral cooperative programs that include technical, in-situ training. Managerial aspects should be carried out with great sensitivity and understanding of local conditions and constraints in the developing countries.

3-6 — As most nations have little knowledge of their own flora and fauna, and as conservation managers and users of natural products require more complete inventories, we urge national governments to establish National Centers for Biodiversity that will set priorities, survey, study, document, and provide the public and policy makers with information about their national heritage. These centers should integrate existing efforts and support existing museums.

3-7 — The Congress calls for greatly increased coordination among museum and other collection centers to provide a united thrust on the biodiversity crisis, including data and technology exchanges.

Issue 4

The Need to Escalate Research and Development of Preservation and Conservation Techniques, and Research in Collections Curation Issues

Increasingly, numerous types of organisms, minerals and cultural materials may not ever be sampled again due to habitat destruction, restrictions on collecting endangered species or species from certain habitats, and cultural change. Furthermore, collections already contain records and specimens of species and populations that no longer exist. Accordingly, there is a need to escalate research and development in management and preservation techniques, as well as to provide a considerable increase in collection management education.

Action:

4-1 — The Congress calls for an increase in educational courses and training programs at the undergraduate, graduate and postgraduate levels for the following: collection management, specimen preparation and conservation, research in applied material science toward preservation and conservation of specimens, and toward industrial development of materials and containers for the treatment and long-term storage of specimens. In education and training programs, existing methodologies must be adapted to local conditions in developing countries based on an understanding of the limitations and constraints in such countries.

4-2 — The WCCR will work with national collections care organizations, agencies, and private funding organizations to provide competitive program support for the education programs given above.

4-3 — The Congress urges the WCCR to develop international cooperation, and to coordinate national and international initiatives aimed at specimen conservation with special reference to: preparation techniques, long-term storage techniques, repair and treatment techniques, disposal and destruction protocols, and conditions for loans and exchanges.

4-4 — The Congress calls for increased application of technology that allows for extraction of data from specimens for research yet minimizes destruction of specimens.

4-5 — The new molecular techniques are now of immense importance in systematics studies, thus the Congress calls on all curators, preparators, and collections managers to prevent the use of treatments that would irreversibly alter or destroy DNA content. Guidelines must be established to preserve useful DNA (and other genetic and biochemical materials) in new collections.

4-6 — The Congress calls for increased research on collections to provide accurate identifications and to systematically update the collections, undertaking the steps necessary to provide accurate data to the user community.

Issue 5

The Need for Trained Systematists, Collections Managers and Conservation Specialists

As approximately 90 percent of biological species diversity is unknown to science, and as collection management for systematic research requires individuals who are authoritative concerning the systematics, taxonomy and nomenclature of genetically allied groups of species and genera, and as today there are too few experts for many groups, especially in taxon-rich developing countries, it is clear that there is an immediate need for the education and training of systematists with emphasis on studying the most poorly known group of organisms with the greatest economic and cultural value.

Action:

5-1 — The Congress calls on universities to upgrade or establish programs in systematics and to form cooperative programs with free-standing museums and other collections centers in order to create strong programs for systematic research and for the training of systematists, collections managers and conservators, as well as administrators.

5-2 — The WCCR is encouraged to work internationally to inform and educate pertinent national agencies and organizations about this pressing need and to work with them to form strategies for problem solving.

Issue 6

The Need for Databases

There are pressing demands for collections-based data. Collection management today requires computerized data management. Increasingly, collections-based data includes information on how the specimens were prepared, the conservation status of the specimens, and actions taken to correct deterioration and damage problems. Effort is needed now to establish data standards and efficient exchange of data through networks within and between institutions.

Action:

6-1 — The WCCR will help facilitate exchange of information that builds on existing and successful data management systems, realizing that there have already been two decades of experience in computerization of museum collections.

6-2 — The Congress calls for all natural history museums to work within existing programs to attain uniformity in data standards, to enhance data standards, to rapidly increase computerization of specimen-based data, and to establish protocols and safeguards for data exchange. It is necessary to establish linkages with other systems such as Global Information Systems, GenBank, the Conservation Information Network (CIN), and other networks.

6-3 — The Congress calls for immediate action to rapidly create databases of all known species, including range and ecological data. To facilitate the process, the catalogue of the known biota of the world is to begin with minimal data (and thus will be necessarily crude). The estimated manpower for this task is 1.5 thousand person years at a cost of some 60 million pounds sterling. This provides for what is known of species diversity and numbers.

Issue 7

Education and Public Awareness

Museums and other collection centers must become highly visible in the public eye if the energy of the people is to impel governments to act promptly to save the world's biota. Museums are ideally suited to establish strategies to create public and private awareness about the biodiversity crisis and the linkage between collections and our knowledge and understanding, use, and preservation of nature.

Action:

7-1 — The Congress calls upon museums to change to an active outward-looking mode, and to build a solid contract with the public through relevant public education programs and exhibits using cultural values appropriate to the audience.

7-2 — The Congress calls on museums to engage our systematics expertise and collection resources to address the crises of our day that endanger all the world's species. Relevant issues include the quality of environment, public health, useful genes/gene products, global databases on species and habitat diversity, training specialists from developing countries, and providing a reference base for the inventory of flora and fauna of protected areas.

Issue 8

Postal Systems: Rules and Regulations

Museums today are faced with an ever-increasing burden of national and international rules and regulations that hinder the efficient and rapid flow of specimens and data for research and educational purposes. Frequently such rules and regulations cause considerable delays in delivery of specimens causing deterioration or destruction of the specimens.

Action:

8-1 — The Congress calls for the WCCR to take the initiative to work and network internationally to derive agreements, conventions, and treaties that will enhance the speed and efficiency of specimen and data flow, and enhance handling procedures for specimen care.

Issue 9

Endorsements: UNESCO, UNCED-RIO

As these issues are of great importance to the good of the human species, and as there is a biodiversity crisis and a crisis in managing rapidly growing collection resources, the Congress requests that these issues and resolutions be carried to UNESCO to receive its endorsement. In so doing the Congress recognizes UNESCO's multiple mandate in the fields of education, science, culture and communications, and its long-standing experience in providing solutions to problems in environment and development, as well as its contribution to the protection and preservation of biological diversity. These resolutions are also to be carried to the United Nations Conference on the Environment and Development (UNCED) to be held in Rio de Janeiro in June 1992 to inform the Conference of these issues and actions deemed necessary, and to attain the endorsement of the Conference. This document is also to be carried to the World Conservation Union (IUCN) to obtain its endorsement.

Collections have been assembled over several centuries, in many parts of the world, where they often document regionally characteristic organisms. Collections can document invasive species that increase in abundance or range over time. Likewise, collections can document the decline in so many species, and may even come to be the only places where extinct species exist.
—Peter H. Raven, Australian Biologist *5, no. 1 (1992)*

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Page 27 Perrot, Paul N. 1987. Remarks. In *Invest in the American Collection* (J. S. Long, ed.). Proceedings from a Regional Forum on the Conservation of Cultural Property. National Committee to Save America's Cultural Collections, Washington, D.C. (p. 5).

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Ward, Philip. *The Nature of Conservation* (p. 32).

Page 39 de La Penha, Guilherme M. Opening remarks. In *Current Issues, Initiatives, and Future Directions for the Preservation and Conservation of Natural History Collections.*

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It is no small thing to outwit time.