

# **Scientific Collections:**

## Mission-Critical Infrastructure for Federal Science Agencies



A Report of the  
Interagency Working Group on Scientific Collections  
(IWGSC)

“Agencies should assess the priorities for and stewardship of Federal scientific collections, which play an important role in public health and safety, homeland security, trade and economic development, medical research, and environmental monitoring.”

Dr. John Marburger, OSTP Director, and Joshua Bolten, OMB Director, in the 2007 Interagency R&D Priorities Memorandum

## ***Scientific Collections and their Impact***

Throughout the report, you will see text-boxes like this that present brief stories about Federal scientific collections and their importance to research and society. Each story will have one or more icons that illustrate the various areas in which that particular scientific collection is having an impact:



***Economy and trade:*** Many regulatory decisions made by the Federal Government that have impact on foreign and domestic trade are supported by research that depends on scientific collections.



***Changes over time:*** The Federal Government has been amassing collections for more than two centuries. By analyzing specimens collected at different points in time, researchers can reconstruct important historical changes. People can't travel back in time, but scientific collections offer scientists a window on the past.



***Environmental Quality:*** Scientific collections document the condition of soil, air, and water, help track pollution, and enable us to model future environmental changes so they can be better managed.



***Invasive Species:*** In today's global economy the easy movement of trade goods through ports is vital to America's economy. At the same time, the movement of invasive species via the transport of everything from fruit to bathroom tiles threatens our crops, ecosystems, and animal and human health. According to Pimentel, et al., (2005), in the United States there are an estimated 50,000 invasive species; collectively, they cause nearly \$120 billion worth of environmental damage and loss per year and can spread infectious diseases to animal and human populations.



***Scientific Treasures:*** Many scientific collections contain unique objects that cannot be collected again easily – or at all, in some cases. They are priceless.



***Food and agriculture:*** Scientific collections of agricultural pests and other threats to food safety and security are used routinely for border inspection, consumer protection, and control measures.



***Public Health and Safety:*** Few scientific collections resonate more deeply with the public than those that have an impact on health and safety. Whether researchers use them to track down the cause of a deadly new epidemic or to learn important lessons from an ancient one, collections are pivotal resources in our fight to save lives and to improve the health and safety of people around the world.



***National Security:*** Homeland Security Presidential Security Directive (HSPD)-9 deals with defending agriculture and food against terrorist attacks, major disasters, and other emergencies. Preparation for pandemics, protection of civil and military aviation, and other activities that can involve scientific collections are also important for national security.



***Unanticipated Uses / New data:*** Collections of objects kept for long periods often serve in ways that the collectors and repositories could not have imagined. These unanticipated uses are often critical to solving today's most pressing scientific problems. Likewise, years, even decades later, a new analytical technique can be created that allows researchers to ask new and more detailed questions using the same specimens.

**Scientific Collections:**  
Mission-Critical Infrastructure for Federal Science Agencies

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## NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

The National Science and Technology Council (NSTC) was established by Executive Order on November 23, 1993. This cabinet-level council is the principal means by which the President coordinates science, space, and technology policies across the Federal Government. NSTC coordinates diverse paths of the Federal research and development enterprise. An important objective of the NSTC is the establishment of clear national goals for Federal science and technology investments in areas ranging from information technologies and health research to improving transportation systems and strengthening fundamental research. The Council prepares research and development strategies that are coordinated across the Federal agencies to form a comprehensive investment package aimed at accomplishing multiple national goals.

For more information visit [http://www.ostp.gov/nstc/html/NSTC\\_Home.html](http://www.ostp.gov/nstc/html/NSTC_Home.html).

## OFFICE OF SCIENCE AND TECHNOLOGY POLICY

The Office of Science and Technology Policy (OSTP) was established by the National Science and Technology Policy, Organization and Priorities Act of 1976. OSTP's responsibilities including advising the President in policy formulation and budget development on all questions in which science and technology (S&T) are important elements; articulating the President's S&T policies and programs; and fostering strong partnerships among Federal, state, and local governments, and the scientific communities in industry and academe. Every fiscal year, OSTP and the Office of Management and Budget (OMB) issue a memorandum entitled "Administration Research and Development Budget Priorities." The memorandum highlights the Administration's research and development priorities and emphasizes improving management and performance to maintain excellence and leadership in science and technology. The FY '08 memorandum is available at <http://www.ostp.gov/html/budget/2008/m06-17.pdf>.

For more information visit <http://www.ostp.gov>.

## OFFICE OF MANAGEMENT AND BUDGET

The predominant mission of the Office of Management and Budget (OMB) is to assist the President in overseeing the preparation of the Federal budget and to supervise its administration in Executive Branch agencies. In helping to formulate the President's spending plans, OMB evaluates the effectiveness of agency programs, policies, and procedures, assesses competing funding demands among agencies, and sets funding priorities. OMB ensures that agency reports, rules, testimony, and proposed legislation are consistent with the President's Budget and with Administration policies. In addition, OMB oversees and coordinates the Administration's procurement, financial management, information, and regulatory policies. In each of these areas, OMB's role is to help improve administrative management, to develop better performance measures and coordinating mechanisms, and to reduce any unnecessary burdens on the public.

For more information visit <http://www.whitehouse.gov/omb/>.

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EXECUTIVE OFFICE OF THE PRESIDENT  
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL  
WASHINGTON, D.C. 20502

December 23, 2008

Dear Colleagues:

I am pleased to forward this report, "*Scientific Collections: Mission Critical Infrastructure for Federal Science Agencies*". It describes the scope of scientific collections under the stewardship of the federal government and how they are used to carry out critical government functions. In addition, it addresses the challenges involved for stewardship of these collections and provides recommendations for ensuring that they are appropriately managed for the benefit of the national and global scientific enterprise.

Scientific collections are an important part of the cumulative evidence base upon which science depends. They are composed of items acquired for *scientific study* rather than simply for historic or artistic value, and they range from moon rocks and dinosaurs to insects and human tissues. They support regulatory, management, and policy decisions and are used for research in biomedicine, global change, biodiversity, and evolutionary biology. Not confined exclusively to big museums in Washington, these collections are widely distributed across federal agencies and throughout the country. Increasingly, they are used in interagency activities as well as international collaborations.

This report represents the first step in an ongoing process of identifying and characterizing these collections and determining their long-term stewardship needs. Robust interagency collaboration will remain vital as we develop a systematic approach to safeguarding these scientific treasures for future generations of scientists.

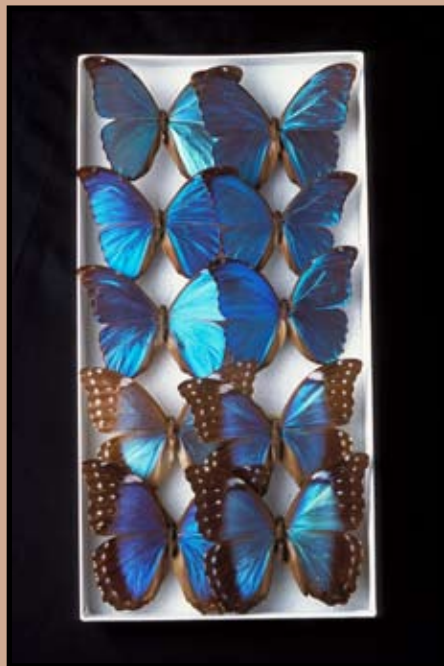
Sincerely,



John H. Marburger, III



Bird collections at the National Museum of Natural History. Photo courtesy Smithsonian Institution



Tropical Butterflies (genus *Morpho*) from the National Museum of Natural History.

Photo courtesy of Agricultural Research Service



Rock cores from the USGS Core Research Center collections.

Photo courtesy of J. Hicks, U.S. Geological Survey



Researchers study specimens from the National Fungus Collection.

Photo courtesy of the Agricultural Research Service



Gold Ore - Photo courtesy of Smithsonian Institution

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<sup>1</sup> Currently at Smithsonian Institution



Fossil Skull of *Smilodon fatalis* (saber-toothed tiger) from Texas.

*Photo courtesy of Smithsonian Institution*



Specimens from the National Animal Parasite Collection.

*Photo courtesy of the  
Agricultural Research Service*



A scientist examines specimens of the black-footed ferret.

*Photo courtesy of U.S. Geological Survey*



Mollusc specimen from U.S. Geological Survey collection.

*Photo courtesy of K. C. McKinney,  
U.S. Geological Survey*

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## Executive Summary

Beginning in 2005, the White House Office of Science and Technology Policy (OSTP) and Office of Management and Budget (OMB) called on Federal agencies to focus attention on integrated support and planning for their care and use of Federally held scientific collections. Based in part on these recommendations, an Interagency Working Group on Scientific Collections (IWGSC) was created, co-chaired by representatives of the Smithsonian Institution (SI) and the U.S. Department of Agriculture (USDA) to examine the current state of Federal scientific collections and to make recommendations for their management and use. This report is a first step in ensuring that this vital research infrastructure is preserved and strengthened for the benefit of both our country and the global scientific research enterprise. This report describes the nature and state of these collections and the issues they face as part of the nation's research infrastructure. It also makes recommendations about improving the care and management of these assets.

Object-based scientific collections (hereafter referred to as “scientific collections”) are valuable components of the Federal government's and the Nation's research infrastructure, alongside buildings, scientific instruments, and human resources. Scientific collections, as discussed in this report, consist of physical objects that are preserved, cataloged, and managed by Federal agencies and other organizations for research and other purposes. Scientific collections do not include art or historical objects, collectibles, or the books and documents that are stored in libraries and archives. The specimens in scientific collections were acquired as objects for scientific study, not for their aesthetic or market value as collectibles. In general, the contents of these scientific collections are documented and publicized with the goal of making the specimens available to other members of the research community for study.

Scientific collections are preserved because they document the results of research, and allow earlier findings to be confirmed and extended. Scientific collections are often re-analyzed using new instruments and techniques, providing new data and insights from old specimens. Collections provide irreplaceable evidence of long-term historical trends, allowing researchers to make predictions into the future. Scientific specimens can also have unanticipated relevance to research being conducted in fields other than the one for which they were collected.

Permanent scientific collections serve a number of general functions:

1. As “vouchers” from earlier observations or findings. A voucher specimen is one on which critical analyses and observations have been performed, and it is likely that future researchers will want to either repeat these analyses to corroborate published findings or to apply new analytical techniques.
2. As standards. Some specimens become permanent references that must be retained for future comparison. For example, the National Institute of Standards and Technology (NIST) of the Department of Commerce retains the standard reference specimens for weights and measures. USDA, SI, the National Institutes of Health (NIH), and other agencies retain biological scientific collections that serve as reference standards for identifying species that are critical to protecting America's food sources. As one example, NIH supports laboratories that preserve microorganisms for study from standard “type cultures” and with known genetic signatures. “Type specimens” of a species of plant, animal, microbe, mineral or rock type are the reference examples of the species that are formally described and attached to its name.
3. As sources of specimens for biological research, conservation, and food security. Some Federal and Federally-supported scientific collections comprise living organisms. These scientific collections include type culture scientific collections, seed banks and plant germplasm repositories, genetic stock centers, zoos, captive breeding programs, and other biological resource centers.
4. As repositories for rare objects. Federal scientific collections also include specimens that record unique events in history and/or unique opportunities to collect specimens. These specimens cannot be replaced and if they are not properly cared for important research opportunities will be lost forever. Such rare objects include such things as moonrocks and specimens of flora and fauna collected by the Lewis and Clark expedition.
5. Sources of ideas and study specimens for education and training. Scientific collections are routinely used by undergraduate and graduate students as research material for theses and dissertations. In this way, Federal scientific collections are having an important impact on professional training of future researchers. Scientific collections have also inspired and informed educators in their development of curriculum and instructional materials for students at all levels. Museum exhibits draw on scientific collections for public education, and radio and television coverage of important research findings are frequently based on scientific collections.
6. Some agencies proactively collect samples for future analysis or experimental use in line with their missions. These are important for documenting diversity and variability in nature. Such samples are also critical resources for epidemiology and research in clinical medicine.

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<sup>1</sup>Acronyms are defined in Appendix A.

Scientific collections provide an excellent return on the taxpayers' investments. Federal agencies consider the following in making decisions about the numbers and sizes of the collections they maintain.

**Immediate access to collections:** Urgent problems can call for immediate access to scientific data. Maintaining scientific collections can provide users with immediate access to critical specimens.

**Replacement costs.** The passage of time, technical challenges, or prohibitive costs make it all but impossible to replace the contents of a collection when it is needed at a later date. Some locales may be physically inaccessible for a variety of reasons.

**Irreplaceable object.** Many specimens collected decades ago can no longer be recollected because the locality has either disappeared or a species has gone extinct.

**Critical Redundancy.** Research organizations keep collections in different places and maintain large collections of similar specimens for several reasons such as in the event of natural disaster.

**Research is a distributed enterprise.** Federal research serves a wide range of constituencies and issues. To serve their mission efficiently, researchers and the collections they use need to be located in many different places.

**Variation in nature.** Studying the variability within and among biological populations and geological specimens often reveals the processes that underlie their nature; this study of variation is a basic component of the scientific method. Large sample sizes are often needed in order to make statistically significant interpretations.

**Safety in numbers.** Scientific collections of living specimens reduce the risk of catastrophic loss by guaranteeing that a pool of genetic variability is available to protect and ensure diversity, and to ensure the reintroduction and replenishment of the genetic stock.

## **History of the Working Group**

The first meeting of the IWGSC took place in September 2005. In defining the scope of its work, the IWGSC considered the entire national infrastructure of scientific collections, including both Federal scientific collections and non-Federal collections that receive Federal support through the National Science Foundation (NSF), NIH, USGS, and other grant programs. To address that broad scope, the IWGSC reviewed published reports on scientific collections, conducted a survey of Federal agencies, and heard expert testimony.

The survey solicited information on the use and condition of Federal scientific collections, staff and budget support for them, their rates of growth, access to the collections and data about them, and policies governing their use. As the first-ever survey of Federal collections, this study creates a baseline of information on Federal scientific collections and provides the basis for future monitoring, coordination, management and policy development.

The IWGSC also gathered information on Federal scientific collections through monthly meetings that included briefings on the scientific collections held by agencies and presentations and discussions on a variety of relevant topics. These included the legislative basis for collection ownership and stewardship, repatriation of Federal scientific collections to Native American tribes, and National Park Service museum collections management. Topics also included International agreements concerning Access and Benefit Sharing of genetic resources in scientific collections, Smithsonian Institution's "right of first refusal" policy regarding scientific collections created by other Federal agencies, and Collection policies.

## ***Findings of the IWGSC***

The IWGSC reported the following findings based on the results of the survey of Federal scientific collections, its other activities, described above, and the extensive knowledge of collections possessed by the IWGSC members.

Federal agencies own and maintain diverse scientific collections. These scientific collections are essential to supporting agency missions and are thus vital to supporting the global research enterprise.

Most Federal scientific collections continue to grow at regular, predictable rates, but adequately trained support staff and funding resources are declining.

There is a lack of documentation of the contents and conditions of some Federally-owned scientific collections.

Scientific collections are generally accessible for scientific research or other uses, but collection databases are not widely developed and Web access to collection information is still in its infancy.

Agencies varied widely in the degree to which they have developed written policies concerning the management and use of Federal scientific collections.

Scientific collections have impacts in areas that were unrelated to their original purposes. These impacts can be difficult to foresee.

Meeting the financial and staffing needs of managing Federal scientific collections can require trade-offs among different competing agency responsibilities.

In response to competing priorities and limited resources, Federal agencies have developed a variety of strategies and business models for long-term management of scientific collections.

The legal status of and legislative authority behind some Federal scientific collections is not well understood by some agencies.

The curators of scientific collections are developing specimen databases that are increasingly integrated and interoperable. Some but not all Federal scientific collections are developing their own specimen databases. While some Federal Agencies have been leaders in standardizing data, the degree to which Federal and non-Federal collection databases can communicate with one another is highly variable.

## **Recommendations**

1. *The IWGSC recommends that agencies with scientific collections work as necessary to support their missions to develop realistic cost projections for collection maintenance and operation, and work to incorporate the needed support as stable budget elements.*
2. *The IWGSC recommends that agencies improve both the documentation of the contents of their scientific collections and access to the documentation on the internet.*
3. *The IWGSC recommends that agencies exchange documents that describe their scientific collections policies, procedures, and best practices in order to minimize the effort needed for agencies to develop collection-specific policies and procedures.*
4. *The IWGSC recommends a review of the legal and legislative basis for the Federal role in scientific collections, thereby clarifying agency responsibilities.*
5. *The IWGSC recommends the creation of an online clearinghouse of information about Federal scientific collections.*
6. *The IWGSC recommends that a periodic report on the status and condition of the scientific collection infrastructure be prepared and submitted to the Committee on Science, OSTP, and OMB.*
7. *The IWGSC recommends that the NSTC Committee on Science continue the work of the IWGSC beyond its March 2009 expiration, to facilitate the implementation of these recommendations and explore options for a mechanism to provide the means to coordinate and improve Federal collections over the long-term.*

## **Next Steps**

Scientific collections are by their nature backward-looking. They record our history and allow us to confirm past findings, but we create collections and maintain them as an investment that will benefit future generations. The recommendations in this report will put in place a system for monitoring and improving the condition of Federal scientific collections and will promote improvements in management, documentation and curation. Providing the facilities, workforce, and curatorial support needed to adequately maintain Federal collections will probably require increased and focused investments by some agencies. Nevertheless, the IWGSC is convinced that these additional investments will provide even greater returns by improving Federal research that serves the U.S. taxpayer and the global community.

## Introduction

What if you awoke one morning to find that some of your favorite breakfast essentials – toast and orange juice -- had completely disappeared? Then what if, throughout the day, you discovered that other foods you take for granted, like pasta, had vanished too? Even chocolate cake? And when you shopped for food later that day, the fish in the market were labeled “Might be red snapper” or “Species unknown” or “Probably safe”?

Thanks in part to Federal scientific research collections, Americans should be confident that their food is both available and the safest in the world. Federal agencies conduct research because they rely on dependable scientific information and sound interpretations of that information. Every day, Federal agencies rely on collections of scientific objects and specimens to enhance security, public health and safety, to conduct environmental monitoring, to make new scientific discoveries and to educate the public. There are more of these collections than you might think. While the Smithsonian Institution might be the first place that comes to mind when you think of collections of scientific objects, a diverse array of Federal departments and independent agencies also own, maintain, and support scientific collections. The Federal Government owns and makes use of collections ranging from microbes to moon rocks.

**Object-based scientific collections**<sup>1</sup> (hereafter referred to as “scientific collections”) are valuable components of the Federal Government’s and the Nation’s research infrastructure, alongside buildings, scientific instruments, and human resources. This report describes the nature and state of these collections and the issues they face. Scientific collections (as described in this report) do not include objects held in Federal collections for research on history and art. The specimens in scientific collections were acquired as objects for scientific study, not for their aesthetic and market value as collectibles. They do not include library materials or archives. The preservation of Federal and Federally-supported documents falls under the purview of the National Archives and Records Administration (NARA)<sup>2</sup> and are not considered here. However, documentation directly related to the scientific objects (e.g., field notes, maps of collecting sites) were included and are referred to as **ancillary scientific collections**.

Scientific collections are vital infrastructure, often outlasting the research projects that created them. By way of analogy, think of scientific collections as performing a role similar to high powered telescopes and astronomical observatories. While individual programs come and go, the facilities remain to support the next program that seeks to explore and discover something new.

Scientific collections are also preserved because they document the results of research and allow earlier findings to be

confirmed and extended. Scientific collections are often re-analyzed using new instruments and techniques, providing new data and insights from old specimens. Collections provide irreplaceable evidence of long-term historical trends, allowing researchers to make predictions into the future. Scientific specimens can also have unanticipated relevance to research being conducted in fields other than the one for which they were collected.

In 2005, recognizing both the importance of these collections and the issues they face, the White House Office of Science and Technology Policy (OSTP) and Office of Management and Budget (OMB) called on Federal agencies to focus attention on integrated support and planning for their care and use. Based in part on these recommendations, OSTP commissioned an Interagency Working Group on Scientific Collections (IWGSC), co-chaired by representatives of the Smithsonian Institution (SI) and the U.S. Department of Agriculture (USDA). The purpose of this report is to present a “snapshot” of the current state of Federal scientific collections and to make recommendations for the next steps that collections managers and administrators can take for ensuring that this vital research infrastructure is preserved and strengthened for the benefit of both our country and the global scientific research enterprise.

Collections of digitized data, and analog versions of large datasets (e.g., seismographs and audio recordings) are covered by standards for Federal and Federally supported data collections that are being developed concurrently by the NSTC Interagency Working Group on Digital Data (IWGDD).

The effective use and management of scientific collections have become a topic of international discussion. Organizations that collect and maintain scientific collections are increasingly recognizing their moral and legal responsibilities to enhance accessibility to their collections to researchers around the world.

## What Are Scientific Collections?

Federal research utilizing scientific collections creates a wide variety of tangible results and products including: inventions and innovations; maps, charts, and databases of scientific observations; scholarly publications; official reports used to support legislative and regulatory processes; instructional materials for students; educational materials for the public as well as for future generations of scientists and engineers; shared knowledge; and scientific collections. Research projects involve the study of physical objects collected from places ranging from the earth’s interior to the depths of the ocean to the reaches of outer space.

Object-based scientific collections, as discussed in this report, consist of physical objects that are preserved, cataloged, and managed by Federal agencies and other organizations for research and other purposes. In general, the contents of these scientific collections are documented and publicized with the goal of making the specimens available to other members of the research community for study.

<sup>1</sup> Terms in bold italic are defined in Appendix B.

<sup>2</sup> Acronyms are defined in Appendix A.

### Keeping International Markets Open

Like all crops, wheat is vulnerable to diseases that can kill it outright, reduce its yield, or simply make it inedible. One such disease is caused by a fungus called Karnal bunt, which makes wheat smell and taste like rotten fish. Even a tiny amount can contaminate an entire railcar full of wheat.

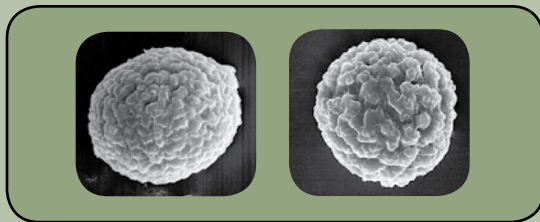
In 1996, Karnal bunt spores blew in on the wind from Mexico to Arizona, and scattered reports of wheat infested with Karnal bunt began to appear. Reports of Karnal bunt from wheat producing areas all around the United States soon followed. Other countries embargoed U.S. wheat and the \$6 billion-a-year wheat export market was faced with a looming economic disaster.



Wheat Harvest.  
Photo courtesy of ARS. (image no. K1441-5)

Karnal bunt has look-alike cousins that can't be readily distinguished from it, even under a microscope. For this reason, investigators were relying on a DNA test to identify the fungus that was infecting the U.S. wheat. Using the USDA's National Fungus Collection for comparison, a USDA scientist discovered that the fungus being identified as Karnal bunt was really a harmless rye grass fungus. By using the collection to develop a more accurate DNA test, the scientist determined that Karnal bunt was limited to a small area in Arizona. Exports of wheat from the rest of the country could safely continue.

In 2005, the Algerian government claimed that a shipment of U.S. wheat was contaminated with Karnal bunt, raising the prospect of trade embargoes again. A scientist traveled to Algeria to investigate and determined that the shipment was not, in fact, contaminated, saving the \$70 million annual U.S. wheat export market in Algeria. USDA's fungus collections provide a way to distinguish false alarms from real infestations, thereby ensuring US access to global markets.



When greatly magnified, a ryegrass bunt spore from Tennessee (right) displays thicker, wider ridges and grooves than those of a Karnal bunt spore (left).

Both specimens are from the National Fungus Collection. Both photos by Jim Plaskowitz, Courtesy of ARS



### Combating agricultural threats

For many people, oranges in Christmas stockings are a family tradition. Clementine oranges are especially prized because they are sweet and easy to peel. Just before Christmas 2001, USDA prohibited imports of Clementine oranges from Spain because Mediterranean fruit fly larvae had been found in several shipments. The Mediterranean fruit fly is not simply a nuisance, but one of the world's most harmful agricultural pests. It requires massive and expensive eradication programs to protect fruit production from destruction (in California alone, the 2005 value of vulnerable fruits was \$9.5 billion). By using USDA's comprehensive fruit fly collection, scientists have developed an expert system that allows port inspectors to rapidly and reliably identify fruit flies in the shipments they inspect. And if the flies stump the inspectors, they can be shipped to USDA's Systematic Entomology Lab where experts can use the collection to provide an identification within 24 hours (ITAP 2008).



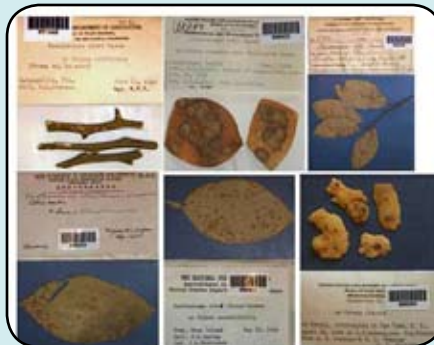
Male medfly resting on a leaf.

Photo by Scott Bauer. Courtesy of ARS



### Old Specimens, New Solutions

Citrus bacterial canker is a devastating bacterial disease of citrus trees that threatens the U.S. citrus industry, and it's causing major problems in Florida. As the disease continues to spread around the world, it's critical to understand where the disease came from and the route of spread in order to develop appropriate methods for control or prevention. How to go back and look at this over time? Herbarium specimens in the National Fungus Collection, collected from Japan and Florida in the early 1900s, proved to be the key. These citrus tree samples were collected because they were infected with fungal diseases; bacterial diseases were not well known at the time. Techniques for analyzing DNA were developed much later, providing new information on bacterial infections. A century after the specimens were collected, scientists found the citrus canker bacteria on them as well, allowing them to unravel the history of the disease and pin down its source. Neither the presence of the bacteria nor the existence of DNA, much less ways to analyze it, were envisioned when the leaf samples were collected. (Li et al. 2007).



Citrus specimens that had symptoms of citrus canker were preserved with date and place of origin over the last century. The USDA ARS has 741 samples like these originally collected from more than 30 countries during the 20th century.



Federal scientific collections are created during the conduct of mission-critical basic and applied research projects. They may be objects of natural history, part of long-term ecosystem/climate monitoring programs, collecting activities on Federal lands, or surveys of Federal resources such as minerals, fishes, fossil fuels, or forests. The Federal Government may also assume stewardship of scientific collections that are created under Federally-supported research projects. Examples include ocean drilling cores, ice cores, or biota on public lands. Scientific collections may also be created when Federal scientists undertake retrospective and prospective research, or establish management, prevention, control, or eradication programs.

### **Why Do We Keep Scientific Collections?**

The Federal Government mandates that collections be preserved for use by the broader research community. The Federal Government has long recognized the importance of long-term management of scientific collections, dating back at least to the Lewis and Clark expedition of 1804-1806 and the United States Exploring Expedition of 1838-42. As early as 1879, Congress indicated that scientific objects no longer needed by one agency should be maintained as Federal collections for broader use (20 USC 59). In 1892, Congress recognized the importance of making "governmental collections" accessible to scientific investigators and students (20 USC 91 and Joint Resolution 1892).

We need to keep items collected in the conduct of research because advances in science depend on a strong and cumulative evidence base. Scientific collections comprise an important part of that base. To build that base, researchers use the scientific method, an approach that includes systematic accumulation of data, the testing of hypotheses, and scientific replication. It is only through repeated observation and documentation that a consistent evidence base is developed and a finding can stand the test of time.

Scientific replication can also result in new or divergent findings. Consider the analogy of physical evidence found at a crime scene which must be preserved not just for the trial, but also for a long time afterwards. Authorities may file appeals and the evidence may need to be re-examined as new analytical techniques are discovered. Without access to the physical evidence, justice could not be served over time. The same applies to scientific collections. A researcher may call findings into question years, even generations, after they were originally published. New evidence and analytical techniques can open new lines of inquiry. Without the ability to re-examine old preserved evidence, the research process would be stymied. It may be very costly to replicate or recollect a sample. In some cases it may be impossible because the specimen was the result of a unique historic event or was collected from an area that is no longer accessible.

Specimens in scientific collections can have unanticipated relevance to research in fields other than the one for which they were originally collected. Oceanographic samples

originally collected for marine ecosystem and geological studies have proven valuable for climate research. Biological specimens originally collected for ecological and evolutionary studies are useful for identifying the origins and spread of **zoonotic** and human diseases and help document the movement of invasive species. In one instance, insect specimens collected for agricultural research had important impact on international relations.

Scientific collections are critical for analyzing long-term historical trends and in making predictions. They are useful in preventing the spread of disease, pests, and environmental damage, and in the study of long-term climate change. For example, scientific collections have been used to chart the history and future of the spread of diseases and pollution. Scientific collections of fossils, rocks, and ice and ocean sediment cores at USGS have been used to "read" the physical and biological history of a region for climate reconstruction. Anthropological scientific collections have been used to reveal diets and diseases of human and animal ancestors and model climate changes over long periods. Fungal scientific collections played a valuable role in enabling researchers to identify infections as a potential cause of amphibian decline. Scientific collections of Asian longhorn beetles were used to identify pests entering ports of entry and also to predict the areas of their potential spread.

### **Administration Priorities in Research and Development**

In their 2005 and 2006 joint memoranda to Federal agencies on research and development (R&D) budget priorities for fiscal years (FY) 2007 and 2008, Dr. John Marburger, Director of OSTP and the President's Science Advisor, and Joshua Bolten and Rob Portman, Directors of the White House Office of Management and Budget (OMB), highlighted the importance of scientific collections as a priority for interagency coordination under the auspices of the National Science and Technology Council (NSTC), stating that:

"Agencies should maximize the coordination and planning of their R&D programs through the NSTC. Two areas requiring special agency attention and focus through the NSTC are Federal scientific collections and R&D assessment."

"Agencies should assess the priorities for and stewardship of Federal scientific collections, which play an important role in public health and safety, homeland security, trade and economic development, medical research, and environmental monitoring. Agencies should develop a coordinated strategic plan to identify, maintain and use Federal collections and to further collections research."

In August 2007, the R&D Budget Priorities Letter for FY09 (Marburger & McMillan, 2007) continued to express concern for scientific collections:

"Federal Scientific Collections: Federal scientific collections play an important role in public health and safety, homeland security, trade and economic development, medical research, and environmental monitoring. Agencies are developing a coordinated strategic plan to identify, maintain and use Federal collections of physical objects and to further collections research. Agencies should participate in the finalization of this plan and in its subsequent implementation."

## New Uses

New chemical analyses increase the value and impact of archaeological collections. Obsidian is a glass-like volcanic rock that has sharp edges when fractured properly. Obsidian tools and weapons are commonly found at archaeological sites and are studied and preserved in collections because the style of fracture and different wear patterns can be distinctive for different human populations.

Researchers at the Smithsonian Museum Conservation Institute (MCI) have found an ingenious new use for obsidian artifacts. The chemical composition of obsidian varies among volcanic terrains – almost a fingerprint that reveals the geographic origin of the tools and weapons. Researchers found that in many cases the obsidian's chemistry didn't match the local volcanic rocks, which means that they had been transported. The new chemical analysis could reveal ancient trade and migration routes.

In collaboration with the University of Alaska, the National Park Service (NPS), and the Russian Academy of Sciences, MCI analyzed over 2,000 obsidian artifacts using non-destructive X-ray fluorescence analysis. Most of the artifacts were from Federally-owned or -sponsored collections at the Smithsonian, NPS, and the Bureau of Indian Affairs. MCI found that at least two of the artifacts came

from northeast Russia, indicating the long-distance movement of obsidian, and therefore people, between Russia and Alaska in prehistoric times.



Obsidian specimens.

Photos courtesy of Smithsonian Institution



## Lichens document air quality changes over time.

Scientists have been collecting and studying samples of a lichen called *Flavoparmelia baltimorensis* from Plummers Island, Maryland, outside of Washington, D.C., for over a century. However, beginning in the 1970s, the researchers began to study them for something new – signs of changes in ambient air quality around the nation's capital city. By comparing concentrations of cadmium, chromium, nickel, zinc, and lead in samples collected at Plummers Island against lichens collected at other nearby research stations, scientists

have been able to track limited, but encouraging, signs of improving air quality in the region (Lawrey, 1993).



Specimen of *Flavoparmelia baltimorensis* lichen.

Photo by Ed Eubel



## Who Knew?

A unique snapshot of early America. The Louisiana Purchase of 1803 greatly expanded the territory of the young United States of

America. To help catalog the residents, flora, and fauna of the new possession, President Thomas Jefferson sent Captain Meriwether Lewis and William Clark to explore the vast new holdings. Over the next two years, the expedition collected a wide range of botanical



Map of the U.S. in the early 1800s.

Photo courtesy of NOAA

and mineral specimens, cultural artifacts, and even a live prairie dog. Those specimens still exist in several scientific collections and they are irreplaceable, unique, priceless artifacts documenting the history of the Western U.S. Because the collection predates the dramatic environmental changes from the Industrial Revolution, the specimens in the collection allow researchers to identify, interpret, and understand environmental changes over time. Lewis and Clark probably didn't imagine that their specimens would be used two centuries later to document environmental change in the modern world. The Lewis and Clark botanical collection was used in numerous curriculum plans across the country for K-12 education. These plans utilized specimen images, label information and journal references to the plant collections. The lesson plans explored the historical legacy of exploration, ethnobotany and food plants discovered by the explorers, and changes in **biodiversity** (Teece et al, 2002).



## Is It Safe?

Mercury levels in several museum specimens of tuna caught between 1878 and 1909 have been used in an effort to determine whether man-made pollution has caused increased concentrations of mercury in ocean fish. Researchers from the Department of Chemistry at the University of California Irvine used instrumental neutron activation analysis to test the museum specimens against recently caught tuna, and found that the mercury levels in the museum specimens were within the same range as the recently caught tuna. This suggests that there had been no appreciable increases in mercury pollution over nearly a century (Miller et al., 1972).



Bluefin-tuna.

Photo courtesy of NOAA



## How do We Decide Which Specimens Become part of Long-Term Scientific Collections?

Specimens in scientific collections originated as objects of study in research projects, but not all such specimens are **accessioned** into collections. How is this decision made? Once a research project is completed and the final products have been generated, researchers must weigh the cost of maintaining the specimen against its future value for research in that field, and its potential use in other fields. If a decision is made not to accession a specimen and it is needed at a later time, the cost of collecting a replacement could be enormous (e.g., Moon rocks or deep sea samples) or impossible (e.g., results of unique events in the past, such as pandemics and species extinctions). In these and many cases, the cost of maintaining them in permanent collections is outweighed by the potential cost of replacement and the possible future benefits to research. In other cases, research specimens are physically destroyed in the course of research, or are so thoroughly altered that their subsequent scientific usefulness is minimal. These specimens are not made part of permanent collections.

Once the decision has been made to accession a research specimen into a permanent Federal scientific collection, it becomes a governmental asset as defined by the Federal Accounting Standards Advisory Board (FASAB) (FASAB, 2005). Auditors at non-Federal institutions also recognize scientific collections as assets (Univ. of Wisc. System, 2002).

The specimens retained in permanent scientific collections can be grouped according to their general functions. The terminology for describing these functions varies by the agency and the type of collection. These functions are not mutually exclusive; however, they illustrate the criteria for determining whether a specimen should or will be retained. Specimens in scientific collections serve as:

1. **"Vouchers"** for earlier observations or findings. A voucher specimen is one on which critical analyses and observations have been performed, and it is likely that future researchers will want to either repeat these analyses to corroborate published findings or to apply new analytical techniques. For example, SI, USDA, USGS, and National Park Service (NPS) scientific collections include the voucher specimens that document the geology, biology, paleontology, archeology, and ethnology of U.S. public lands and waters.
2. **Standards.** Some specimens become permanent references that must be retained for future comparison. For example, the National Institute of Standards and Technology (NIST) of the Department of Commerce retains the standard reference specimens for weights and measures. NIST and USGS provide samples of chemical and physical standards to laboratories for validation and calibration. USDA retains biological scientific collections that serve as reference standards for identifying species that are

## International Interest in Scientific Collections

The Global Science Forum (GSF) Workshop on Policy Issues Related to Scientific Research Collections, organized by the Organization for Economic Cooperation and Development (OECD), is responsible for identifying bottlenecks that prevent scientific collections from being used effectively, and to propose appropriate national and international policies and programs. The GSF Workshop held its first meeting in Leiden, The Netherlands in 2007.

In its preliminary report on findings and recommendations, the workshop made three recommendations that will result in economies of scale through improved networking opportunities for collections information, methodology and data sharing, and common priorities:

- Organizations responsible for scientific collections should develop criteria and/or mission statements that establish scientific collections as research infrastructures.
- Those organizations should furthermore develop mission statements and operational standards that define curatorial, scientific, and service standards suitable for scientific collections as research infrastructure.
- Governments should also recognize scientific collections as research infrastructure and encourage organizations that collect and fund collections to update their mandates by adopting and enacting those mission statements and operational standards.

critical to protecting America's food sources. The regulatory importance of these scientific collections has increased with concerns about biosecurity and bioterrorism. NIH supports laboratories that preserve microorganisms for study from standard "type cultures" and with known genetic signatures.

**"Type specimens"** are another important kind of standard that must be maintained in scientific collections. The **type specimen** of a species of plant, animal, or microbe is the example of that species that is formally described and attached to that name, as stipulated in Codes of Nomenclature. Type specimens are normally sent to a designated official depository for permanent preservation. The Smithsonian Institution is one of these depositories. All future identifications of a species are based on comparison with the "type specimen."

3. **Sources of specimens for biological research, conservation, and food security.** Some Federal and Federally-supported scientific collections comprise living organisms. These scientific collections include type culture collections, seed banks and plant **germplasm** repositories, genetic stock centers, zoos, captive breeding programs, and other biological resource centers. These organisms with known genetic and physiological characteristics are critical **bioresources** for research, agriculture, and the protection, recovery and reintroduction of endangered species. Farm animals, crop plants, and other food sources can be decimated by disease and climatic shifts or other disasters. Seedbanks and germplasm collec-

tions provide the backup of last resort for reintroducing these critical food sources.

Such samples are also critical resources for epidemiology and research in clinical medicine.

4. **Repositories for unique objects.** Federal scientific collections also include specimens that record unique historical events or come from unique opportunities to collect specimens. These specimens are irreplaceable and are important research resources. Federal scientific collections provide opportunities to study the evolution of diseases, the biology of extinct species, and the passage of material through our solar system. Some of these specimens such as gems, anthropological artifacts, fossils, and rare animals may also have extremely high market value.

Research specimens are added to permanent scientific collections through a variety of pathways:

- **From intramural research labs.** Federal research organizations generally have protocols for deciding which research specimens should be accessioned into permanent scientific collections and which ones can be transferred to other agencies, donated to non-Federal organizations, or discarded. Of the Federal agencies that participated in the survey, SI has developed some of the most detailed guidelines for collection management.
- **From one Federal agency to another.** In some cases, Federal agencies transfer important research specimens to another agency's permanent scientific collections. SI incorporates specimens from USDA, USGS, and NOAA on a regular basis. NPS often provides specimens to SI and non-Federal repositories on a long-term loan basis but retains title to them.
- **From non-Federal researchers.** Retiring professors sometimes offer their scientific collections to Federal agencies if their universities do not maintain permanent scientific collections. Federal agencies, especially SI, have absorbed important "orphaned" scientific collections when a university, college, or private museum decides that it can no longer afford to maintain a collection. These scientific collections might represent the life's work of many productive

5. **Sources of ideas and study specimens for education and training.** Scientific collections are routinely used by undergraduate and graduate students as research material for theses and dissertations. In this way, Federal scientific collections are having an important impact on professional training of future researchers. Scientific collections have also inspired and informed educators in their development of curricula and instructional materials for students at all levels. Museum exhibits draw on scientific collections for public education, and radio and television coverage of important research findings are frequently based on scientific collections.

6. **Samples for future analysis or experimental use.** These are important for scientific inquiry and for documenting diversity and variability in nature.

### ***The Value of Government Assets***

The Federal Government recognizes the fiduciary value of scientific objects in its collections. In 2005 the Federal Accounting Standards Advisory Board (FASAB) issued Heritage Assets and Stewardship Land: Statement of Federal Financial Accounting Standards 29, which integrated all Federal accounting standards related to heritage assets and stewardship land into a single document.

The FASAB document stated that heritage assets are property, plant and equipment (PP&E) that are unique for one or more of the following reasons:

- historical or natural significance,
- cultural, educational, or artistic (e.g., aesthetic) importance; or
- significant architectural characteristics.

Heritage assets consist of (1) collection type heritage assets, such as objects gathered and maintained for exhibition, for example, museum collections, art collections, and library collections; and (2) non-collection-type heritage assets, such as parks, memorials, monuments, and buildings. They are generally expected to be preserved indefinitely.

The FASAB guidelines state that agencies that have custody of heritage assets must reference a note on the balance sheet that discloses information about heritage assets [which should],

- specify the relationship between the assets and the organization's mission,
- describe its stewardship policies and describe the major categories of such assets,
- quantify assets in terms of physical units, and
- report on the condition of its assets.

### Charting Changes in the Atmosphere

Ice cores, geological samples, and anthropology collections contribute to climate research. Amber and some types of volcanic rocks trap tiny bubbles of air, and coffins made of iron or lead can also trap air inside them. Ice cores from Antarctica allow scientists to chart variations in CO<sub>2</sub> concentrations over the past 650,000 years. By carefully sampling these trapped air samples and analyzing them with new chemical techniques, researchers are getting new information about the chemical composition of our atmosphere at different points in history. These scientific collections, used in combination with new analytical techniques, have provided new insight into changes to the atmosphere and have demonstrated that CO<sub>2</sub> levels have risen dramatically in the past 100 years. This insight is helping us understand the complex atmospheric system and predict future climate change (*Intergovernmental Panel on Climate Change, 2008. Ice Core Working Group, 2003*).

Ice Cores (like those shown at right) are remarkable archives of climate and environmental change, more so than any other natural recorder of climate such as tree rings or sediment layers. Ice cores preserve records of temperature, precipitation, chemistry and gas composition of the lower atmosphere, volcanic eruptions, solar variability, sea-surface productivity and a variety of other climate indicators on time scales of months to hundreds of thousands of years. Understanding the difference in magnitude of the pre-industrial CO<sub>2</sub> levels and current values is central to the global warming debate. In addition, the variation in CO<sub>2</sub> levels during glacial cycles provides clues to the forces behind climate change and to whether or not industrialization has had an impact on those forces. The Vostok Core from Antarctica has allowed scientists to extend the CO<sub>2</sub> record back 420,000 years. Most U.S. ice cores are curated at the National Ice Core Lab in Lakewood Colorado which is jointly operated by the USGS and the NSF Office of Polar Programs.



Ice Core Storage facility.

Photo from National Ice Core Laboratory, USGS



### Ensuring Accuracy

Calibration standards ensure consistent scientific measurements. How do you know that the scale at your doctor's office is accurate and that it isn't saying you weigh more than you really do? The National Institute for Standards and Technology (NIST) maintains a collection of reference weights and measures that are the official definition of what a "pound" or a "gram" or an "inch" is. Weights and measures are calibrated using processes that can be traced back to this very special collection, so that when you use a scale or pump a gallon of gas, you know that the measurement will be accurate.

NIST and the U.S. Geological Survey (USGS) also create and maintain special collections of calibration standards for chemical analyses. Measuring iron in steel requires a somewhat different chemical procedure than measuring iron in a hamburger or in a soil sample because the "matrix," or surrounding material, is different for each of these materials. Thus, NIST and USGS prepare large collections of Standard Reference Materials (SRM) that encompass more than 1300 SRMs for everything from cholesterol to copper ore to fertilizer. Samples of these SRMs are distributed to labs all over the country to be used to verify the true identity of unknown samples and ensure quality and accuracy.



USGS reference materials program: serving the needs of the global analytical community.

Photo courtesy of USGS



### Saving Endangered Species from Extinction.

The black-footed ferret is one of the most endangered animals in the world. This species once inhabited the grasslands of the western Great Plains, but it has declined dramatically with the loss of the North American prairie ecosystem. The Smithsonian Institution's Conservation and Research Center in Front Royal, VA is home to the Black-Footed Ferret Recovery Plan, developed in collaboration with the U.S. Fish and Wildlife Service. The program emphasizes natural breeding programs, developing assisted breeding, especially artificial insemination, and establishing multiple reintroduction sites. An original population of 18 individuals has grown to 250 ferrets that reside in breeding facilities and more than 300 animals that have been reintroduced survive in the wild (Miller et al, 1997).



Black-footed ferret.

Photo from National Zoological Park, Smithsonian Institution



[Voucher specimens are] “deposited in museums and similar facilities, where they are available for further study and reinterpretation. Without the deposited vouchers, it would be impossible to verify and build on the results of papers in those fields.”

Source: National Research Council. 2003.

researchers and provide vital documentation for their scholarly publications.

- **From private collectors.** Dedicated amateur collectors of fossils, insects, birds, rocks, minerals, meteorites, and other natural objects donate or will their scientific collections to Federal scientific collections. Their donated specimens can fill crucial gaps in geographic or *taxonomic* coverage.
- **From international collaborations and exchange.** Federal researchers are often involved in international initiatives (e.g., polar ice coring) and collaborations with colleagues in other countries. In some cases, the specimens collected under these projects are divided among participating institutions, including Federal agencies. Collections of plants, seeds, and germplasm also actively exchange specimens to help ensure the safety of and access to critical living resources.

### How many collections do we really need?

Scientific collections provide an excellent return on the taxpayers’ investments. Federal agencies consider the following in making decisions about the numbers and sizes of the collections they maintain.

1. **Immediate access.** Urgent problems can call for immediate access to scientific data. Maintaining scientific collections can provide immediate access to critical specimens, such as the geologic specimens that pointed to the cause of gas explosions in Hutchinson, Kansas in January 2001.
2. **Replacement costs.** The passage of time, technical challenges, or prohibitive costs make it all but impossible to replace the contents of a collection when it is needed at a later date. The high cost of research ship-time and the limited availability of research submersibles make it difficult to obtain new deep-sea specimens. New collections of Moon rocks can only be obtained through a massive and expensive scientific undertaking. And, of course, environmental specimens collected in a time series can never be replicated in the absence of time travel.
3. **Irreplaceable objects.** Many specimens collected decades ago can no longer be recollected because

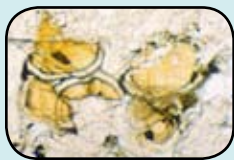
the physical location has disappeared. In some cases, such as the passenger pigeon, the species may be extinct.

Bringing specimens together for safekeeping in Federal scientific collections pays extra dividends. By co-locating diverse specimens in the same repository, researchers can conduct comparative, integrative research. For example, having the collections of host species and their parasites stored in the same place supports the study of the spread of diseases and pest outbreaks. Scientific collections of different types of building materials enable researchers to study the long-term effects of corrosion, for example. Co-location reduces or even eliminates the cost of traveling to examine equivalent scientific collections maintained in multiple locations.

Research organizations keep collections in different places and maintain large collections of similar specimens for several reasons.

1. **Research is a distributed enterprise.** Federal research serves a wide range of constituencies and issues. To serve their mission efficiently, researchers and the collections they use need to be located in many different places.
2. **Variation in nature.** Casual observers don’t always understand why scientists keep so many examples of the same thing. Do we really need a collection of 30 million insect specimens in which there may be hundreds of examples of the same species from the same place? Wouldn’t a single example be enough? Studying the variability within and among biological populations and geological specimens often reveals the processes that underlie their nature; this study of variation is a basic component of the scientific method. Large sample sizes are often needed in order to make statistically significant interpretations.
3. **Safety in numbers.** Having duplicates or partial series of specimens of the same species or sample at different locations helps eliminate the possibility that a fire or other natural disaster could completely destroy all known examples of any species, fossil, core, etc.. Scientific collections of living specimens also reduce the risk of catastrophic loss by guaranteeing that a pool of genetic variability is available to protect and ensure diversity, and to ensure the reintroduction and replenishment of the genetic stock. Without such scientific collections, a disease or other catastrophe could wipe out a major food crop. The National Zoo’s scientific collections were the source of black-footed ferrets for a breeding and reintroduction program of the U.S. Fish and Wildlife Service (FWS).

Recent news reports illustrate the challenges facing agencies in balancing long-term scientific value of collections against available resources. (Snydman et al. 2008, Bawaya 2007, Amato 2006, and Anonymous 2008). These tradeoffs



Carbonate globules in Martian meteorite ALH84001 that are the site of suggested biological signatures.

Photo courtesy Allan Treiman, Lunar and Planetary Institute, NASA

### Increasing Knowledge

Meteorite ALH84001 was collected in Antarctica as an extraterrestrial geologic specimen. Researchers identified it as Martian and dated it at 4.5 billion years old. Some scientists have suggested that the meteorite contained evidence of ancient life on Mars in the form of organic chemicals, minute structures, and minerals of possible biological origin. Geologists and biologists hotly contested this conclusion, and as a result the meteorite became the most analyzed rock on earth. In time, the sample taught scientists that we need to better understand how to identify extreme and ancient life on earth and to advance our techniques before we can positively identify biological signatures in Mars samples (McKay et al, 1996).



### Spotting Alien Invaders

In June 1998, the Virginia Institute of Marine Science (VIMS) collected two softball sized marine gastropods from the lower Chesapeake Bay that they had never seen before. Researchers asked the invertebrate zoology researchers at the Smithsonian Institution for assistance in identifying the snail. Using their collections for reference, they were able to positively identify the snails as veined rapa whelks, an invasive predator that eats Chesapeake Bay's native oyster and clam populations. These whelks almost certainly came to the Chesapeake Bay in ballast water from a visiting ship. Since then, over 16,000 adult whelks have been captured in the Chesapeake Bay and VIMS scientists are actively working to describe the distribution, ecology, and possible control measures (Richerson, 2008).



Shell of veined rapa whelk.

Photo courtesy Michael Vecchione, NOAA



### Re-discovering extinct species.

The Ivory-Billed Woodpecker lived in the south-east U.S. and Cuba but was thought to be extinct in both regions until recently. The bird collections of the Smithsonian's National Museum of Natural History include specimens from Cuba and the U.S. collected between 1861 and 1923. DNA analysis of these specimens has demonstrated that there are at least two separate species. These DNA samples are being compared with DNA from feathers and bird droppings of newly sighted birds to determine if they belong to either species (Fleischer et al, 2006).



Ivory-billed woodpecker specimens.

Photo courtesy Carla Dove, Smithsonian Institution



among different agency responsibilities can necessitate difficult decisions. These incidents also illustrate the need for a better mechanism for government wide coordination.

### Creation of and Processes Used by the IWGSC

Following the July 2005 Interagency Memorandum on R&D Priorities, the National Science and Technology Council (NSTC) created an Interagency Working Group on Scientific Collections (IWGSC). The Working Group was co-chaired by the U.S. Department of Agriculture's Agricultural Research Service and the Smithsonian Institution and included representatives of 12 Federal agencies. The IWGSC began meeting monthly in September 2005. The NSTC's Committee on Science approved the IWGSC's Charter in December 2005.

The IWGSC's charter recognized that "object-based scientific collections provide the fundamental infrastructure for contemporary and future scientific advancements" and called on the IWGSC to:

- "Conduct an initial survey of the scope and breadth of collections of interest to the working group," to identify resources and requirements for collection stewardship;
- Establish "processes for planning, developing, and managing integrated cross-agency collections activities" and "develop a coordinated strategic plan to identify, maintain and use Federal and Federally supported collections and to further collections research;"
- "Identify education/workforce requirements for ensuring long-term appropriate stewardship of scientific collections" including establishing an outreach process, identifying existing public, private, and commercial collections networks, and interacting with stakeholder networks; and finally
- "Formulate draft U.S. positions and coordinate participation in international collections activities as appropriate."

IWGSC participants agreed at an early stage that under the terms of its charter, the Working Group would consider the entire national infrastructure of scientific collections, including both Federal scientific collections and non-Federal collections that receive Federal support through NSF, NIH, USGS, and other grant programs.

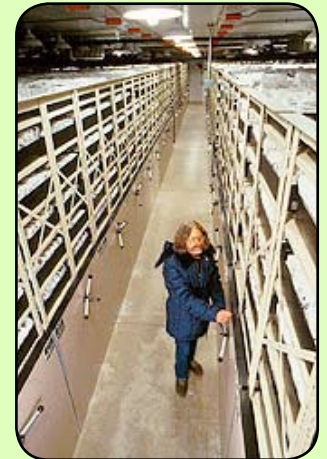
IWGSC began its work by reviewing published and unpublished reports on scientific collections to take advantage of previous studies of collections, especially those held by the Federal Government (see Appendix C for the results of this review). Most of the formal studies and surveys of scientific collections have been conducted since 1970, and most of those were restricted to **systematic biology** collections held

by non-Federal museums, herbaria, and other repositories. In general, the only Federal organization included in these studies was the Smithsonian Institution's National Museum of Natural History. There was particularly intensive attention paid to these collections in the 1970s through a series of workshops supported by NSF. These studies concluded that systematics collections were critical resources for a wide range of research activities and a dedicated grant program was needed for their maintenance and improvement. Based on these studies, NSF created the Biological Research Resources Program in 1975. Only a single study has been devoted to collections in the geosciences (National Research Council, 2002). This study considered Federal, State, private non-profit and private for-profit collections, and found that these collections were valuable resources that were "in peril."

The IWGSC concluded that a survey of Federal agencies would be needed to identify the scope and range of Federally held scientific collections. The survey solicited information on the use and condition of Federal scientific collections, staff and budget support for them, their rates of growth, access to the collections and data about them, and policies governing their use (see Appendix D, Survey Questions).

#### Food for the Future

When a new crop disease or pest shows up, agricultural scientists go looking for genetic traits that enable the plant to resist disease or insect damage. Usually, the first place they look is in germplasm collections—collections of plant material that can be propagated (as opposed to dried specimens). USDA maintains seed banks and germplasm repositories around the country with thousands of specimens of food plants and their wild relatives as documentation of the genetic diversity of these crops. If breeders find genetic resistance in a plant, they can breed it with a commercial variety to introduce the genetic disease resistance into the crop, or using biotechnology, can transfer the specific gene directly into the crop. When soybean rust arrived in the U.S. in 2004, scientists screened more than 20,000 varieties of soybeans and their relatives looking for genetic resistance to rust that could be bred into this important crop. The "Fort Knox" of the Nation's germplasm collections is the National Center for Genetic Resources Preservation at Ft. Collins, CO, where collections of seeds are frozen in "suspended animation" in a highly secure facility. Some material is preserved in liquid nitrogen at -196° C (-320° F). This material can be warmed up and propagated if needed. Even this material is backed up further in the Svalbard Global Seed Vault in Svalbard, Norway. This facility in the far north of Norway opened in 2008; it is built to withstand an earthquake or a nuclear strike, so that in case of a major disaster, humanity would still have the seeds to produce food.



Staff at the National Seed Storage Laboratory in Fort Collins, Colorado, preserve more than 1 million samples of plant germplasm. Here, technician Jim Bruce retrieves a seed sample from the -18° C storage vault for testing.

Photo by Scott Bauer, ARS Image no. k5586-14.



The data collection period extended from June 2006 to September 2007. A total of 153 responses were received from 14 agencies and these responses reflected a total of 291 scientific collections (see Appendix D, Survey Questions). As the first-ever survey of Federal collections, this study, while not exhaustive, creates a baseline of information on Federal scientific collections and provides the basis for future monitoring, coordination, management and policy development.

In addition to Federally-owned scientific collections, Federal research support (grants principally by NSF and NIH) enabled creation, maintenance, and improvement of important scientific collections that are owned and managed by non-Federal grantee institutions. NSF support for preservation of the Lewis and Clark collections at the Academy of Natural Sciences in Philadelphia is one example. NSF agreed to conduct a parallel survey of non-Federal scientific collections that had received NSF support during the preceding two decades. The NSF survey was distributed in December 2007 and remained open through March, 2008. The results of that

survey will complement the results of the survey of Federal scientific collections reported here.

IWGSC also gathered information on Federal scientific collections through its monthly meetings. IWGSC representatives briefed the other members on the scientific collections held by their respective agencies. IWGSC also heard invited presentations on a variety of relevant topics such as:

- The legislative basis for collection ownership and stewardship;
- Repatriation of Federal scientific collections to Native American tribes;
- NPS museum collections management;
- International agreements concerning Access and Benefit Sharing of genetic resources in scientific collections;

## **Survey Methodology**

### **Survey design**

Working with the Science and Technology Policy Institute (STPI) of the Institute for Defense Analyses (IDA) under contract to OSTP, the IWGSC met on a regular basis to develop and test a questionnaire and methodology that could be used to collect information from Federal agencies. The survey was intended for those agencies represented on the Committee on Science. Five IWGSC member agencies participated in a pilot test of the survey that was conducted through the OSTP website in early 2006 and many members of the IWG supplied ideas for and corrections to the questions. STPI conducted interviews with participants in the pilot test to get feedback on issues such as:

- total time to complete the survey (to estimate the burden on the agencies);
- ease of access to the online survey and paper version of the survey;
- clarity of the instructions and the questions;
- ability to answer questions;
- relevance of the questions; and
- completeness of the survey.

The information gleaned from the pilot test was used to clarify instructions to respondents, revise questions, and to develop a list of frequently asked questions that could be used for full survey administration. The pilot test suggested that given the diversity of agencies and collections, respondents had difficulty responding to a single universal questionnaire. As a result, more collection-specific versions of the questionnaire were developed to reflect differences among agencies and collection types. Respondents were asked to classify each collection into one of ten categories (archeological/anthropological, botanical, cellular/tissue, chemicals, technological, geological, paleontological, vertebrates, invertebrates, and other) and to respond to the relevant version of the questionnaire.

Some agencies had a single collection; however, most had multiple types of collections and/or multiple collections of the same type. A determination was made to allow agencies to submit many separate survey responses for separate collections, or to report on up to six scientific collections of the same type on the same questionnaire.

### **Survey administration and follow up activities.**

A cover letter was developed describing the purpose of the survey, encouraging agency participation, and providing information on access to the survey through the OSTP website. An introductory letter to agency heads was sent in May 2006 announcing the survey. Agency contacts were identified by IWGSC members and a letter with directions for completing the survey was sent to them by the IWGSC co-chairs later that month. A follow-up letter was sent to agency heads from Dr. Marburger in August 2006.

The original data collection period was to have ended in the fall of 2006. By early fall 88 survey responses had been received. However, many others had downloaded the survey but had not submitted responses. To increase agency participation, survey follow up included:

- Verifying that the initial contact letter was received by the agency;
- Ensuring that the announcement letters found their way to the appropriate agency officials;
- Correcting contact information as required;
- Providing assistance and clarifications to respondents, and
- Reissuing the survey with a new deadline if necessary.

During the fall, STPI reviewed survey responses and worked with agency respondents to verify that reporting was complete, to correct any survey items if necessary, and to resolve any data issues.



Apollo astronaut Harrison "Jack" Schmitt collects soil and rock samples in the Moon's Taurus-Littrow Valley.

Photo courtesy of NASA.

### Visitors from outer space

Did you know that NASA has scientific collections of extraterrestrial materials? These collections include Moon rocks and soil collected by Apollo astronauts, meteorites collected by NSF funded expeditions to Antarctica, and cosmic dust collected in the stratosphere. Recent collections include solar wind ions returned by the Genesis mission, and comet particles returned by the Stardust mission which flew through the coma (tail) of comet Wild-2.

Proposed future missions would return samples of an asteroid, a comet nucleus, the Moon, and Mars. Sample return missions are the proverbial "gift that keeps on giving." The Apollo samples have been studied throughout the 35 years since they were collected, and are now being used to plan for future lunar missions.



The Oakland Municipal Auditorium in use as a temporary hospital during the 1918 flu epidemic.

Photo by Edward A. "Doc" Rogers, courtesy Oakland Public Library

### Preventing and curbing pandemics

Researchers compared preserved samples of influenza virus taken from Smithsonian bird specimens with human tissue samples from the notorious 1918 Spanish flu pandemic to determine that the disease was not a type of avian influenza, as had been previously thought, but rather was related to strains that commonly infected pigs and humans. This discovery of the pandemic's true vectors has helped to guide the development of containment policy. Further studies of the virus's evolutionary history have helped improve vaccine development.

By studying the Smithsonian's mosquito collections, researchers are developing a better understanding of the vectors of rapidly emerging and potentially fatal diseases such as avian malaria and West Nile virus. Genetic analysis of rodent specimens was used to identify the presence and transmission of hantavirus in the early 1990s.



### Supporting emergency response

On the morning of January 17, 2001 an appliance store in Hutchinson, Kansas burst into flames due to a natural gas explosion. Later that evening, geyser-like fountains of natural gas and brine, started to erupt 3 miles from the fire. The following day this gas caused an explosion under a mobile home, killing two residents. Hundreds were displaced from their homes and businesses.

Officials suspected that the gas had leaked from a salt cavern used as an underground natural gas storage facility and had migrated 8 miles underground. Within hours of the explosions, the Kansas Geological Survey (KGS) scientists had created maps of the local geology from digitized records of thousands of wells drilled decades ago. Fortunately, the KGS had "cores preserved in its repository from a project the Atomic Energy Commission had conducted in the 1960s to investigate the geology of localities being considered for nuclear storage." Despite being unused for decades, these cores held critical information regarding paths for gas flow through the rock. Using geoscience data and collections, the KGS quickly advised the gas company where to drill holes to vent the leaked gas. The KGS's collection of cores played a vital role in aiding the emergency response (National Research Council Staff, 2002).



Building burns as result of gas explosion.

Photo from Hutchinson, Kansas Fire Department



- SI's "right of first refusal" policy regarding scientific collections created by other Federal agencies; and
- Collection policies.

### Findings of the IWGSC Concerning Federal Object-Based Scientific Collections

The IWGSC reports the following findings based on the results of the survey of Federal scientific collection, its other activities, described above, and the extensive knowledge of collections possessed by the IWGSC members.

1. *Federal agencies own and maintain diverse scientific collections. These scientific collections are essential to supporting agency missions and are thus vital to supporting the global research enterprise.*

There are a wide variety of sizes and types of scientific collections owned by the government. These include but are not limited to: preserved and living plants, animals and microbes; whole organisms, tissue samples, and individual cells; rocks, minerals, fossils, and extraterrestrial samples; chemicals, scientific instruments, and examples of technology. As noted above, an agency may have one or a few closely related and highly specialized scientific collections, such as NASA, or they may have a wide variety of scientific collections, such as Smithsonian. The number of specimens in a scientific collection can range from tens to tens of millions.

Federal scientific collections are used primarily for basic research (according to 84% of respondents), as well as for regulation, enforcement, and other missions. Many scientific collections represent the only available means for documenting and studying past events, which makes them irreplaceable assets. Other scientific collections are the result of large investments by the government, and the cost for maintaining them is small relative to the cost of replacing them when needed.

2. *Most Federal scientific collections continue to grow at regular, predictable rates, but adequately trained support staff is declining.*

The majority of respondents (78%) reported an increase in scientific collection holdings between FY2000 and the close of the survey (September 2007). Of these:

- seventy-four percent reported between 1-25% growth during that time
- ten percent reported a doubling in size since FY2000

In the majority of cases, these increases were predicted (93%) and were the result of routine collecting activity (92%).

In contrast to the steady and predictable growth of collection size, only 27% of the respondents reported that their scientific collections have budget line-items devoted to maintenance and management. In addition:

- forty-one percent reported that their agencies have not specifically allocated any funds at all for collection care and management;
- forty percent of respondents reported declining numbers of collection support staff; and
- only five percent reported increasing staff resources.

This lack of dedicated budget and staffing support suggests that the true agency expenditures for collection management by agencies are unknown.

3. *There is a lack of documentation of the contents and conditions of some Federally-owned scientific collections.*

When asked to characterize the overall physical conditions of their scientific collections (on a five-point scale from "very poor" to "very good"), 78% of the respondents reported that they considered their scientific collections to be in "good" or "very good" condition. However, when asked if the condition of the collections had been surveyed:

- more than 50% of respondents reported that they had never done a condition survey, and

**Table 1. Percent of Collections with Accessible Information**

	More than half of the Collection	Entire Collection
Specimen data are accessible for research or other uses	85%	47%
Specimen data are <i>cataloged</i>	68%	27%
Specimen data are in a computerized database	40%	16%
Specimen data are accessible via the Web	14%	5%

- only 18% had recently performed at least a partial assessment
- only 12% had ever performed a complete assessment.

The IWGSC therefore concluded that some Federal agencies have only a general impression of the condition of their scientific collections.

The Government Accountability Office (GAO) and professional societies have periodically raised questions about the physical security of Federal collections, especially related to long-term maintenance of facilities and physical curation (Bawaya, 2007; GAO, 1987; GAO, 2007).

4. *Scientific collections are generally accessible for scientific research or other uses, but collection databases are not widely developed and Web access to collection information is still in its infancy.*

Nearly half of respondents (47%) reported that 100% of their scientific collections were accessible for scientific research or other uses, and most respondents (78%) reported that more than 50% of their scientific collections are accessible. The principal reasons given for the inaccessibility of collections were related to lack of adequate storage space and equipment. Discussion with respondents indicate that inaccessibility could also be due to lack of staff who could locate specimens for researchers.

Documentation of collections, and access to this information, was highly variable. More than half of all collections (61%) reported that none of the information about the collection was accessible via the web. Table 1 specifies the proportion of collections that reported that most or all of their collection information was accessible through different mechanisms.

5. *Agencies varied widely in the degree to which they have developed written policies concerning the management and use of Federal scientific collections.*

Written policies can be useful in managing scientific collections. Twenty-eight percent of respondents reported that their units have no written and approved collection policies. Less than half of scientific collections have policies approved by their agency concerning:

- documentation (45%),
- acquisition (44%),
- access and use (39%),
- preservation (39%),
- disposal (34%),

- handling (33%), and
- security (25%).

6. *Scientific collections have impacts in areas that were unrelated to their original purpose. These impacts can be difficult to foresee.*

The IWGSC has confirmed many instances in which specimens collected for one research purpose have proven to be valuable, even critical, for research in unforeseen areas (see the many examples highlighted in the sidebars throughout this report). For this reason agencies possessing scientific collections should consider the possible value of their collections to other sectors of the government and the scientific community as a whole.

7. *Meeting the financial and staffing needs of managing Federal scientific collections can require trade-offs with other competing agency responsibilities.*

- Federal agencies have several different roles with respect to their scientific collections:
- as owner of heritage assets with associated intellectual property rights, and trustee responsibilities;
- as manager of these resources that are critical to that agency and of value to other agencies and to civil society;
- as steward for the long-term preservation of heritage assets that could be critical to future generations; and
- as provider of financial and staff support for collection curation and for research projects that use these resources.

These roles often come into conflict, forcing agency officials to make difficult choices between research activities, the near-term management of scientific collections, and their long-term preservation.

8. *In response to competing priorities and limited resources, Federal agencies have developed a variety of strategies and business models for long-term management of scientific collections.*

While the survey did not solicit information on the management practices used for Federal scientific collections, the IWGSC explored this issue in other ways. Based on its discussions with agency representatives, the IWGSC discovered a number of strategies and procedures used by managers of Federal scientific collections. Many of these arose in response to the problems of limited staff and space.

Federal agencies have developed several different business and management models for their scientific collections. Scientific collections that originated in one agency may find

### Restoring threatened species

Both the Miami Blue and Atala hairstreak butterflies, once widespread in southern Florida, could not be found in the Everglades National Park. The park's museum collection contains two Miami blue and six Atala specimens documenting that the butterflies previously occurred in the park. Based on this evidence, in 2004, the park began restoring the two species, which will contribute to restoration of native biodiversity and attract visitors to see these rare and beautiful butterflies. Maintaining and, as appropriate, increasing populations of rare and endangered species is an important function of national parks.



Miami Blue butterfly.

Photo courtesy of Smithsonian Institution.



### Protecting America

In 1997, Cuba's sugarcane crop was being damaged by an insect known as thrips and the Cuban government accused the US of dropping these insects from planes as an act of economic and biological warfare. USDA collections include insects found in shipments that arrive at the Miami agricultural inspection station from Latin America. Using these collections, USDA researchers mapped the geographic distribution of thrips on Caribbean islands over time and were able to demonstrate that the insects arriving in Cuba were spread by wind, a natural process by which agricultural pests disperse. The USDA data were presented to an international body that concluded that no deliberate attack by the United States on Cuban agriculture had taken place.



Sugarcane field.

Photo courtesy of USDA.



Liquid nitrogen tanks for storage of cell specimens.

Photo courtesy of NIH.

### Preventing disease

For over two decades, researchers at the National Cancer Institute of the National Institutes of Health (NIH) have been working to identify the causes of cervical cancer, which kills nearly 4,000 women between the ages of 35 and 55 annually in the United States and over 200,000 women worldwide. The researchers systematically amassed large collections of cell specimens from volunteers in population studies to establish a connection between cervical cancer and a set of 15-18 types of human papillomavirus (HPV). They found that while most HPV infections do not lead to cancer, virtually all cases of cervical cancer could be traced directly to HPV infections, and that about 60% of all cancers are linked to two specific HPV types.

Armed with this information obtained from scientific collections, the NIH researchers set out to find ways to boost the human body's immune response to resist HPV infection. Using genetic engineering and working closely with colleagues in the pharmaceutical industry, they were able to create a vaccine that was then tested in clinical trials and led to the vaccine which now protects women from this deadly cancer threat.



their way to other agencies, State governments, universities, and other non-government organizations. In some cases, ownership of and title to some Federal scientific collections have in some cases become unclear because they are being maintained and managed by non-Federal organizations.

9. *The legal status of and legislative authority behind some Federal scientific collections is not well understood by some agencies.*

The legislative authority and requirements for retaining, managing and maintaining scientific collections in many Federal agencies is not clear. If agencies have been charged through legislation with creating and maintaining Federal scientific collections, then the authorities of these agencies to deaccession contents of their scientific collections need to be clearly delineated.

10. *Scientific collections are developing specimen databases that are increasingly integrated and interoperable. Some but not all Federal scientific collections are developing their own specimen databases. While some Federal Agencies have been leaders in standardizing data, the degree to which Federal and non-Federal collection databases can communicate with one another is highly variable.*

Federal agencies have been involved to varying degrees in these **informatics** initiatives.

## Recommendations

1. *The IWGSC recommends that agencies with scientific collections work as necessary to support their missions to develop realistic cost projections for collection maintenance and operation, and work to incorporate the needed support as stable budget elements.*

The long-term curation and management of Federal scientific collections should be recognized as part of the long-term infrastructure needs of Federal science agencies and the broader research community. Accordingly, the costs associated with maintaining and operating this infrastructure need to be included in the operating budgets of the agencies that own scientific collections, using a consistent approach. It would be useful to develop consistent tools for projecting the long-term infrastructure costs associated with scientific collections.

Many agencies do not distinguish between overall research costs and the costs of managing and curating scientific collections. As a result, many agencies do not know what the real costs of management and curation are, as distinct from the costs of research that uses the collection. In some cases, this has led to management and curation being poorly supported, thus threatening the long-term preservation of critically important collections.

The proper maintenance of our country's roads and bridges is inextricably linked to the commerce that relies on them. The Department of Energy (DOE) particle accelerators are essential for research in physics. Astronomical research relies on large telescopes. The same is true for scientific collections, which are also critical infrastructure, but an infrastructure that is distributed among institutions and across a broad geography.

2. *The IWGSC recommends that agencies improve both the documentation of the contents of their scientific collections and access to that documentation on the internet.*

The effective use and management of all scientific collections rely on documentation such as catalogs and indexes. Without access to this information about the scientific collections, researchers will not find the specimens they need for their research and agencies will not realize the full potential impact of their collections.

There are many incentives for maintaining and providing good collection documentation of Federal scientific collections, including but not limited to:

- Ensuring the accuracy, usefulness, and reliability of data derived from the specimens in the collection;
- Meeting accountability requirements such as the FASAB standards;
- Estimating management costs reliably;
- Documenting and justifying requests for funds to support collection curation and management;
- Attracting more research users;
- Facilitating interagency coordination and collaboration; and
- Demonstrating the impact of scientific collections on achieving agency missions as well as broad Federal goals.

Electronic catalogs of scientific collections should do more than support collection management and accounting requirements. The collection catalogs developed and maintained by agencies should facilitate the exchange of information and interoperate to support research as well as strategic decisions concerning cross-agency coordination.

Federal accounting standards require that agencies report on their stewardship of scientific collections as heritage assets. The survey results indicate that many scientific collections are not completely cataloged in computerized databases. Investments in the electronic cataloging of scientific collections should serve the dual purpose of improving collection management while meeting the accounting requirement.

### Resources for medical breakthroughs

The National Center for Agricultural Utilization Research (NCAUR) in Peoria, Illinois – part of the USDA's Agricultural Research Service (ARS) – maintains a vitally important Culture Collection,

which includes more than 150,000 yeasts, other fungi, and bacteria. The collection, which was started in 1940, has been used to support cooperative research with the private sector to develop many beneficial medicines and food additives. In 1942, the production process could only generate enough penicillin to treat ten patients. Faced with the need for much larger supplies of antibiotics during World War II, the lab found a strain of *Penicillium* in the collection that increased the efficiency of the fermentation and production processes. By 1945, production had increased 25,000-fold, saving hundreds of thousands of lives by the end of the war.



Photo courtesy of the Research and Development Division, Schenley Laboratories Inc., Lawrenceburg, IN



### Enhancing public safety

Southern California is one of the country's most productive petroleum basins, and thousands of oil and gas wells were drilled in Southern California during the first half of the 20th century. Many of the cuttings or cores from those wells are curated in Federal repositories. Geologists are now going back to these samples to find evidence of historic earth movements along different faultlines, extending back in time our records of earthquakes in the region.



Part of Interstate 10 west of downtown Los Angeles collapsed in the shaking of the 1994 Northridge earthquake.

Photo courtesy of the U.S. Department of Transportation

Southern California accounts for 50% of the country's earthquake risk, and Los Angeles County represents 25% of the total risk. The reanalysis of these samples is improving our ability to identify areas of greater risk and to take precautionary measures. This information would be unavailable without the Federal collections. Urbanization, environmental restrictions, and other land access issues would make it impossible to collect these samples today at any cost (Source: USGS Fact Sheet 001-01, 2001 and NRC 2002).



The USDA's Germplasm Resources Information Network (GRIN) could serve as a model for such a collection database. A program within USDA's Agricultural Research Service (ARS), the GRIN web server provides information about plants, animals, microbes and invertebrates in USDA's germplasm collections. Using GRIN, researchers can obtain round-the-clock access to essential data about the origin of a germplasm specimen, its characterization, evaluation, inventory, and distribution. This permits national germplasm collections to be managed and used effectively. GRIN has been so successful that many nations around the world have modeled their own germplasm databases on it and made them interoperable.

Several agencies have already initiated activities that address this issue. The USGS is working with the state geological surveys to archive their geological and geophysical collections. This is being done through the newly formed National Geological and Geophysical Data Preservation Program. The data will be available via the new National Digital Catalog on the USGS web site. The inventories will be updated and the catalog will be expanded on an ongoing basis. USDA's Agricultural Research Service has conducted an extensive internal survey of its scientific collections and has developed a detailed status report on them.


3. *The IWGSC recommends that agencies exchange documents that describe their scientific collections policies, procedures, and best practices in order to minimize the effort needed for agencies to develop collection-specific policies and procedures.*

Scientific collections are actual property assets and their ownership by Federal agencies carries with it trustee responsibilities. To meet these responsibilities, agencies should have clear policies that ensure the proper management, security, and legal and ethical use of these scientific collections. These policies could perhaps be made available in the clearinghouse recommended below.

4. *The IWGSC recommends a review of the legal and legislative basis for the Federal role in scientific collections, thereby clarifying agency responsibilities.*

The IWGSC could work with the Congressional Research Service (CRS), the Government Accountability Office (GAO), and/or agency legal counsels to help clarify agency authority concerning scientific collections. Likewise, the IWGSC should consider commissioning a study or holding a workshop on the subject to seek the input of stakeholders. Issues to be explored include the creation of a statutory definition of a Federal scientific collection and issues such as:

- Does the Smithsonian have a right of first refusal for scientific collections being deaccessioned by another Federal agency?
- Does a Federal agency have the right to claim scientific collections that are held by another agency?





**Combating illegal trade**

Lobster is one of the most sought after (and expensive) menu items in restaurants around the world. Most spiny lobsters are sold only as "tails," which are much harder to identify than whole Maine lobsters. For years, unscrupulous dealers were able to falsify the countries of origin reported on seafood imports because identification was so difficult. As a result, U.S. consumer regulations for food safety and consumer protection could be violated. To thwart the importation of deliberately mislabeled spiny lobster tails, regulatory officials turned to the collections of lobsters from around the world maintained by NOAA's National Marine Fisheries Service. NOAA's experts used the collections to develop and publish a definitive lobster tail identification guide. Using this guide, customs officials at ports can now identify the origins of tails in shipments. In one famous instance, port officials using the NMFS guide were able to prevent entry of a shipment of "Spanish" spiny lobsters that were actually from Cuba and thus banned from importation (Williams, 1986; Williams and Dore, 1988).

Tails of spiny lobsters.

*Photo courtesy of Ruth Gibbons, NOAA*

- Do Federal collections include everything collected on public lands, territorial waters, the Extended Economic Zone (EEZ), and international waters?
- Do States have claims to objects collected on public lands?
- Do Federal collections include everything collected by Federal employees?
- Do they include material collected under Federal grants?

5. *The IWGSC recommends the creation of an online clearinghouse of information about Federal scientific collections.*

This clearinghouse would include information on the contents of scientific collections, as well as the results of the initial survey of Federal scientific collections. To minimize the reporting burden, discretion will be applied by individual Federal agencies as to how often the survey data is updated. Such a clearinghouse would overcome the current fragmentation of Federal scientific collections and would enable agency scientists, as well as non-governmental researchers, to locate scientific collections with potential value for their research. Because agencies might use the data in the clearinghouse to meet their reporting requirements, they could have an incentive to keep their data up to date. To the degree possible, this clearinghouse should be consistent with, perhaps even integrated with, data about non-Federal scientific collections.

Agencies have developed a variety of business models and management plans for their scientific collections. There should be a mechanism for sharing this information across agencies and for identifying effective strategies that are appropriate to different circumstances.

The clearinghouse would provide the research community and the general public with valuable information on the contents and condition of Federal scientific collections, and would be analogous to other existing programs such as the Office of Labor Statistics and the NSF Division of Science Resources Statistics (SRS), which maintains the Science and Engineering Statistics web page ([www.nsf.gov/statistics/](http://www.nsf.gov/statistics/)) that provides links to publications, data, and analyses about the nation's science and engineering resources.

The clearinghouse would also provide the agencies with a useful management tool. When an agency concludes that a collection's potential research impact no longer justifies the maintenance costs, other agencies that could realize benefits from that collection could be apprised that it will be deaccessioned. The proposed information network would optimize the cost-effectiveness of collection management for the government as a whole.

6. *The IWGSC recommends that a periodic report on the status and condition of the scientific collection infrastructure be prepared and submitted to the Committee on Science (COS), OSTP, and OMB.*

The IWGSC has identified a number of issues that should be monitored over time. Much of the data needed for reports on these topics could be extracted from the online clearinghouse recommended above. Some additional data collection may be needed, especially if the COS requests information on specific topics. This report would be used to monitor the condition of Federal scientific collections in a manner parallel to NSF's reports on major research expenditures (e.g., National Science Board 2003.) and the science and engineering workforce. Such monitoring would be analogous to periodic inspections of bridges and other elements of the transportation infrastructure.

7. *IWGSC recommends that the NSTC Committee on Science continue the work of the IWGSC beyond its March 2009 expiration, to facilitate the implementation of these recommendations and to coordinate and improve Federal collections over the long-term.*

The Federal Government's need for scientific collections is permanent, and a long-term mechanism for monitoring and improving their management is needed. There is a need for continued interactions with other Working Groups like Digital Data and Biotechnology and oversight to improve the overall quality of collection management. In the long run, a standing body which would have the same scope as the IWGSC could continue its mission on a more permanent basis.

The scope of responsibilities that need to be addressed well into the foreseeable future could include:

- coordinating the regular collection, compilation, sharing, and archiving of data on Federal scientific collections;
- establishing best practices and tools for evaluating the health of scientific collections and for evaluating how well scientific collections are managed;
- creating procedures and objective criteria that agencies can use in tracking their heritage asset management;
- equipping agencies for projecting the costs associated with curating, documenting, and maintaining scientific collections on a long-term basis; and
- developing ranking factors for the importance of scientific collections and a common decision-tree that agencies can use in making decisions concerning the disposition of scientific collections

The IWGSC identified several additional areas of interest that need attention in the future. Examples include the training

and certification of collection managers and the development of the future scientific collections workforce.

### ***Looking Ahead***

Scientific collections are by their nature backward-looking. They record our history and allow us to confirm past findings, but we create collections and maintain them as an investment that will benefit future generations. The recommendations in this report will put in place a system for monitoring and improving the condition of Federal scientific collections and will promote needed improvements in management, documentation and curation. Providing the facilities, workforce, and curatorial support needed to adequately maintain Federal collections will probably require increased and focused investments by some agencies. Nevertheless, the IWGSC is convinced that these additional investments will provide even greater returns by improving Federal research that serves the U.S. taxpayer and the global community.

### Improving air safety

At 550 miles an hour, a small bird striking a \$38 million dollar F15 fighter jet can cause enough damage to bring down the plane. Even a giant 747 airliner can be endangered by a single seagull sucked through an engine at takeoff. That's why it's so important for the Federal Aviation Administration (FAA), the military, and airport administrators to find ways to avoid or mitigate bird strikes on aircraft.

Scientific collections play an important role in solving this public safety challenge. Researchers are able to identify the species of birds involved in collisions by comparing their remains – often nothing more than a bit of feather or tissue – with specimens in the National Museum of Natural History's bird collections and library of DNA barcodes. This information helps aviation authorities to develop techniques for keeping those species away from danger areas like runways and departure routes. In a 4 year period the Smithsonian made more than 14,000 bird strike identifications for the United States Air Force (USAF) and FAA. The result is millions of saved dollars – and, potentially, hundreds of saved lives.



Damage to military helicopter from crane strike.

Photo courtesy of Dept. of Defense



### New Medicines

Since the 1950s, scientists have been collecting and testing marine organisms for their medicinal properties. Over the past 30 years, NIH has sponsored many global expeditions for this purpose, and so far NIH scientists have extracted and screened tens of thousands of substances from the marine organisms collected on those expeditions. NIH receives around 1,000 new organisms every year. Such a large effort is necessary because out of all the substances tested, only one out of every several thousand has the potential for medical applications. Soon, scientists expect, automated chemical probes and advanced gene-copying techniques will speed up the laborious process of identifying and testing promising compounds.



Divers collect organisms from a coral reef.

Photo courtesy of NOAA



### Forestalling biological invasions

Researchers use scientific collections to determine the source, distribution, rate of spread, and impact of invasive species. For example, museum collections were used to chart the spread of the invasive Argentine ant (*Linepithema humile*) in the United States over the preceding century. This aggressive pest displaces native ant species that disperse seeds and pollinate plants, thus disrupting native ecosystems. Researchers used the information they found in the collections to better control and curb this pest.



Argentine ant worker.

Photo courtesy of Smithsonian Institution



## **Appendix A: Acronyms and Abbreviations**

ARS: Agricultural Research Service, U. S. Department of Agriculture

BRR: Biological Research Resources Program (now the Biological Research Scientific Collections Program), National Science Foundation

COS: Committee on Science, National Science and Technology Council, OSTP

CRS: Congressional Research Service

DOE: Department of Energy

DOI: Department of the Interior

EEZ: Extended Economic Zone

FAA: Federal Aviation Administration

FASAB: Federal Accounting Standards Advisory Board

FDA: Food and Drug Administration

FEMA: Federal Emergency Management Agency

FS: Forest Service, US Department of Agriculture

FWS: Fish and Wildlife Service

FY: Fiscal Year

GAO: Government Accountability Office

GRIN: Germplasm Resources Information Network

GSF: Global Science Forum

HHS: Department of Health and Human Services

HPV: Human Papilloma Virus

IDA: Institute for Defense Analyses

IPCC: Intergovernmental Panel on Climate Change

IWGDD: Interagency Working Group on Digital Data

IWGSC: Interagency Working Group on Scientific Collections

KGS: Kansas Geological Survey

MCI: Smithsonian Museum Conservation Institute

NARA: National Archives and Records Administration

NASA: National Aeronautics and Space Administration

NCAUR: USDA's National Center for Agricultural Utilization Research

NIH: National Institutes for Health, Department of Health and Human Services

NIST: National Institute of Standards and Technology, Department of Commerce

NMFS: National Marine Fisheries Service, National Oceanic and Atmospheric Administration

NOAA: National Oceanic and Atmospheric Administration, Department of Commerce

NPS: National Park Service

NRC: National Research Council

NSF: National Science Foundation

NSTC: National Science and Technology Council, OSTP

OECD: Organization for Economic Cooperation and Development

OMB: Office of Management and Budget, Executive Office of the President

OSTP: Office of Science and Technology Policy, Executive Office of the President

PP&E: Property, Plant, and Equipment

R&D: Research and development

SFSC: Subcommittee on Federal Scientific Collections

SI: Smithsonian Institution

SRM: Standard Reference Material

SRS: Science Resource Statistics, a division of the National Science Foundation

S&T: Science and Technology

STPI: Science and Technology Policy Institute, Institute for Defense Analyses

USAF: United States Air Force

USDA: United States Department of Agriculture

USGS: United States Geological Survey

VIMS: Virginia Institute of Marine Science



### Understanding earthquakes

San Andreas rock cores may be the earthly scientific equivalent of moon rocks. As part of the San Andreas Fault Observatory at Depth, the National Science Foundation and the USGS have drilled a deep hole directly into the San Andreas Fault Zone near the initiation of the Parkfield earthquake. This is the first time that rocks have been extracted from a geologically active fault zone. Geologists bored 2.5 miles into the Earth and retrieved 135 feet of rock cores. These rocks hold important clues to how fault zones develop and behave and perhaps ultimately to how and when earthquakes occur.

San Andreas fault zone, Carrizo Plains, central California.

Photo by R.E. Wallace, Courtesy of USGS



### Predicting the impact of global climate change

Our changing environment has become one of today's hottest topics. Collections can provide clues to how the earth has changed in the past and how it may change in the future.

Scientific collections document the impact of past climate variations on species. For example, they identify shifts in species ranges, document climate-induced morphological evolution over time, and identify the causes of species extinctions. Butterfly collections have been especially helpful in establishing local extinction rates, enabling researchers to track the ranges of butterfly populations over time. Scientists can use this information to extrapolate the potential impacts of future climatic variation on plant and animal species – and on humans (Suarez Tsutsui, 2004 ).

### Using the past to see the future

Fifty-five million years ago the Earth entered a global warming episode. In just about 10,000 years the climate of Bighorn Basin in Wyoming "went from Floridian to something more like southern Mexico". Scientists are using Federally collected and owned fossil collections to understand how plants will respond to the current global warming episode. During this 10,000 year time period, the fossil record indicates that several species of southern plants surged north some 1,000 miles. At the end of the global warming period, these species disappeared from the Basin. The fossil plants from the Bighorn Basin are the first example of how rapidly plants can respond to warming events. Knowing how plants have responded to global warming in the past may help in predicting effects of future climate change. (Lipske, 2007).

A fossil leaf of *Populus wyomingiana* possibly a relative of living poplar trees.

Photo courtesy of Scott Wing, Smithsonian Institution



## Appendix B: Glossary

**Accession:** To formally accept a holding into physical and legal custody.

**Ancillary scientific collection:** Collections that include important materials that are associated with an object-based scientific collection, but only if the material is directly used for scientific research, such as researcher field notes. Excluded are historic and artistic collections that do not function as scientific collections and library collections that do not directly support research objects.

**Biodiversity:** The variety of life on Earth at all its levels, from genes to ecosystems, and the ecological and evolutionary processes that sustain it.

**Bioresource:** A collection comprised of living organisms which have known genetic and physiological characteristics.

**Catalog:** A guide to the contents of a scientific collection. Catalogs can take many forms, including (but not limited to) inventory lists, databases, spreadsheets, written descriptions, and archival finding aids. As a verb, to catalog a scientific collection means to develop such a guide for its contents.

**Collection (Object-based scientific collection):** A long-term research asset, as opposed to an expendable research supply. A collection can be considered to be a set of specimens that are catalogued together in one database or numbering system. They are created for the purpose of supporting or doing science, rather than for their market value as collectibles or their historical, artistic, cultural, or other significance. Specimens in a Federal research laboratory or on Federal property are not necessarily, or automatically, part of a collection. Scientific collections may consist of objects that are organic or inorganic, living or inanimate, small or large.

**Germplasm:** Plant germplasm consists of seeds, plants, or plant parts that are useful in crop breeding, research, or conservation. Plants, seed, or cultures that are maintained for the purposes of studying, managing, or using the genetic information they possess. Animal germplasm includes semen, embryos, ova, eggs, and the broodcomb of bees.

**Informatics:** The use of computer science hardware and software to manage, compile, analyze, interpret, and display data.

**Rarity:** A specimen that is, or that records an historical event that is unique.

**Standard:** A specimen used as a permanent reference for future comparison.

**Systematic biology, systematics:** A research field within biology that deals with the evolution and taxonomy of organisms.

**Taxonomy, taxonomic:** Taxonomy is a research field within biology that deals with the classification and naming of organisms. A taxon is a single category of organisms.

**Type specimen:** A specimen designated as the example of a species of plant, animal, microbe, mineral or rock type, to which the name of that species is associated formally in the original description.

**Voucher:** A specimen on which critical analyses and observations have been performed, preserved for future research to corroborate published findings or to apply new analytical techniques.

**Zoonotic:** A term used to describe a disease that can be transmitted from animals to humans.

### Improving species conservation

For decades, the number of marbled murrelets (*Brachyramphus marmoratus*) – sea-birds that live between Vancouver Island and British Columbia – has been steadily dwindling. Ryan Norris (University of Guelph) and Peter Arcese (University of British Columbia) suspected that changes in the birds' food supply were responsible, and tested their theory by analyzing marbled murrelet specimens in dozens of museum collections, some of which date back to 1889.

By chemically analyzing feathers from museum specimens, they reconstructed the birds' historical diet and found that it had indeed changed over time – from fish to invertebrates, which are much less energy-rich. This information will help conservationists preserve the species from extinction.

"There are millions of specimens in museums across the country, many of which were collected before habitats started to decline and that can give you really important baseline information for designing plans to conserve species," said Norris.



A marbled murrelet.

Photo by Gus Van Vliet. Courtesy U.S. Fish and Wildlife Service



### Safeguarding National Borders

Have you ever wondered why, when returning from a trip overseas, you have to fill out a form asking you to identify any fruits, plants, or other natural items that you brought back with you? It's because some of those items could threaten or even destroy local crops and animals, and could spread human diseases if they were allowed to escape into the wild. By law every boat, plane, and truck entering the U.S. must be inspected to ensure that no unexpected "hitchhikers" are aboard. Every day, inspectors find stowaway insects, slugs, animals, plants, and fungi. Many of these stowaways are readily recognized, but others can't be identified at the ports where they arrive. That means whole planeloads of flowers, boatloads of bananas, and truckloads of other cargos must be held up until the potential invaders are identified – at the cost of thousands of dollars in lost revenue for the companies that await their delivery. Each year losses run to the millions of dollars.

Using scientific collections at places like the Smithsonian Institution and the Beltsville Agricultural Research Center, scientists drop whatever they're working on to provide the necessary information about these unidentified visitors which are shipped via overnight express to the labs. It's not uncommon for them to receive specimens that represent species new to science. Are the new and unknown species dangerous or safe to let into the country? By comparing specimens to known organisms in a collection, scientists can assess the risk and make recommendations. The safety of our food supply, our environment, and our trade rest on these collections.



USDA port inspector searches imported flowers for signs of insects or diseases.

Photo courtesy USDA, APHIS



## **Appendix C: Previous Studies of Scientific Collections**

Previous reports on scientific collections have established the need for rigorous and systematic surveys to assess their condition, uses, and value. The biological research community has been especially proactive in monitoring the state of their reference collections. Many of these reports included surveys of scientific collections and their condition, though none focused on the scientific collections owned by the Federal Government.

In a report of the National Academy of Sciences, Mayr and Goodwin (1956) described the research and educational roles played by preserved biological scientific collections in museums and herbaria and their importance to basic and applied research. Most of the functions performed by scientific collections that are described above (e.g., documenting research results, enabling research on rare events or extinct species) were articulated by Mayr and Goodwin. They called on NSF “to help maintain the scientific collections which are part of the cultural wealth of our nation.”

In 1969, a Panel on Systematics and Taxonomy of the U.S. Federal Council for Science and Technology issued a report that described the role of taxonomy in numerous Federal agencies. The report presented budget figures for intramural programs and extramural grants in taxonomy, separating the FY1968 Federal expenditures for research (54.6%), services (23.8%), and care of scientific collections (21.6%). The Panel did not identify particular problems associated with Federal scientific collections but recommended interagency coordination and planning for future space needs.

A Conference of Directors of Systematic Collections issued a report to NSF in January 1971 (*The Systematic Biology Scientific Collections of the United States: An Essential Resource*), in which they argued for Federal support for collection infrastructure and maintenance. The report called for systematic surveys of the scientific collections and their needs. The SI National Museum of Natural History was the only Federal collection among the 31 institutions surveyed for the report.

The Association of Systematic Collections (ASC) (later renamed the Natural Science Collections Alliance) published *America's Systematic Scientific Collections: A National Plan* (Irwin et al. 1973) and conducted an NSF-supported survey and workshop in 1975 (Edwards and Grotta, 1976) to assess progress following publication of the plan. Among the principal issues addressed by the plan were funding, growth of scientific collections, standards for computerized databases, educational impact of scientific collections, and inter-organizational cooperation. Of the 65 responses received, 3% were from Federal Government scientific collections.

The 1971 and 1973 reports by the ASC triggered a series of surveys and reports on the status and needs of taxon-specific scientific collections in biology that were published in professional society journals (e.g., Anderson, 1974; Solem, 1975; Collette and Lachner, 1976; Lee et al, 1982; Miller,

1991; Poss and Collette, 1995). Surveys of complete museum scientific collections, including international systematics and natural history scientific collections, among others, have been published by the American Association of Museums, the National Scientific Collections Program, and other organizations. These surveys and reports were not systematic and coordinated across fields of study and none of them focused on the scientific collections owned by the Federal Government.

In 1975, NSF launched the Biological Research Resources Program (BRR) in response to these studies. BRR (now the Biological Research Scientific Collections Program) is one source of support for non-Federal research scientific collections in biology. It supports facilities renovation, curatorial improvements, and computerization of scientific collections used for research in systematic and evolutionary biology. NSF later created a program that supported improvements to scientific collections in archeology and anthropology from 1984 to 1999. NSF and NIH both have grant programs that provide operational support to living stock centers and cell and tissue scientific collections which provide the biological and biomedical research communities with standardized research specimens.

In 1980, NSF's Systematic Biology Program provided support for a series of five workshops devoted to compiling information and formulating recommendations to NSF concerning priorities for research and infrastructure. The summary report of these workshops (Steussy and Thomson 1981) called for a synthesis of field-specific surveys and more comprehensive data-gathering on the condition of physical research infrastructure. In 1988, as part of its workshop entitled “Collections Resources for the 1990s,” the ASC conducted a comparative survey of the collections and financial data of member institutions for 1976, 1981, and 1986. The survey results (Mabee and Hoagland, 1988) suggested that collections grew approximately 5% annually. However, aside from several disciplinary reports (e.g., insects and fishes), the complete survey results were never published.

In 1992, the Department of the Interior's (DOI) Interior Museum Program formed a group called the Interagency Federal Collections Working Group. They developed a survey, conducted in 1994, of Federally Associated Collections Housed in Non-Federal Institutions. This survey was sent to 12,000 museums and academic departments in collaboration with the USDA. The American Association of Museums, ASC, and the Institute of Museum Services encouraged the effort. This was a broad survey that included collections beyond the realm of science. Relatively little information on biological collections was obtained, in part because of concerns by non-Federal institutions that providing such information might lead Federal agencies to withdraw collections from their institutions. The survey report (National Park Service, 1996) identified issues similar to those the current IWGSC has found: problems with definition of ownership; uncertainty about what standards apply to curation; unclear criteria for deaccessioning of specimens. Results of this survey were not published.

In 1998, the Biotechnology Working Group of the Organisation of Economic Cooperation and Development (OECD) initiated an international project on Biological Resource Centers, which explored scientific collections and called for international standards of practice.

In a 2002 study commissioned by DOE, the National Research Council (NRC) developed a strategy for the preservation and management of geoscience collections (e.g., rocks, minerals, cores, fossils) maintained by Federal and state agencies, universities, and private companies (NRC 2002). The NRC report illustrates the benefits to research and society derived from geoscience collections and the cost-effectiveness of maintaining them for future reference. Based in part on the recommendations in this report, Congress established the National Geological and Geophysical Data Preservation Program which is administered by the USGS for state geological surveys and relevant DOI Bureaus. The cornerstones of the program include an extramural program to the state geological surveys to archive geoscience collections and the development and population of a National Digital Catalog of geoscience collections.

The 2005 report “A Public Trust at Risk: The Heritage Health Index Report on the State of America’s Collections,” published by Heritage Preservation, Inc., was the first comprehensive survey of the physical condition and preservation needs of national scientific collections. The survey found that many scientific collections held as a public trust are at risk due to lack of environmental controls, improper storage, inadequate staffing and training, and insufficient budget among other factors.

Concern has also been expressed regarding curation of archaeological collections (Bustard, 2000; GAO, 1987; Ferguson and Giesen, 1999).

A report from GAO indicated that funding challenges affected facility conditions and security at the Smithsonian Institution and were thus endangering collections (GAO, 2007).

## Appendix D: Survey Questions

### A. Reporting Unit Information

A-1. Name of the reporting unit:

A-2. Name of parent agency or organization, if applicable:

A-3. Name of the individual completing this survey:

A-4. Which level listed below best describes the level at which you are reporting about your scientific collection? (Mark just one.)

A-5. May the NSTC Interagency Working Group on Scientific Collections include your reporting unit on a published list of survey participants? (Mark just one.)

### B. Description of the Reporting Unit

B-1. Which of the following most closely describes your reporting units governance?

B-2. Which of the following most closely describes your reporting units primary function or service? (Mark just one.)

### C. Purpose and Use

C-1. In the space provided, list the scientific collection you will be describing in this survey. You may list up to six collections. This information will be used to guide your responses in sections D, E, F, and G that follow.

C-2. What is the primary purpose of the collection? (Mark all that apply.)

C-3. What percentage of the collection is duplicated in other repositories? (Mark just one.)

C-4. Who are the primary users of the collection? (Mark no more than 3.)

C-5. In the questions below, estimate the number of individuals and institutions that used the collection(s) themselves or associated ancillary collections in FY2005. (Mark just one per row.)

### D. Scope and Size

D-1. What is the geographic scope of the objects in the collection? (Mark all that apply.)

D-2. In the boxes provided below, describe the size of your unit's object-based scientific collection. Estimate the number of objects in the collection using the defined unit of measurement for each category or enter UNK if the number of units is unknown or enter 0 for holding categories that do not apply.

D-3. How has the size of the collection(s) changed since FY2000? (Mark just one per collection.)

D-4. FOR THOSE COLLECTIONS THAT INCREASED IN SIZE, estimate the average annual growth in the collection since FY2000. (Mark just one per collection.)

D-5. Was the increase predicted or anticipated? (Mark just one per collection.)

D-6. What were the primary reasons for this increase? (Mark all that apply.)

D-7. FOR THOSE COLLECTIONS THAT DECREASED IN SIZE, estimate the average annual decrease in the collection(s) since FY2000. (Mark just one per collection.)

D-8. Was the decrease predicted or anticipated? (Mark just one per collection.)

D-9. What were the primary reasons for this decrease? (Mark all that apply.)

### E. Condition of the Collection

E-1. How would you characterize the overall condition of the collection? (Mark just one per collection.)

E-2. Has your reporting unit ever completed a condition survey or an assessment of object-based scientific collections? (Mark just one.)

### F. Care and Preservation

F-1. What percent of the collection is stored under conditions considered to be adequate for its care and preservation? (Mark just one per collection.)

F-2. For those collections stored under inadequate conditions, indicate areas of MAJOR need. (Mark all that apply.)

F-3. Which of the following areas are MOST IMPORTANT to the maintenance of the collection(s)? (Mark all that apply.)

### G. Collection Documentation and Accessibility

G-1. Estimate the percentage of the collection(s) that is catalogued. (Mark just one per collection.)

G-2. What percent of the collection(s) is accessible for scientific research or other uses? (Mark just one per collection.)

G-3. For those collections deemed inaccessible, indicate areas of MAJOR need. (Mark all that apply.)

G-4. Estimate the percentage of the collection that is accessible through an electronic database. (Mark just one per collection.)

G-5. Estimate the percentage of the collection that is accessible via the Web. (Mark just one per collection.)

G-6. Indicate the types of information about the collection that are accessible via the Web. (Mark all that apply.)

G-7. Does your agency charge user fees? (Mark just one.)

#### H. Funding

H-1. Does your agency's FY06 budget have funds specifically allocated for the care and management of your collection(s)? (Mark just one.)

H-2. For FY05, what was the agency's annual budget designated specifically for the care and management of your scientific collections?

H-3. What is the source of your agency's funds designated for the care and management of scientific collections? (Mark all that apply.)

H-4. Does your agency rely on external funding sources to support scientific collections-related activities? (Mark just one.)

#### I. Policies and Procedures

I-1. For which of the following activities does your reporting unit have written, approved policies and procedures for the management of these collections? (Mark all that apply.)

I-2. Which policies and procedures are current and up-to-date? (Mark all that apply.)

#### J. Staffing

J-1. In the spaces below, describe the current staffing associated with your object-based scientific collection(s). Number of Full-time paid staff

J-2. Please characterize recent staffing experiences for this collection. (Mark just one.)

#### K. Additional Questions

K-1. In the space provided, please list one question you wish we would have asked you about your reporting unit's object-based botanical collection(s):

K-2. In the space provided, briefly explain the answer you would give in response to that question. (No more than 25 words.)

## **Appendix E: A Preliminary Inventory of Federal Scientific Collections**

The IWGSC planned and implemented a survey of Federally-owned scientific collections. The Science and Technology Policy Institute (STPI) of the Institute for Defense Analyses (IDA), under contract to OSTP, conducted a pilot test of the survey questionnaires in early 2006 using five IWGSC member agencies. Subsequently, OSTP hosted an on-line, full-scale survey between June 2006 and September 2007, which produced 153 responses from 14 agencies (see Appendix F, Survey Questions). STPI analyzed the results for 291 different scientific collections (Institute for Defense Analyses 2007).

### **Diversity of Scientific Collections**

Respondents were asked to classify each collection into one of ten categories (archeological/anthropological, botanical, cellular/tissue, chemicals, technological, geological, paleontological, vertebrates, invertebrates, and other). Agencies varied widely in the diversity of scientific collections they maintain (see Table 1). The greatest diversity of scientific collections held by an agency was reported by NPS, SI and USDA's Forest Service, each of which reported having scientific collections in seven categories. Others (specifically the Department of Transportation, Centers for Disease Control, and the Department of Veterans Affairs; see Table 1) reported having scientific collections in only a single category.

The most commonly reported categories of collections were (see Figure 1):

- Cellular/tissue scientific collections, representing 22% of the 291 responses. Ten of the 14 responding agencies reported having cellular/tissue;
- Geological collections comprised 21% of the collections and are held in eight agencies; and
- Vertebrate and botanical collections each represent 12% and 11% of the 291 collections, respectively, and are each held by seven agencies.

### **Numbers of Scientific Collections**

The survey responses indicated a wide variation in the numbers of scientific collections held in the different categories by each agency (see Table 1). Some of this variation may have resulted from two factors described below, but it may also reflect genuine diversity of scientific collections within a category.

The questionnaire did not specify a definition of a collection, which led to variability in agency responses. It left agencies free to make independent and varying decisions about which scientific collections should be included in their responses. Since most agencies do not have electronic databases or even lists of their collections, the workload associated with this first-ever survey depended to some degree on how much agencies decided to aggregate collections in their response (e.g., to decide if geographically dispersed germplasm collections comprise one collection or many). Furthermore, a collection could not be defined by size, as this varies widely depending on the types of specimens and the reason for collecting them. There are enormous numbers of specimens held in the labs of individual researchers and research teams in each of the 14 agencies that responded to this survey. In many cases, there is no clear and objective point at which these research specimens become part of a Federal collection that is available to the research community. As a result, each responding agency had to make an independent decision about which scientific collections would be included in their survey responses. For example, NIH recognized that a "collection" could be defined as anything from a box of tubes in a researcher's freezer, to a massive biorepository. However, they focused their survey response on federally held, routinely used collections and chose 25 collections to serve as representative samples. Clearly, the collections most routinely used by biomedical researchers would also tend to be large, well catalogued, well staffed, and highly accessible to the research community through a website. Therefore, although the NIH survey data provides valuable insights into the breadth of federal collections and their uses, it may be inappropriate to compare NIH collections to those of other agencies who chose different scopes for their survey responses. Similarly, conclusions and recommendations drawn from survey averages may not apply equally to all agency collections. The lack of a formal definition of "collection" allowed responding agencies to aggregate their data in varying ways. A collection, as reported in the survey responses, may or may not correspond to a physical storage locality or a discrete management unit. The results of the survey are reported here using different levels of organizational aggregation. For example, the Smithsonian's scientific collections are reported together, but USDA's are reported under two different agencies. Some agencies, like USDA/ARS, aggregated specimens in the same category (e.g., insects) but in different storage sites into a single reported collection, while other agencies reported each storage site or management unit as a separate collection. While this complicated detailed analysis of numeric data from the survey, the overall trends and policy issues that emerged were clear.

Most agencies reported having a few scientific collections within each category (e.g., NASA, Department of Veterans Affairs,

Department of Transportation, DOE, FDA). Other agencies reported that they have many scientific collections in a single category. For example:

- USGS reported having 86 separate scientific collections, more than any other responding agency. Of these 86 scientific collections, 41 were geological and 28 were paleontological.
- The USDA Forest Service reported having 47 scientific collections, 23 of which were botanical.
- NOAA reported on 40 scientific collections, 20 of which were vertebrates; and
- NIH reported on 25 scientific collections, 19 of which were cellular.

A third group of agencies reported having an intermediate number of collections per category distributed across several categories. This group included agencies with the largest numbers of specimens, totaling tens of millions or more per agency. This may have influenced the way the agencies aggregated them into a modest number of reported collections.

- The Smithsonian reported a total of 45 scientific collections across seven types of scientific collections. There were four to nine scientific collections in each category.
- ARS also aggregated their collection data, reporting a total of only 13 scientific collections with one to five scientific collections per category.
- NPS aggregated separate collections from over 360 National Parks into eight scientific collections in seven categories.

This variable approach to reporting on scientific collections suggests that the approach to organizational structure may vary widely among agencies.

### ***Sizes of Scientific Collections***

The questionnaire allowed respondents to report the size of their scientific collections in a variety of ways (e.g., numbers of specimens, linear feet, and volume). The sizes of individual scientific collections vary widely, ranging from four railroad bridges maintained by the Department of Transportation to more than 50 million parasitic worms in the scientific collections of ARS. A few agencies reported scientific collections with as few as tens of specimens (e.g., the insectary of the U.S. Food and Drug Administration). At the other extreme, individual scientific collections can include hundreds or thousands (moon rocks, anthropological artifacts), millions (plants, fossils, rock samples) to tens of millions (archeological artifacts, insects, and other invertebrates) of specimens. Many agencies were able to provide only rough estimates for the numbers of specimens in each collection. Given the uncertainty about the sizes of many scientific collections and the extraordinary variation in the sizes of many others, only a qualitative analysis is reasonable at this time.

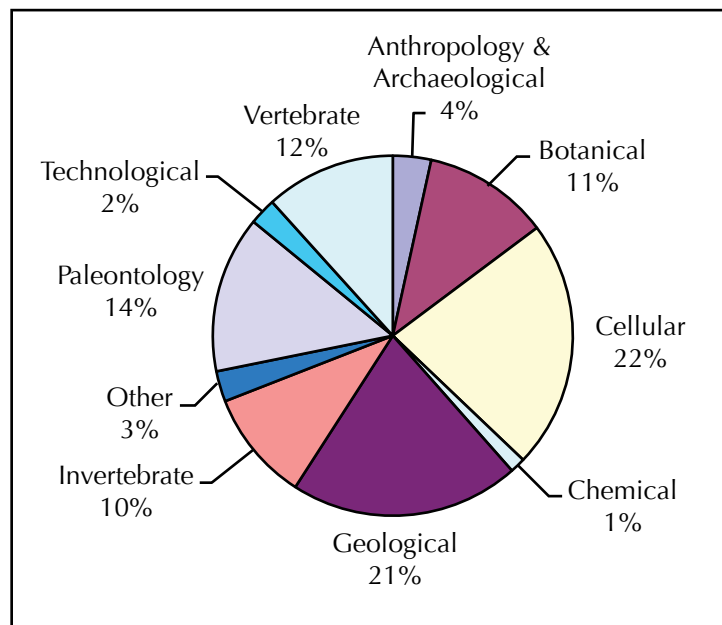
Following completion of the survey, STPI also prepared a compilation of the survey results other than those concerning the number, size and diversity of scientific collections. This compilation was presented to the IWGSC.

**Total Reported Scientific Collections by Survey Type**

Parent Agency	Anthropology & Archaeological	Botanical	Cellular	Chemical	Geological	Invertebrate	Other	Paleontology	Technological	Vertebrate	Totals
DOI-USGS		1	9		41	5		28		2	86
USDA-FS		23	2		6	5	3	6		2	47
Smithsonian	8	4	9		4	7		6		7	45
DOC-NOAA		2	12	1		5				20	40
DHHS-NIH		1	19				5				25
USDA-ARS			5	3	1	3				1	13
DOC-NIST			6		1						7
DOI-NPS	2	1	1		1	1		1		1	8
DOT									6		6
NASA					5				1		6
DHHS-FDA		1				3					4
DOE					1					1	2
DHHS-CDC			1								1
VA			1								1
	10	33	65	4	60	29	8	41	7	34	291

**Table 1.** Numbers and categories of scientific collections reported on by 14 Federal agencies. Columns are arranged by scientific discipline. Rows are presented in descending number of total scientific collections reported. The number of scientific collections reported by agencies cannot be compared across agencies because no standard definition of “collection” was used.

**Collections by Collection Types**



**Figure 1.** The 291 scientific collections reported by fourteen Federal agencies in 153 survey responses were each classified in one of ten categories.

## Appendix F: Bibliography and References

- Amato I. 2006. Daly's Adventure. NIH Scientist has Trekked the World to Chronicle Nature's Own Chemistry but Now Faces Toughest Road. *Chemical & Engineering News* 84 (26):36-37.
- Anderson, S. 1974. *Report and Recommendations of the Advisory Committee for Systematic Resources in Mammalogy*. American Society of Mammalogists.
- Anonymous. 2008. "Valuable Bacterial Archive Destroyed." *Nature*. 452:398.
- "Archaeological and Historical Preservation Act of 1974." Public Law 93-291, 16 USC 469 et seq.
- Bawaya, M. 2007. "Curation in Crisis." *Science* 317: 1025-1026.
- Bustard, Wendy. 2000. "Archeological Curation in the 21st Century." *CRM* 5(4): 10-15.
- Collette, B. B. and E. A. Lachner. 1976. Fish collections of the United States and Canada. *Copeia* 1976 (3) 625-642.
- Conference of Directors of Systematic Scientific Collections. 1971. *The Systematic Biology Scientific Collections of the United States: An Essential Resource*. NY Botanical Garden.
- Edwards, S. R. and L.D. Grotta, eds. 1976. *Systematics '75: A Report on a Workshop Assessing the Current Status of Systematics Scientific Collections*. Association of Systematics Scientific Collections.
- Federal Accounting Standards Advisory Board. 2005. Heritage Assets and Stewardship Land. Statement of Federal Financial Accounting Standards 29. [www.fasab.gov/pdffiles/sffas\\_29.pdf](http://www.fasab.gov/pdffiles/sffas_29.pdf)
- Ferguson, B. and Giesen, M. 1999. "Accountability in the Management of Federally Associated Archeological Collections." *Museum Anthropology* 23(2): 19-3.
- Fleischer RC, Kirchman JJ, Dumbacher JP, Bevier L, Dove C, Rotzel NC, Edwards SV, Lammertink M, Miglia KJ, and Moore WS, 2006. Mid-Pleistocene divergence of Cuban and North American ivory-billed woodpeckers *Biological Letters* 22:466-469.
- Frierson, E. and Leonard, M.A. 2008. *Blueprint for Success: the National Agricultural Library 2008-2012*. NAL Staff Discussion Paper.
- Government Accountability Office. 1987. *Cultural resources: Problems Protecting and Preserving Federal Archaeological Resources*. GAO/RCED-88-3.
- Government Accountability Office. 2007. Smithsonian Institution: Funding Challenges Affect Facilities' Conditions and Security, Endangering Collections. GAO-07-1127.
- Ice Core Working Group, 2003. Recommendations for the Future. [http://www.nicl-so.snr.unh.edu/icwg/ICWG2003\\_ExSumm.pdf](http://www.nicl-so.snr.unh.edu/icwg/ICWG2003_ExSumm.pdf).
- Institute for Defense Analyses. Science and Technology Policy Institute. December 2007. "Findings from the IWGSC Survey of Object-Based Scientific Collections: 2007" P. Flattau, et al. Available at [www.ida.org/stpi](http://www.ida.org/stpi).
- Intergovernmental Panel on Climate Change, 2008. "Frequently Asked Question 6.2: Is the Current Climate Change Unusual Compared to Earlier Changes in Earth's History?" [http://ipcc-wg1/FAQ/wg-1\\_faq6.2.html](http://ipcc-wg1/FAQ/wg-1_faq6.2.html).
- Irwin, H.S., Payne, W.W., Bates, D.M., and Humphrey, P.S. 1973. *America's Systematic Scientific Collections: a National Plan*. Association of Systematics Scientific Collections.
- ITAP - Federal Interagency Committee on Invasive Terrestrial Animals and Pathogens (ITAP). 2008. *Protecting America's economy, environment, health, and security against invasive species requires a strong Federal program in systematic biology*.
- "Joint Resolution to Encourage the Establishment and Endowment of Institutions of Learning at the National Capital by Defining the Policy of the Government with Reference to the Use of its Literary and Scientific Collections by Stu

dents," 27 Stat. 395, 1892.

- Lawrey JD, 1993. "Lichens as Monitors of Pollutant Elements at Permanent Sites in Maryland and Virginia." *The Bryologist*, 96: 339-341.
- Lee, W. L., Bell, B.M. and Sutton, J.F., eds. 1982. *Guidelines for Acquisition and Management of Biological Specimens: a Report of the Participants of a Conference on Voucher Specimen Management*. Association of Systematics Scientific Collections.
- Li, W., Song, Q., Bransky, R. and Hartung, J.S. 2007. Genetic diversity of citrus canker pathogens preserved in herbarium specimens. *Proceedings of the National Academy of Science USA* 104 (47):18427-18432.
- Lipske, M. 2007. Fossils hold clues to predicting how plants will respond to global warming. Inside Smithsonian Research. Winter, 2007.
- "Literary and scientific collections accessible to investigators and students," 20 U.S.C. sec. 91, 1901.
- Longcore, J. E., Pessier, A. P. & Nichols, D. K. 1999. "Batrachochytrium dendrobatidis gen. etc. sp. nov., a chytrid pathogenic to amphibians." *Mycologia* 91: 219-227.
- Mabee, P.M. and K. E. Hoagland, "Progress and Needs of Systematics Collections Revealed by ASC Survey," ASC Newsletter 16:6 (December 1988), 1-8.
- Marburger, J.H. and Bolten J. Memo Aug. 12, 2004, Office of Science and Technology Policy and Office of Management and Budget. "Updated Administration Research and Development Budget Priorities."
- Marburger, J.H. and Bolten J. Memo July 8, 2005, Office of Science and Technology Policy and Office of Management and Budget. "FY2007 Administration Research and Development Budget Priorities."
- Marburger, J.H. and Daniels, EM, Jr. Memo June 5, 2003, Office of Science and Technology Policy and Office of Management and Budget. "FY2005 Interagency Research and Development Priorities"
- Marburger, J.H. and McMillin S.S. Memo Aug. 14, 2007, Office of Science and Technology Policy and Office of Management and Budget. "FY2009 Administration Research and Development Budget Priorities."
- Marburger J.H. and Portman R. memo June 23, 2006, Office of Science and Technology Policy and Office of Management and Budget. "FY2008 Administration Research and Development Budget Priorities."
- Mayr, E. and R. Goodwin. 1956. *Biological Materials, Part I: Preserved Materials and Museum Scientific Collections*. Biology Council, National Academy of Sciences-National Research Council, Publication No. 399.
- McKay D. S., Gibson E. K., Thomas-Keprta K. L., Vali H., Romanek C. S., Clemett S. J., Chiller X. D. F., Maechling C. R., Zare R. N., 1996. "Search for Past Life on Mars: Possible Relic Biogenic Activity in Martian Meteorite ALH84001". *Science*, 273: 924 - 930.
- Miller, B., Reading, R. P. & Forrest, S. 1997. *Prairie Night: Black-Footed Ferrets and the Recovery of Endangered Species*. Washington, D. C. : Smithsonian Institution Press.
- Miller G.E., Grant P.M., Kishore R., Steinkruger F.J., Rowland F.S., and Guinn V.P., 1972. "Mercury Concentrations in Museum Specimens of Tuna and Swordfish." *Science* 175: 1121 - 1122
- Miller, S. E. 1991. Entomological collections in the United States and Canada: current status and growing needs. *American Entomologist* 37 (2) 77-84.
- National Park Service memo, Aug. 8, 1996. No author. "Revised Final Report: summary of Data"
- National Research Council. 2002. *Geoscience Data and Scientific Collections: National Resources in Peril*. National Academy Press.

- National Research Council. 2003. Sharing publication-related data and materials: Responsibilities of authorship in the life sciences. National Academies Press, Washington, DC.
- National Science and Technology Council. Committee on Science. 2005. Charter of the Interagency Working Group on Scientific Collections.
- National Science Board. 2003. *Science and Engineering Infrastructure for the 21st Century: The Role of the National Science Foundation*. National Science Board Report NSB 02-190.
- Panel on Systematics and Taxonomy of the Federal Council for Science and Technology. 1969. *Systematic Biology: a Survey of Federal Programs and Needs*. Office of Science and Technology, Executive Office of the President.
- Pimentel, D. Zuniga, R., and Morrison, D. 2005. "Update on the environmental and economic costs associated with alien-invasive species in the United States." *Ecological Economics* 52: 273-288.
- Poss, S. G. and B. B. Collette. 1995. Second survey of fish collections in the United States and Canada. *Copeia* 1995 (1): 48-70.
- Richerson, M. 2008. *Rapana venosa*. USGS Nonindigenous aquatic species database. Gainesville, FL. (<http://nas.er.sgs.gov/queries/factsheet.asp?species id=10187>revision date 4/24/2006).
- Solem, A. 1975. "The Recent Mollusk Collection Resources in North America." *Veliger* 18:222-236.
- Snydman D.R., Anaissie E.J., and Sarosi G.A. 2008. Destruction of Isolates from the Pittsburgh Veterans Affairs Laboratory. *Clinical Infectious Diseases* 46:1053-9.
- Steussy, T.F., and Thomson, K.S. 1981. *Trends, Priorities and Needs in Systematic Biology: A Report to the Systematic Biology Program of the National Science Foundation*. Association of Systematics Scientific Collections.
- Teece, M. A., M. L. Fogel, N. Tuross, E. E. Spamer, and R. M. McCourt, (2002) "The Lewis and Clark Herbarium of the Academy of Natural Sciences, Part 3. Modern Environmental Applications of a Historic Nineteenth Century Botanical Collection," *Notulae Naturae*, . 477:1-16.
- University of Wisconsin System, Office of Internal Audit. 2002 *Stewardship of University of Wisconsin Art, Science, and Special Library Collections*. <http://www.uwsa.edu/audit/collections.pdf>
- Williams, A. B. 1986. Lobsters - identification, world distribution, and U. S. trade. *Marine Fisheries Review* 48 (2): 1-36.
- Williams A. B. and Dore I., 1988. *Lobsters of the World: an Illustrated Guide*. Osprey Books, Huntington, NY. 186pp.

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