Data Reuse in Museum Contexts:
Experiences of Archaeologists and Botanists

by

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Abstract

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In recent years, data reuse has become a prominent goal in a number of disciplines, in recognition of the potential of new combinations and analyses of data to address new research questions. While data sharing infrastructure supporting research communities has grown, so too has a body of literature addressing the barriers to data reuse. One institution largely omitted from examinations of data reuse, however, is the museum.

Museums have long been sites of data reuse. They hold a vast array of objects related to natural and human history, which, along with the information known about them, function as important sources of evidence in the work of many researchers. Decisions made by museum staff about methods of data selection, validation, and representation have important implications for future research use. However, little is known about the ways that researchers find, evaluate, and interpret data in museums.

In response to this gap, I developed two research questions. First, *what is the relationship between museum objects, their representations, and research use*? Second, *what factors influence the practices of staff members as they describe and manage museum data*? These questions specify the individuals whose activities form the core of this study: researchers, as they analyze museum data to address specific goals, and museum staff, as they create representations of museum data to facilitate use.

I addressed these research questions by conducting a comparative case study of the data practices of staff and researchers using two museum collections, an archaeology museum and a herbarium. I conducted a total of 45 semi-structured interviews with 14 staff members and 31 researchers between the two sites. I supplemented this primary data with non-participant observation of the data management and reuse practices of six of these individuals, and with archival research into the historical factors influencing the representation and use of data at the two museums.

The main contribution of this work is an understanding of how researchers select and use museum data as evidence in two domains. Researchers used complex accumulations of museum objects and their representations, including metadata, to address different types of research goals, applying the evidential norms of their research communities to their approach to data. I characterized their use of research data as primarily type-based, involving comparative analysis of objects, or provenance-based, in which documentation of an object's source was the most vital information. The study also contributes a nuanced understanding of the work of collection managers and curators to increase the value and accessibility of museum data through the application of their own expertise in information systems and content.

Chapter 1

Introduction

1.1 Background

As massive data sets are increasingly exploited across research disciplines, along with the expectations for data deposit and sharing in a number of fields, interest in infrastructure for data sharing has also grown. In various disciplines, systems are being built for the collection, analysis, and distribution of digital data among members of research communities (Atkins et al. 2003). While many strides in this area have been taken in scientific fields, where expectations for sharing observational, experimental, and simulation-based data are growing, some infrastructure for data sharing in the social sciences and humanities has also emerged (American Council of Learned Societies 2006). A great deal of research has also taken place into the necessary conditions for data sharing and reuse, including incentives to share (Borgman 2007), trust in data created by others (Van House 2002a), and standard data collection methods (Zimmerman 2008).

One long-standing data repository that has been largely omitted from these examinations is the museum. As collecting institutions, which have been involved in the preservation and interpretation of objects for public and research audiences for centuries, museums hold great potential as resources for the creation of new knowledge. In a number of fields, such as archaeology, ecology, and art history, analysis of museum objects is a common method of inquiry. No systematic analysis has taken place of the means by which knowledge is created through the use of museum data in these and other research domains. In order to understand the requirements for research use of museum data in the development of infrastructure for data sharing, the present study intends to address this gap.

For hundreds of years museums have served several important educational, informative, cultural, and symbolic functions. They collect and make accessible artifacts of historic, scientific, and cultural value, while interpreting their meaning to the audiences they serve. Museums have seen a shift in purpose from private collections of objects to public collections that serve as educational institutions and community resources (Weil 2002). Throughout this history they have acted as an important source of evidence about the world to members of various epistemic communities involved in the development of knowledge. By providing access to a range of objects, museums have made it possible for researchers to compare materials, forming theories about relationships in nature and human cultures (Hedstrom and King 2006). In fact, research is considered to be a primary function of museums (Gunn and Prescott 1999; Anderson 2005; Dube 1990).

For the majority of museum visitors, information about museum collections has traditionally been available through exhibits of carefully selected objects and their interpretation through physical groupings and explanatory text. A common view of the experiences of the museum-going public is leisure-oriented learning, a phrase that combines the educational and entertainment functions of these institutions for most visitors (Falk and Dierking 2000). While visitors experience museums primarily through exhibits, most museums have vast collections that are not on display.

Access to these hidden collections is frequently granted to researchers with permission from museum staff. Researchers are often able to use objects in storage that are the focus of the day-to-day work of curators and collection managers but are by and large invisible to the majority of museum visitors (with the exception, in some cases, of digital representations of objects in public catalogs) (Hamma 2004). This dichotomy of space within the museum, between public exhibition areas on the one hand and behind-the-scenes research work (including object storage) on the other, reflects dichotomies in access to museum collections and personnel. Although online catalogs offer metadata and other representations of museum objects to visitors, direct access to objects is generally not granted to that group.

On the other hand, researchers in a number of fields (including archaeology and botany, the disciplines at the center of the current study) may both contribute objects to museum collections and use them as data sources, being granted access to collections and behind-the-scenes areas within a museum. In addition, information about museum collections can also be a valuable data source for these researchers, who are often allowed access to more extensive information than is made available in an online catalog (Hamma 2004).

While research use of museum collections is much less visible to the public than the visitor experience at exhibitions, it is an important function of these institutions. In many museums collections are created through the efforts of researchers who systematically document their findings, offering not only the objects but also information about them (their metadata) to museums for study and long-term preservation. Research use of museum collections, by curatorial staff and external specialists, is also an important source of new information, as researchers offer new insights into the objects themselves (Fenton 2005).

Although the use of museum collections by researchers is often an important function in the activity of a museum, it has received scant attention from those who study museums. Little is known about how researchers use museum collections to create new knowledge in their field, a problem both for understanding the research value and functions of museum collections and for understanding the needs of researchers who make use of museum collections. Making museum collections more accessible and usable to researchers in both in-person and digital contexts will require a more thorough understanding of the research uses of museum data.

1.2 Research Questions

Aligned with a broad interest in the construction of new knowledge, and the ways in which this takes place in specific epistemological contexts, in this dissertation I investigate the processes involved in the research uses of museum collections. Given the goal of understanding the research use of museum data, this study addresses the major research question *What is the relationship between museum objects, their* *representations, and research use?* This question deals with the practices of researchers using museum collections, seeking to understand how they use museum data to make new contributions to their own field.

A related question, looking specifically at the management of museum resources, specifies and informs the investigation into this subject. *What factors influence the practices of staff members as they describe and manage museum data?* Through this question, I address the transformation of museum objects into data that is performed by museum staff through the description of collections, asking what norms structure that activity.

In this dissertation, I posit a definition of museum data that is comprised of museum objects and a host of representations of the objects. Representations of museum objects can take a number of forms, including field notebooks describing a collecting expedition, photographs depicting objects in a previous (or the original) context, papers documenting the ownership history, measurements and descriptions written by the collector or by museum staff, and database records describing objects. Depending on their research question, researchers require different types of "data" ranging from first hand interaction with museum objects themselves (to examine their characteristics or verify past identifications) to database records documenting objects' geographic provenance (to create a GIS model). At times, various representations of objects may be more useful data to a researcher than the physical objects to which they relate. In this study, I focus on researchers' various uses of the components of museum data (objects and their representations).

My goal is to characterize and understand the ways in which museum data are used as evidence by researchers in several fields to make knowledge claims. This study aims to gain insight into the intersections of museum and field-specific scholarly practice that influence the representations and research uses of museum data.

1.3 The Study in Brief

In chapter three, I outline the methods used in this study, and provide great detail about the study design. In this section, I will briefly introduce the methodology and sites used in this study in order to provide context for the rest of this introductory chapter. This research is designed as a comparative case study of two university museums serving research communities. The museums, chosen on the basis of their commitment to facilitating scholarly research and their diversity of focus, have collections focused on natural history and archaeology. Specifically, the museums selected are the University of Michigan Herbarium and the Kelsey Museum of Archaeology at the University of Michigan, serving researchers in botany and archaeology, respectively. The variation between these museums brings to light a number of differences in methods used by researchers in creating new knowledge in their own disciplines based on the resources available to them and the norms of their field.

Within the two sites, I examine activity dealing with the research use of collections through interaction with two primary groups: museum staff responsible for the representation of collections and researchers who make use of them for their own work. Data were collected through semi-structured interviews of museum staff and researchers and observation of their work practices describing collections and using them in research. This qualitative study reveals the practices relevant to research use of museum collections at the two sites from both staff and researcher perspectives.

1.4 Conceptual Framework

Creators and users of museum data must be examined within the specific contexts in which their work takes place. Looking at the social contexts in which individual action takes place, a symbolic interactionist approach to social groups emphasizes the behaviors and modes of expression in individuals' everyday practice through which they act as members of communities. For Strauss (1978), people organized around an activity comprise *social worlds*, sharing and developing communication methods, technologies, sites, and forms of organization centered on the activity in which they participate. Social worlds can encompass any area of human activity, including professional occupations, artistic or intellectual pursuits, and recreation. Individuals are members of multiple social worlds associated with the numerous activities in which they participate. By thinking of fields of research and museum work as social worlds, I focus my attention on the activities and norms that are shared among members of these worlds that help define them and identify their members.

Becker (1982) applies a social worlds analysis to art, noting that an entire network of people and processes is required to make art, from artists to critics to audience members to makers of art supplies. The combined work done by all of the people involved in an art world make the production of art possible, from defining tastes to setting standards for the size of art objects or the length of performed music. While these conventions can occasionally be ignored, flouting them comes at a great cost to art creators, who must forgo some of the services and resources of an art world and make do in other ways. An essential feature of social worlds is participation – it is one's activity in this world that makes an individual a member. From Becker we gain the insight that a network of individuals, both directly and indirectly involved in an area of scholarly inquiry, makes that community's work possible through their participation in a social world. The norms and standards of their behavior help coordinate the activity needed to do the work of that community.

Using a social worlds perspective, I depict the two social worlds central to this research in Figure 1.1, below. The circle on the left represents the social world of the museum. It is comprised of a complex, interrelated web of people, from the original collectors of objects that become part of the museum's collections to curators of those objects in the museum. The social world of the museum includes groups like guards, docents, visitors, funding sources, and professional organizations. Membership in the social world is defined by the actions of those involved in it – those whose activities contribute to the museum.

The circle on the right represents a research social world, the context in which researchers within their individual disciplines engage in the activities that define their work. This social world consists of a range of people including researchers, administrative and support staff, funding agencies, journal publishers and reviewers, conference planners, students, research assistants, and many more people involved in the production of knowledge through research. Depending on the discipline, these activities may include data collection, writing, and literature search and review, along with the many tasks that fulfill the other responsibilities of a researcher's position aside from research itself. For academic researchers, for instance, activities defining this social world include things like applying for grants, teaching classes, advising students, and service to specific academic and research communities. These activities, and the people involved in them, vary between research social worlds.

The range of people in differing roles that make possible the activity of a social world renders the selection of particular activities for investigation difficult. The focus of this study on the research use of museum data and the role of representation in shaping that use, however, helps narrow the area of interest considerably. The point of intersection for the two social worlds (in the diagram, where the two circles meet) is the research use of museum collections, an activity performed by individuals in various research contexts which is facilitated by description done within the museum context. It is this intersection where the central activity examined by the present study takes place.

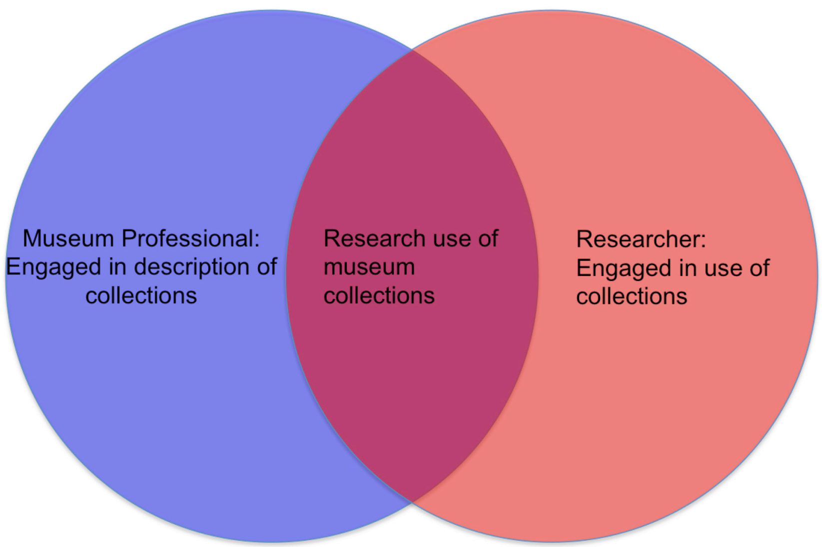

Figure 1.1 Diagram of the intersection of social worlds engaged in research using museum collections, after Anselm Strauss (1978)

For the purposes of this study, the central museum activity is the description of collections. While the people in this role may have various job titles and responsibilities (those of registrar, curator, and collection manager, to name a few possibilities), the shared activity of museum collection description unites them as a social world. It is this activity that must be traced throughout a given museum to understand the forces shaping the representation of museum collections.

Similarly, an entire community of people is involved in the creation of new knowledge using research collections. This includes colleagues within a given discipline, who judge the quality of scholarship produced and evaluate the methods used in coming to conclusions in research. Research funders are another important part of these social worlds, determining who may have access to the economic resources needed to begin new work. The infrastructure of a researcher's home institution is another of the many parts of this social world, providing access to resources like support staff and technological tools that enable the researcher's work. As with museums, the scope of a research social world is quite large. In this case, the activity of producing new knowledge through the use of museum resources is the central activity, leading to a focus on the researchers who are at the center of this work. By analyzing the work of these individuals, an understanding of relevant aspects of their social worlds will be possible.

Lave and Wenger (1991) use the term *community of practice* to describe people who share an activity (e.g. a profession or craft), knowledge about that activity, and an understanding of the meaning of that activity. Membership in a community of practice implies "participation within an activity system about which participants share understandings concerning what they are doing and what that means in their lives and for their communities" (Lave and Wenger 1991, p. 98). Through participation in a shared activity, members learn the "culture of practice" in their community—how to be an archaeologist, botanist, museum curator, or collection manager, for example—and what it means to do so, shaping participants' identities. New members engage in less central, lower stakes work contributing to the shared activity, which Lave and Wenger call *legitimate peripheral participation*. As they gain experience and knowledge, apprentice learners perform increasingly crucial tasks related to the shared activity, becoming masters over time. Communities of practice are not static, however. They change with the participation of new members who introduce new outlooks on practice. In fact, "since activity and the participation of individuals involved in it, their knowledge, and their perspectives are mutually constitutive, change is a fundamental property of communities of practice and their activities" (Lave and Wenger 1991, p. 117). With communities of practice, Lave and Wenger provide a valuable framework for understanding how knowledge, norms, and practices are communicated between members of social worlds through participation in a shared activity, and how those elements of a community of practice change over time though the efforts of participants.

Taken together, these perspectives on social worlds and practice are useful for thinking about researchers' use of museum data. Through their research work, members are acculturated into a social world, learning its forms of practice, embodying them in their own activity, and introducing new perspectives on the social world's shared activity. These forms of practice are embedded in norms that govern members' work in their communities. The social worlds approach is helpful for considering the ways in which individuals' activities embody the norms for data collection, analysis, reporting, retention, and sharing, among the myriad norms they learn as a part of everyday practice. The community of practice framework provides perspective on continuity and change within a social world: while norms are communicated to new members through practice, those members contribute new perspectives to the community, changing practice over time as they displace, and themselves become, old-timers.

These perspectives are helpful in emphasizing the socially-situated nature of data practices. The practices of members of two overlapping social worlds in each museum will be important to understand in this study: those of museum staff involved in collections management and those of researchers making use of museum collections. These categories overlap for some research users of museum collections, particularly curators, who share a disciplinary background with a collection's primary users. Accordingly, the areas of convergence and divergence among the practices of people involved in the use of a collection are an important aspect of this study.

A useful tool for conceptualizing the coordinated work and transfer of knowledge and information between social worlds is Galison's discussion of *trading zones*. Galison (1997) looks at experimental, theoretical, and instrumental physics for an explanation of how these three subdisciplines with very different practices and understandings of their field manage at times to work together and to share information. He uses the concept of the *trading zone* as a metaphor to explain how the subdisciplines alter their own languages to speak to one another, creating the equivalent of pidgin and Creole forms of language to establish a space where ideas and information can be shared and collaboration can take place. In trading zones, differences between social worlds are de-emphasized through the communication members develop to facilitate interaction. Both communities develop forms of communication based in their own languages and norms, changed somewhat to fit the other group's language and understanding. The various parties have different interpretations of the meaning and value of the objects or information they exchange, yet they are able to exchange them nonetheless. In the context of social worlds, trading zones help explain how the norms relevant to each group are negotiated for shared communication. For museum staff and researchers, the norms of both social worlds must be navigated for a successful interaction.

While this conceptualization of the interaction between social worlds is helpful for understanding how groups communicate despite their differences, many of the relevant norms are in fact similar between researchers and museum staff within a discipline. Curators, for example, generally hold advanced research degrees in the field that their collection serves. These degrees and the training they signify, along with many curators' active participation in research in their field, mean that their perspective on research using museum collections may be quite similar to that of a researcher who is not a curator.

The two groups are also likely to share some resources but assign different meanings to them and use them in different ways. A public museum catalog, for instance, is a useful tool for members of both groups. A researcher might use it to determine whether there are items in the collection that have research interest for them. For museum staff, the public catalog may be a manifestation of a database which holds much more information about the collection than is made openly available through the catalog. Museum staff could be concerned with the catalog as a public representation of the collection, thinking about how the collection is perceived by users and deciding which kinds of information to make available. The different use of resources by members of these social worlds, where their uses converge and diverge, is an important aspect of this study.

Throughout the dissertation, I refer not only to the norms guiding museum-based research, but also to the relevant infrastructure. Star and Ruhleder (1996) describe infrastructure as technology in relation to organized practices, a conceptualization that highlights the social dimensions of infrastructure and its availability to particular social worlds. Continuing the example above, considering a museum's online catalog as infrastructure draws attention to the organized practices related to its creation, maintenance, and use by members of various social worlds. In the following chapter, infrastructure in relation to museum-based research is discussed in greater depth.

A key aspect of my discussion of infrastructure is *boundary objects*, shared artifacts that help coordinate the work of members of more than one social world. As various stakeholders access boundary objects, "people from different worlds can use or borrow from the 'pile' for their own purposes without having directly to negotiate differences in purpose" (Star and Griesemer 1989, p. 410). The botanical specimen, annotated by researchers and managed by museum staff, is a primary example of a boundary object that I discuss throughout the dissertation.

1.5 Structure of the Dissertation

This dissertation is organized in six chapters. Following this introduction, in chapter two, I present a review of the relevant literature situating this study among other work discussing the use of evidence to create new knowledge, with a special emphasis on the use of museum objects and the norms for evidence in the disciplines that I examine in this study. I discuss data (and museum data in particular) as part of the information infrastructure enabling research.

In the third chapter, I outline and justify the comparative case study research design and methods I used to analyze representation and research use of museum collections. In addition to a discussion of the specific data collection and analysis methods employed by the study, I explain my site and participant selection in detail. The specific semi-structured interview protocols I used in meetings with museum staff and researchers can be found in Appendices A and B.

Following the methods section, I turn to my findings in chapters four and five. In the fourth chapter, I examine staff creation of object representations in the two museums, comparing their representation methods over time, including the present day, while in the fifth chapter, I discuss the experiences of researchers at the two sites. The data presented and discussed here were derived from the interviews and observation described in the upcoming methods section. In chapter six, I summarize my findings and highlighting remaining questions to be addressed by future work.

1.6 Significance of the Study and Contributions

This study offers several contributions to scholarship in data reuse and museum studies. Within studies of data reuse, there has been a lack of attention to museum data, while in museum studies, researchers' practices as they interact with museum data remain largely uninvestigated. In response to these gaps, this dissertation identifies what constitutes data within museums from the perspective of researchers, investigating the role of objects and representations in the research process. This study augments our limited understanding of how researchers seek, extract, analyze, and use data in museums.

Several pragmatic applications of this research bear mention as well. In an era of great investment in infrastructure designed for data sharing and analysis, empirical studies of the use of data are necessary in order to build systems that adequately meet the needs of their intended users. While data sharing infrastructure for museums is in place at different institutions to different degrees, it is essential to study the research use of museum collections in order to guide the design of infrastructure for that particular audience. This study addresses that need by investigating the research uses of museum collections and their representations in the infrastructure already in place in museums, whether based in paper, databases, other electronic files, or the objects themselves. By looking at the convergence of museum and discipline-based scholarly practices, this study creates an understanding of the flow of data from objects to museums to researchers and its transformation into new knowledge.

A major contribution of this study is a greater understanding of the use of museum data in research contexts. By using a comparative case study design, in particular, I am able to analyze the similarities and differences in museum-based research in two disciplines, including their methods of analysis. The study also reveals trends in the management of museum collections and their implications for research use. It explores the adequacy of online representations of museum objects for researchers selecting materials to examine or for those examinations themselves to take place, determining what contextual information is necessary to make use of these objects from a research perspective. This study contributes an understanding of the relationships of museums to their research users while adding to the larger data sharing discussion currently taking place across the world.

Chapter 2

A Review of the Literature

2.1 Overview

In this literature review I lay the groundwork for an exploration of the scholarly use of research data in museums. Guided by the theoretical framework presented in the introductory chapter, I explore the social worlds of museums and the scholarly researchers who use research data in museums, paying particular attention to the norms guiding the representation of museum objects, and the use of these representations and the underlying objects for research purposes. I begin this chapter with a brief clarification of the terminology used in this study, after which I move on to a discussion of the infrastructure for scholarly work, particularly as it relates to data reuse. Infrastructure is an important part of the environment governing the work of social worlds: it consists of a collection of resources and the social organization that directs their access and use, as I discuss below. As researchers within a discipline and systems designers develop infrastructure for data reuse, they build assumptions about the data at hand and users' research practices into those systems, making an understanding of a range of data uses important.

I continue the chapter with a discussion of a particular aspect of the infrastructure for scholarly research: its social nature. This discussion is a backdrop for the field-specific inquiry I undertake throughout the present work, which argues that norms within the fields of archaeology and botany are a major factor influencing the uses and meanings of data for its members. I give special attention to data reuse in these particular scholarly contexts. Next, I introduce museums as a particular type of information infrastructure, reviewing the literature on scholarly use of museum data and museum informatics.

Finally, I conclude with an argument for the present research into the conditions surrounding the scholarly use of museum data.

2.2 Terminology

Data reuse, secondary data use, and the term *data* itself have different meanings and implications in the various settings where they are used. The discipline in question and the kinds of research questions explored by its members, the ways in which they investigate those questions, and the specific practices of researchers influence the meanings of data and data reuse in practice. Data may consist of historical documents, laboratory notebooks, field notes, observational data, experimental parameters and results, specimens and other artifacts, or be in other formats depending on the norms of the field of inquiry (Borgman 2007). Because "[t]he unifying aspect of data has been in terms of its evidentiary role within the research process," a wide range of information resources may be considered data, even within a single discipline (Wynholds 2011 p. 218).

While data are often conceptualized as the output of research or observation, Hilgartner and Brandt-Rauf suggest a "data stream" model arguing that, "data should be conceptualized not as the end-products of research or even as isolated objects, but as part of an evolving data stream." They define data as, "information or other resources produced by or needed for scientific work," a definition which includes things like samples, equipment, techniques, protocols, algorithms, and instruments (Hilgartner and Brandt-Rauf 1994, p. 359). While this definition is quite expansive, it allows analysts to take into account the broad spectrum of resources used by members of research communities in the production of new knowledge. In the museum context, it also makes possible a conceptualization of data that can include museum objects, representations of the objects, including documentation of their origins and images and metadata describing them (held in a variety of paper-based and electronic systems), and information a researcher might derive from the object, including but not limited to measurements, samples, and qualitative assessments.

As I use three categories of museum data: object, representation, and metadata extensively throughout the study, I will briefly define them here. The museum object is often the central interest of researchers using museum data. In the Herbarium, the object is a botanical specimen preserved and presented in a specific way to enable research use. In the Kelsey Museum, researchers' focus is an artifact obtained by the museum through its excavations, purchases, or donations. Because they specialize in "ancient and medieval objects from the civilizations of the Mediterranean and the Near East," the objects collected by the museum largely fit this description (Kelsey Museum of Archaeology 2011c). The *object*, then, is the material that has been collected by the museum and is made available to researchers, and in an exhibiting museum (the Kelsey exhibits its collections to the public but the Herbarium does not) the object is usually the focal point of exhibitions. In this study I use the term object to refer generically to items owned by the two museums, and I use the terms specimen and artifact when referring to items at the Herbarium and the Kelsey, respectively.

The term *collection* is used frequently by participants in this study to refer to several things: the act of acquiring an object or objects through research (i.e. botanists "making a collection" of specimens); the entire corpus of objects owned by a museum (often administered with the use of a collection management system to track object metadata); some particular subset of objects with a shared quality, such as place of origin, object type, or collector (i.e. the Karanis collection at the Kelsey); and groups of documentation and representations managed by the two museums (i.e. collections of field notebooks at the Herbarium). While my participants used the term collection frequently, I limit my use to the first and second definitions: 1. the act of data collection as part of the research process and 2. the entire corpus of objects owned by a museum.

Representations of museum objects take many forms, and can have many audiences. In botany, for instance, the botanist documents where and when he or she finds a specimen, describing its growing conditions in their field notebook, which becomes an essential representation. The audience for a field notebook is the botanist him or herself, who records information in forms that they will understand for years to come. Botanists use information from their field notebooks to create a label, or to provide label data, for each specimen they give to a herbarium. Each subsequent representation, made by the herbarium or by future researchers in the form of notes, spreadsheets, photographs, database records, or academic papers, may add or remove information making each new representation unique in terms of audience, content, and purpose. Some representations of museum objects, such as botanical field notebooks or lists of archaeological finds, may have special status as *documentation*, recording the source from which an object was obtained. The relationships between representations, and their implications for research use, are an important consideration for the present work.

Metadata is a specific type of representation I discuss throughout the study. *Metadata* associated with a museum object is, simply put, information about that object. It may include a description of its physical attributes, origins, or other qualities of the object determined to be important by those who interact with it. Descriptive metadata allows users to interact with museum objects through their representations, whether these are catalog entries, databases, exhibition catalogs, labels, or other resources. Metadata also enables sorting based on attributes deemed important by the creators of those representations. Metadata about an object may be assigned by an object's original collector, museum staff, or by users through the course of their interactions with objects. In this study I am particularly interested in user-created metadata and the various circumstances under which it is or is not incorporated by the museum in its own representations.

Taken together, the museum object and various representations of that object, including metadata, form the basis of what I am calling *museum data*, the range of museum resources that researchers make use of in their work. In my interviews with museum staff and researchers, I often used the term "museum materials" to refer to data held by museums, in acknowledgement of the variation among disciplines regarding whether they identify the information sources they use as "data" (e.g. Fear 2011). I discuss this concern in the upcoming Methodology chapter.

From Zimmerman I borrow the terms s*econdary data use* and *data reuse* to describe, "the use of data collected for one purpose to study a new problem" (Zimmerman 2003, p.7). Data reuse is central to this discussion of museum resources. Along with a number of other data-focused activities including data creation, analysis, description, and management, I include it in the term *data practices,* which I use to refer to the interactions data collectors, users, and intermediaries have with data, mediated through social relationships and technical systems.

Another important scoping concern is my use of the term *researcher*. I use this term broadly to refer to people who conduct studies within a specific field of inquiry, which they then present to their peers in that field, primarily through publication. Researchers may be associated with various institutions, including academia, industry, government, or the non-profit sector; however, they share the goal of conducting original research to create new knowledge that is distributed to other members of their field. Data practices vary along with the norms of disciplines and fields, and it is the researcher's work in furthering understanding within a particular discipline and field that is of primary interest here.

The *infrastructure* within which their activity takes place is a crucial aspect of the work of communities of practice. Leigh Star and Karen Ruhleder (1996) describe infrastructure as technology in relation to organized practices. Infrastructure is *embedded* in other structures, social arrangements as well as technologies; *transparently* supports those practices; has a *reach or scope* beyond a single event or site; is *learned as a part of membership* and taken for granted by members of the community of practice for which it functions as infrastructure. Infrastructure *embodies standards* that allow it to function with other technologies, becoming transparent to community members; it is *built on an installed base*, inheriting characteristics from the technological and social arrangements that precede it; and it *becomes visible upon breakdown*, when it does not work as it should and the community's practices must adapt to that breakdown (Star and Ruhleder 1996, 113). *Organizing work* is performed as part of the daily activity of those who develop and manage infrastructure (Ribes and Finholt 2009).

Importantly, infrastructure is composed of myriad technical and social factors. For example, a museum's online catalog of its holdings is dependent on electricity to run, computer hardware and software to store and render the database, people who create and manage content for the site, a range of standards for encoding and transmitting electronic data, and organizational decisions about what content will be featured, and in what fashion, to name only a few aspects of the relevant infrastructure. The information infrastructure of a scholarly field may include journals, conferences, funding agencies, information repositories, universities and academic departments, email, telephone, and other communication tools, and a plethora of other resources, including museum objects and metadata standards to share information about objects. With this brief discussion of terminology, I now turn to a review of the literature relating museums and data to the research infrastructure of academic disciplines, including archaeology and botany.

2.3 Museums as Information Infrastructure

Hedstrom and King (2006) argue that museums, along with libraries and archives, have an important historical role as epistemic infrastructure, helping people create knowledge about the world. They explain that Renaissance-era private collections of objects, known as cabinets of curiosity or *Wunderkammern,* created a culture in which "collecting became a form of inquiry: a means of creating a didactic resource that initially made sense only to the collector but with organization and codification was transformed into a resource that could be shared among collectors and with inquisitive people to create a common knowledge" (Hedstrom and King 2006, p. 115). Cabinets of curiosity were formed by the individual tastes and interests of amateur or scholarly collectors, who might amass natural history objects along with artifacts from various human cultures and works of art, acquired through both their own collecting efforts and trade (Crane 2000). Through first-hand contact with objects, viewers of cabinets of curiosity were able to ascertain differences between objects, classifying them into groups and creating new understandings of their relationships. In this way, the precursors to museums served an important role as data aggregators and facilitators of data reuse at a time when few other institutions fulfilled this function. A number of these early museums also produced catalogs of the objects they held, spreading information about them over greater distances through these representations (Shelton 1994). Crane identifies a distinction among collectors that arose in the eighteenth century when the "*merely curious* collector began to be disparaged in opposition to the *connoisseur*. The distinction rested primarily on the amount of skill given to the study as well as the depth of the desire to learn as opposed to the desire to be reflected in the glory of the possessions" (Crane 2000, p. 69). At this early time, then, the value of these objects was tied to the learning that could be derived from them, not simply the amassing of objects.

Through the political upheaval of the French Revolution, Hooper-Greenhill (1989) describes the appearance of the public museum in France, where collections belonging to the aristocracy were claimed for the broader French populace. She attributes two functions to the public museum from its beginning, "that of the elite temple of the arts and that of a utilitarian instrument for democratic education" (Hooper-Greenhill 1989, p. 68). Museums showcased objects collected by the elite through exhibitions developed for the purpose of public education.

The eighteenth and nineteenth centuries saw the widespread development of public museums. As Bennett notes,

> The timing of these developments varied: what was accomplished in France, violently and dramatically, in the course of the Revolution was, elsewhere, more typically the product of a history of gradual and piecemeal reforms. Nevertheless, by roughly the mid-nineteenth century, the principles of the new form were everywhere apparent: everyone, at least in theory, was welcome. (Bennett 1995, p.95)

In tandem with this educational mission, museums were also sites of social reform, designed to "function as a space of emulation in which civilized forms of behavior might be learnt and thus diffused more widely through the social body" (Bennett 1995, p. 24).

Writing in 1895, George Brown Goode, in his influential book *Principles of Museum Administration*, defines the purpose of the museum with preservation of artifacts and education of the populace as central functions. "A Museum is an institution for the preservation of those objects which best illustrate the phenomena of nature and the works of man, and the utilization of these for the increase of knowledge and for the culture and enlightenment of the people" (Goode 1895, p. 3). Bennett reports that museum objects of this era were organized following this educational mission.

> Governed by the new principles of scientific taxonomy, the stress was placed on the observable differences between things rather than their hidden resemblances; the common or ordinary object, accorded a representative function, was accorded priority over the exotic or unusual; and things were arranged as parts of series rather than as unique items. (Bennett 1995, p. 96)

As museums entered the modern, era, however, they began to embrace an evolutionary view of collections, moving towards arrangements that emphasized historical relationships. These new arrangements were derived from the disciplines supported by museums.

> The birth of the museum is coincident with, and supplied a primary institutional condition for, the emergence of a new set of knowledges – geology, biology, archaeology, anthropology, history and art history – each of which, in its museological deployment, arranged objects as parts of evolutionary sequences (the history of the earth, of life, of man, and of civilization) which, in their interrelations, formed a totalizing order of things and peoples that was historicized through and through. (Bennett 1995, p. 96)

The dual function of museums, as preservers of objects and educators of people, has led to debates since the institution's early days about how best to achieve those goals. John Cotton Dana, an influential early writer in the museum field, called in 1917 for more accessible museums that were physically closer to the communities they served and collected materials that were more relevant to their audiences (Dana 2004). In more recent years, authors have called upon museums to transition from an emphasis on objects to an emphasis on users, "from being *about* something to being *for* somebody" (Weil 1999, p. 28). Finding more meaningful ways to connect with audiences has become a central theme in museological debate. From building mixed-use space into museums to promote activities and interactions traditionally outside the scope of museums (Gurian 2006) to emphasizing the experiential aspect of a museum visit (Hein 2000) to considering the visitor as an active participant in meaning-making (Falk and Dierking 2000), museums are increasingly concerned with becoming important resources for their users and communities.

A growing and changing infrastructure has influenced this conversation. A post-World War II prosperity boom in the United States was accompanied by a boom in the number of museums. Writing in 1998, Hudson stated, "Three-quarters of the museums we have today were not there in 1945" (Hudson 1998, p. 43). Government funding for museums did not increase at the same pace, however, leaving museums to rely on entrance fees and gift shop sales to cover a larger portion of operating costs, turning their attention to attracting visitors (Weil 2002).

The professionalization of museum staff largely began in the 1970s. Referring to museum professionals, Hudson wrote,

> Such people did not exist in the museum world until the 1970s. Before that time, those who worked in museums had found their way into their jobs largely by accident. They might have become teachers or craftsmen/artists or civil servants or, in some cases, university professors, but fate and an inclination towards the quiet life led them into museums. (Hudson 1998, p. 47)

Along with educational programs in museum theory and methods that emerged in the 1970s, organizations like the American Alliance of Museums (AAM, formerly the American Association of Museums) in the United States and the International Council of Museums (ICOM) internationally play an important role in determining the direction of museums. Founded in 1906, the AAM has been an accreditor of museums since 1971. Its accreditation guidelines have shifted over time, reflecting a changing focus from object care to education (Weil 2002). This emphasis is also clear in the periodic reports on the state of the museum sector in the United States published by AAM, including the influential *Museums For a New Century*, which emphasized visitor learning as a core function of the museum (American Association of Museums 1984).

Large organizations like AAM and ICOM are joined by smaller groups for specialists within museums, which help to advance museum practice. The Society for the Preservation of Natural History Collections (SPNHC), for example, brings together members to develop best practices for the care and digitization of natural history specimens (Society for the Preservation of Natural History Collections 2010). In archaeology, the Society for Museum Archaeology in the United Kingdom promotes "museum involvement in all aspects of archaeology and emphasizes the unique contribution of museums to the essential unity of the archaeological profession" through an annual conference, publications, and lobbying within the archaeological arena (Society for Museum Archaeology 2013).

Within this context, university museums in the United States (like the two sites examined in this study) face somewhat different pressures with somewhat different resources than the public museums discussed earlier in this chapter. Whereas public museums rely directly on government and visitor derived funding for their operation, university museums rely on institutional funding (much of it from government sources) allocated through departmental and organizational relationships. Museum collections may be vulnerable during difficult economic times (King 2012; Novacek 1990).

> University collections, particularly art collections, are increasingly being viewed as disposable and coveted assets by parent organizations desperate to shore up faltering endowment funds or to fill budget gaps caused by reduced funding from states. Even those university museums that have worked hard to ensure that their parent college or university views them as an essential part of the academic enterprise may face threats when severe economic crises hit. (King 2012)

University museums also have a different audience than public museums. They are responsible to their academic community: faculty, staff, and students of the university itself, and often, a local museum-going public as well. Ensuring that they are an active part of the university, as a participant in its research, teaching, and cultural life, is important to these museums' success.

With this brief introduction to museums as participants in scholarly information infrastructure, I turn now to the topic of data sharing and its relationship to information infrastructure. Then, after a discussion of data use and reuse in botany and archaeology, the two disciplines examined in this study, I return to museums and their role in these processes.

2.4 Data Sharing and Information Infrastructure

While physical museum collections remain important data sources for researchers, a good deal of discovery and reuse of data now takes place online. A confluence of several social and technological factors has caused a heightened interest in online data sharing in a number of disciplines. Because of computational advances, there are greater possibilities for combining and analyzing data from prior studies in many fields (Hey et al. 2009). With growing possibilities in data reuse, there has also been a growth in resources for data sharing, like online databases and repositories built for specific communities of researchers, including botany and archeology (see, for example, Open Context, an online repository for archaeological data and the Global Biodiversity Information Facility, GBIF, which offers occurrence data for plant and animal species throughout the world). There have also been growing expectations for data sharing in many fields, particularly the sciences, where several major government funding agencies now require applicants to submit data management plans (e.g. National Institutes of Health 2003; National Science Foundation 2009).

These social and technical factors have led to the current movement in a number of disciplines to build the infrastructure to share digital data. In the United States, the predominant conceptualization of developing the infrastructure for online data production and sharing is known as *cyberinfrastructure*, while in Europe it is frequently called eScience. Cyberinfrastructure consists of “hardware, software, personnel, services and organizations” (Atkins et al. 2003, p. 13), specifically “those layers that sit between base technology (a computer science concern) and discipline-specific science” (Edwards et al. 2007, p. 5). While cyberinfrastructure supporting the sciences is advancing rapidly, interest in cyberinfrastructure for the social sciences and humanities is also prevalent, and growing, in those fields (American Council of Learned Societies 2006).

The vision for cyberinfrastructure systems includes access to large-scale computational resources, tools for research collaboration as well as data deposit and analysis, and complex social structures of people who contribute to, use, and manage them. The central issues in cyberinfrastructure creation are not simply technical (Edwards et al. 2007). “Advanced cyberinfrastructure offers the potential to conduct new types of research in new ways. Doing this effectively requires holistic attention to mission, organization, processes, and technology” (Atkins et al. 2003, p. 15). Not only must data and software be interoperable, but cyberinfrastructure resources must also be compatible with the work processes and norms of the disciplines they serve. Cyberinfrastructure “should provide an effective and efficient platform for the empowerment of specific communities of researchers to innovate and eventually revolutionize what they do, how they do it, and who participates” (Atkins et al. 2003, p. 5).

Cyberinfrastructure is most developed for the types of research carried out in the sciences, where widespread factors like long-distance collaboration, expensive equipment, and computationally intensive techniques have favored the development of tools and systems for sharing resources and minimizing redundancy. Similar systems for the qualitative social sciences and the humanities have taken longer to develop, due in part to different knowledge creation practices in these fields, leading to different infrastructural needs. As the American Council of Learned Societies reported, in their comparison of cyberinfrastructure needs in various fields,

> Humanities scholars and social scientists will require similar facilities but, obviously, not exactly the same ones: 'grids of computational centers' are needed in the humanities and social sciences, but they will have to be staffed with different kinds of subject-area experts; comprehensive and well-curated libraries of digital objects will certainly be needed, but the objects themselves will be different from those used in the sciences; software toolkits for projects involving data-mining and data-visualization could be shared across the sciences, humanities, and social sciences, but only up to the point where the nature of the data begins to shape the nature of the tools. (ACLS 2006, p. 8)

Thus, while some of the advances made by cyberinfrastructure projects in the sciences are applicable to the social sciences and humanities, others need to be developed anew.

Museum data are an important part of the cyberinfrastructure of a number of fields, housing data geared towards the research needs of a community of practice (Bowker 2000; Van House 2002a). Metadata about museum objects has been recorded and stored in a number of formats over time, including ledger books, field notebooks, card catalogs, file folders, and photographs. Since the 1960s, databases have been a growing resource for object metadata, providing contextual information about objects themselves (Burton-Jones 2008). Through networked databases a broad public, including scholarly researchers, has gained greater access to information about museum objects.

Researchers can often access museum data through aggregation services that pool data from a variety of sources, including institutions and individual researchers. Botanists use a number of online resources for data sharing, including the Global Biodiversity Information Facility (GBIF)[1] and iDigBio,[2] aggregators of biodiversity data, and the JSTOR Global Plants resource,[3] which includes high-resolution scans of botanical specimens. Herbarium and museum data comprise a significant part of these resources. Those who work with gene sequences use GenBank,[4] both to submit the sequences they discover and to analyze genetic data sequenced by others.

Through grants from organizations like the National Science Foundation in the United States, botanists working at herbaria have created a number of databases focusing on specific kinds of plants. For the University of Michigan Herbarium, these include a

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[1] http://www.gbif.org/
[2] https://www.idigbio.org/
[3] http://plants.jstor.org/
[4] http://www.ncbi.nlm.nih.gov/genbank/

database of the plant family *malpighiaceae*, the research area of its three collaborators, two curators at the University of Michigan and one at Harvard University (Anderson et al. 2006), and a database called "Seed Plants and Bryophytes of Mexico, Central America, and the West Indies" (University of Michigan Herbarium 2011b). In addition, botanists at the University of Michigan Herbarium are involved in ongoing collaborative, multi-institutional projects to create high-quality digital scans of the type specimens held at Michigan and other herbaria. I will examine many of these projects in greater detail in my discussion of the relationship between museum objects and the databases describing them in chapter four.

In anthropology, several digital data repositories have emerged that provide access to data from a number of resources, focusing on material obtained through archaeological fieldwork. In the United States, the Digital Archaeological Record (tDAR)[5] and Open Context[6] are two resources offering access to digital archaeological data including object records and images, site descriptions, and excavation details created by researchers in this country. For the most part, data held by these repositories comes from researchers rather than museums. Yet, archaeology museums are a source of data, particularly artifacts and documentation of excavations done in the past. The relationship between the University of Michigan Herbarium, the Kelsey Museum, and data aggregators, will be discussed in the respective chapters analyzing data practices in those museums.

2.4.1 Infrastructure and Standardization

The standards-embodying property of infrastructure is particularly relevant to discussions of data reuse. Datasets shared between their creators and secondary users often embody common standards which help them transition from one context to another. Standards relevant to data reuse include data structure, data content, and data value standards.

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[5] http://www.tdar.org/
[6] http://opencontext.org/

Standardization of a shared dataset has been quite successful in the case of the Human Genome Project, in which Fujimura and Fortun (1996) argue that shared standards (including the letters that make up representations of genetic code) mask the "complexities, uncertainties, and guesses of the work that produces the 'phenomenon' under study" (Fujimura and Fortun 1996, p. 168). As Star and Ruhleder (1996) note, participation in this infrastructure requires a standardization of data, so that different pieces of information are commensurate within the system, and can be treated alike despite their differences. The standardized methods of extracting genetic sequences, requiring specialized equipment, as well as the standardized way of representing those sequences, using a limited group of alphabetic letters, no doubt contribute to the relative ease of standardization in this case. GenBank, another database for deposit and retrieval of genetic code, similarly relies on a number of standards to make its materials usable by a broad range of biologists. Scientific name and taxonomy of the organism sequenced, "coding regions and their protein translations, transcription units, repeat regions, and sites of mutations or modifications" are all required of sequence depositors, combining standard methods of describing genetic code with a taxonomic standard used more broadly (Benson et al 2003).

Data standardization, even within a given field, however, is not as widespread as the Human Genome Project and GenBank examples might seem to indicate. Shankar's (2007) ethnography of an academic biology laboratory examines the recordkeeping practices of its members, finding a wide range of non-standardized practices. She characterizes the personalized forms of recordkeeping developed by members as creative acts, where each individual formalizes his or her records by creating their own system for recording information, tracking the same kinds of details about each experiment in the same format. Each scientist brings his or her own loose form of standardization to their data, but these practices are not shared within the larger group (Shankar 2007). Similarly, in studying a small academic materials science lab, Akmon et al. (2011) report that the lab director was hesitant to create data recording and management standards for her graduate students, leaving each scientist to document and manage their own data as he or she deemed best. Although their data ultimately belonged to the lab and its director, lab members' specific research questions, the purposes for which data were being collected, and their individual record keeping styles took precedence over data reuse concerns. Kervin et al. (2012) found that members of small lab groups learn data management practices from the practices modeled by the lab group head. New members learn data management and sharing practices largely by following others in the lab group. While practices are shared between lab members to a greater or lesser extent in different laboratory contexts, they do not necessarily have training in or follow standards and best practices for data sharing within a field (Tenopir et al. 2011).

Some differences between these examples may be attributable to the different scales of practice in the research communities. Fujimura and Fortun's example profiled a large, international effort involving researchers from a number of institutions with varying resources while Shankar described a single lab. In the former case, researchers contributed to a very large dataset in a centralized project, while in the latter case, practice was much more localized to a particular group of biologists. The two groups required entirely different levels of standardization in order to do their work, and the degree of standardization they used varied accordingly.

Differences in the standardization of museum data may follow similar patterns. In cases where museums contribute their object metadata to a consortium of museums or other data sources, we might expect to see a greater amount of standardization of data due to a need for interoperability (Rinehart and White 2008). Museum data standardization follows norms within a community of practice, so that resources like the Getty Research Institute's Art & Architecture Thesaurus, for example, are used widely by a variety of types of museums (including art history, anthropology, and archaeology) as a controlled vocabulary for the description of objects (Getty Research Institute 2011). With biological specimens, Darwin Core is a common standard for the description of objects, including a glossary of taxonomic terms.[7] These shared standards make aggregation of data easier while improving search and retrieval within and between systems.

Standardization of data within a museum can also be achieved through the standardization of practice among data collectors. Star and Griesemer's (1989) discussion of the Museum of Vertebrate Zoology at the University of California,

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[7] http://rs.tdwg.org/dwc/

Berkeley uses a historical case study approach to understand the coordination of work of people from a number of different social worlds in the development of the museum's collection. Collectors of specimens for the museum included animal trappers, amateur naturalists, and professional biologists, each with their own uses for their specimens and different ideas about collecting practices. The collecting work of these disparate groups was made cohesive through the standardization of practices for collecting specimens and documenting information about them. Without common modes of description, labeling, and preservation of specimens, their scientific value to researchers would be minimal. These different types of collectors were convinced to follow procedures that would make the specimens and their metadata amenable to research use, while not requiring too much of amateurs, who participated in specimen collecting for their own hobbyist purposes. The museum enabled standardization by giving collectors methods for obtaining and documenting museum objects, including printed forms asking for specific information about specimens gathered.

Star and Griesemer use the term *boundary object* to refer to things like procedures and forms used by members of various social worlds (biologists, amateur collectors, and animal trappers, in this case) to coordinate their work. Procedures and forms can be shared by members of these various groups, standardizing their work so that comparable representations can be made, while still permitting members to meet their individual goals. In his later study of recordkeeping processes at the same museum, Ilerbaig comments, "By institutionalizing stringent record creation standards, the MVZ itself would become that ideal researcher whose lifespan would be commensurate with the timescale of its object of study" (Ilerberg 2010, p. 474). In other words, standardization of records makes long-term storage and access to the museum's memory possible. As various stakeholders access records, "people from different worlds can use or borrow from the 'pile' for their own purposes without having directly to negotiate differences in purpose" (Star and Griesemer 1989, p. 410). Within several research social worlds, including botany and archaeology, guidelines have emerged for data description in order to promote interoperability of data sets and to encourage best practices. I will discuss these in the later sections on these social worlds and their norms for data creation, description, and management.

One interesting example of a boundary object relevant to museums is the object catalog, which, when made public, acts as a search and retrieval system for researchers and other users while serving as a tool for museum staff to manage information about the objects (Bearman 2008; Knell 2003). While providing an outward facing tool to access object metadata, public catalogs generally reflect a portion of larger collections management systems maintained by and accessible only to staff. The collections management system operates as important infrastructure, capturing complex data about objects held by the museum. In addition to information about a museum object such as its creation date and place, material composition, and physical description, these databases record information about conservation treatments, exhibition histories, loans, and insurance valuation, among other types of metadata generally not made publicly accessible. In addition, sensitive information, such as the location of active archeological sites or endangered species, often remains hidden from the public although it is recorded in these systems (Trant 2008). Differences in information made accessible to researchers and to staff will be an important part of the present study, explored in upcoming chapters presenting the management histories of these two collections.

2.5 Museum Data: The Object

At the heart of museum data is the object: an artifact or specimen accessioned by the museum into its collection, interpreted and represented by museum staff and researchers, and made accessible to various audiences through exhibitions, object databases, and hands on access. The objects collected by archaeology museums and herbaria, the two types of museums examined in this study, are different in nature. Botanical specimens are samples of plant life collected in the course of fieldwork and attached to metadata (including a species identification and information about the circumstances of collection) through a collector number, all of which are recorded by the botanist in a field notebook. Archaeological museums collect artifacts of past human activity, as well as the documentation that provides context for those artifacts (whether excavation records or records of ownership). I discuss both kinds of objects in detail in the upcoming sections on archaeological and botanical social worlds and data.

Here, however, I deal more generally with the use of objects as sources of evidence. Pearce (1992) has argued that the "materiality of objects and the physicality of their anchorage in time and space gives them some special characteristics: […] their social life; their power of physical survival which gives them a unique relationship to past events that moves curators and others to call them 'the real thing'; and their particular susceptibility to possession and valuation" (Pearce 1992, p. 17). These characteristics permit interpretations of objects based on their origins, use, history, and physical attributes.

Through their physicality, objects bear traces of the meanings attributed to them. "If the meaning so constructed is a secondary or later meaning, earlier meanings still remain as traces [...] Earlier meanings or events may even be marked on the object itself in the form of erosions, surface patina, or evidence of damage. Earlier meanings may, therefore, still be dug up, evoked, made visible" (Hooper-Greenhill 2000, p. 50). However, an understanding of an object's meaning is constructed by the viewer, who brings their own interpretive framework to bear on their cognitive and affective engagement with objects (Hooper-Greenhill 2000). An individual's social world membership is a powerful factor shaping the interpretive framework they bring to understanding objects.

Prown (1994) has proposed a general methodology for learning from material culture. He suggests that analysts begin by creating a description of the object in question, move on to deduction about the object, and finish with speculation about the object. Each of these stages is comprised of multiple steps moving the process from one that is mainly object-based to one that is mainly analyst-based. Through this method, he hopes to bring a level of objectivity to the subjective process of learning the meaning of an object. The process begins with measurements of the object, using tools like rulers and scales to learn the basic properties of the item in question. This physical description becomes more detailed and complex as the analyst moves to an investigation of the substance of the object, its content, and its form. In the deduction stage, the analyst brings him or herself into the process to a greater extent, by imagining the interactions he or she might have with the object. This includes sensory, intellectual, and emotional engagement. During the speculation stage, the analyst creates hypotheses about the object and proposes a plan of research to test those hypotheses. For Prown, following these steps in order can help the analyst move in a structured way from objective to subjective information gathering. While he acknowledges the difficulty of performing these steps separately, he believes their separation makes the process and the analyst's findings more reliable.

In an approach more situated in the observer's relationship to museum objects, Taborsky argues that there are three primary meanings of a museum object, identified by three "namers." Each of these namers is socially situated in the circumstances surrounding their interaction with the object, so that their interpretation is not solely individual, yet each interpretation is equally valid. She calls these individuals the original namer, who first created and used the object; the curatorial namer, who defines the object within the museum; and the visitor namer, who defines it in relationship to their own life and society. Taborsky argues that the interpretations created through a person's interaction with an object "are each valid, within their different societies," (Taborsky 1990, p. 67). A researcher external to the museum can be seen as a type of "visitor namer," who brings a degree of subject expertise to their interpretations.

Given the centrality of the object to museums and the rising propensity of museums to create digital surrogates (one of many forms of representations) of objects we can ask how users perceive the differences between museum objects and their surrogates. Theorists like Benjamin (1970) have argued that the mechanical reproduction of objects removes the element of authenticity from our interactions with the object represented. This idea is echoed in more recent claims that "the real object has a special psychological standing that the digital doesn't have, as primary evidence" (Hooper-Greenhill 2000, p. 114). While digital surrogates are carefully constructed to capture the evidential qualities of objects, they serve to increase the value of the objects themselves:

> [T]he museum object tends to take on a new meaning of ''real,'' a new objective stance even though we know what objects really are, embedded with cultural, disciplinary meanings, and values. This is because objects are viewed within this new space in which ''real'' means material—the physical presence of things as opposed to the illusion, the virtual. The materiality of an object is seen as having a more objective presence than the virtual due to its ascribed connection with a historical or aesthetic actuality. (Cameron 2007, p. 58)

The relationship of museum objects, digital surrogates, and other forms of representation to the evaluation and use of data by researchers is addressed in this study.

2.5.1 Museum Data: Representations

Museums create representations of objects as a normal part of workflow, to permit access to information about objects without requiring physical access to the objects themselves. However, a loss of information is inherent in any representation of a museum object, from photographs and drawings to descriptions and metadata (Buckland 1991). Some information that can be gained through hands-on interaction with an object, such as texture, weight, and fine distinctions in color, is difficult to capture in digital representations, but hands-on interaction with museum objects is not regularly offered to most users due to preservation considerations. Museum staff members make choices when creating a digital representation of a museum object that will have ramifications for future use, and those anticipated future uses will determine the kinds of representations they create (Knell 2003; Hamma 2004). As Knell (2003) describes, creating a representation of a museum object requires determining its essential characteristics, which staff members identify largely by considering the anticipated audience and uses for the representation:

> In the museum, the real object is capable of being an archival resource, a site of meaning making, a component in an educational programme, primary data in a research project and so on. But museums tend to select different objects for different jobs; a tattered item of costume might present a researcher with critical clues to an aspect of textile history but will never form an exhibit. The question, then, is how should the object be digitised to preserve its essential characteristics? When we digitise a 1960s miniskirt do we invest in high resolution capture of lining, buttons and zip or just capture an overview? The answer to these questions lies in intended use: if for research then the answer is 'yes', if for display then 'no.' (p. 138)

As museums are increasingly expected to make digital representations of their collections interactive and interesting for visitors ("for display" in Knell's terms), following the educational and entertainment missions of the museum (European Commission 2002), the competing needs of researchers (digitization "for research") may receive less attention and fewer resources. Hamma states, "No one has ever expected scholars to be happy with the label next to an object in the gallery. They have had and always will have access to files, publications, correspondence, etc." (Hamma 2004, p. 8). The expectation is that researchers will interact more deeply with a wider range of information resources about museum objects than casual visitors. The digital representation of museum objects need not account for these complex information needs, since researchers will have broader access to information about the object (often including physical access to the object itself) than the majority of museum users.

Complicating the notion of museum digitization for research or for display is the growing expectation that museum data be amenable to reuse and repurposing. Data reusability and interoperability are emphasized in the best practices for digitization from the National Information Standards Organization (NISO) written with support from the Institute for Museum and Library Services (IMLS). The NISO guidelines note that while earlier digital collections were considered successful if they met the needs of a particular community of practice, cultural heritage organizations should follow standards and best practices to make collections useful beyond the confines of a specific project.

> Digital collection development has now evolved and matured to a third stage, where simply serving useful digital collections effectively to a known constituency is not sufficient. Issues of cost/value, sustainability, and trust have emerged as critical success criteria for good digital collections. Objects, metadata, and collections must now be viewed not only within the context of the projects that created them, but as building blocks that others can reuse, repackage, repurpose, and build services upon. "Goodness" now demands interoperability, reusability, persistence, verification, documentation, and support for intellectual property rights. (National Information Standards Organization 2007, p.1)

These growing expectations for interoperability and reusability in digital collections may influence the norms and practices of museum staff as they work with objects.

Metadata standards for the organization and description of objects are an important aspect of museum information infrastructure. They tend to vary by museum type. For example, an art museum may follow conventions such as use of the data content standard Cataloging Cultural Objects for description of collections (Visual Resources Association 2006) based on best practices among art museums, while a natural history museum might describe parts of its collection in various ways that are chosen for their compatibility with the disciplinary norms of various communities of researchers using its collection (Callery 2002). The data description standard Darwin Core mentioned above is one such example. By describing specimens using the Darwin Core standard, museums can enhance the usability of their specimen data. Understanding the standards used in collection description and the reasons behind their adoption is an important aspect to learning about changes in museum representation over time. I discuss the standards adopted by the two museums and the reasons for those selections in chapter four, which deals with the representations of objects created by museum staff.

Museum collections management systems have changed from card catalogs, ledgers, and file systems, to databases that reflect both the ability to handle complex data in a single system and the museum's changing data management practices over time (Callery 2002). A collections management system can help coordinate work for staff from a number of departments, acting both as a boundary object within that institution that coordinates information related to the separate work of many museum departments and as a form of organizational memory for the museum, ensuring that important information related to objects is not lost due to staff turnover (Argote 1999). Given the long life spans of some museum collections (the Ashmolean Museum at Oxford University, for instance, was founded in the 17^{th} century and is still active today), staff members' knowledge about collections over time is an important asset to museums. Organizational memory held by members and embedded in the technologies and routines used in a museum are relatively short-lived when compared to the time span of a museum collection. Staff members rely on stable systems for the management of metadata about objects as an essential component of museum information infrastructure.

The same collections management system may be used by staff members throughout the organization who function as readers or editors of content, entering information as appropriate to their area of expertise and responsibility (e.g., conservation, exhibition history, etc.) (Trant 2008). Gilliland-Swetland and White (2004) highlight the changing nature of museum information, showing that metadata about a museum object may change over time as a result of input from a large number of sources including curators, registrars, and researchers. Aspects of an object, such as date of creation or provenance, can accumulate and change over time as more information becomes clear to staff or as interpretations (or taxonomic classifications, in the case of botany) change. Choosing how to represent this fluidity is an important part of infrastructure building for museum data (Gilliland-Swetland and White 2004). In botanical collections, for example, the species name given to an individual specimen may change several times while owned by a herbarium, as experts on that species consult a specimen and now run increasingly sophisticated genetic tests on the specimen leading to an update of its identification (Research Information Network 2009). Individual herbaria must decide whether to provide a history of determinations to database users or simply the most recent accepted name. An upcoming findings chapter discusses how these decisions have an influence on the use of specimen data by researchers.

A broad range of people update and refer to collections information systems. Instead of data entry taking place solely with registrars when new objects are acquired, conservators may use the systems to record treatments and curators may use them to keep track of exhibits in which they appeared and the labels used to describe the objects (Gilliland-Swetland and White 2004). Varying amounts of these different kinds of object data are increasingly available to visitors and end users through websites and information kiosks within museums (Coburn and Baca 2004).

2.6 Norms and Practices in Research Social Worlds

Given the above discussion of museum practices for the representation of objects, I turn now to another aspect of the museum research infrastructure, the contexts of scholarly data use in research communities. Like museums, research communities create and use information infrastructure to meet their particular needs. In this section, I review the function of norms within scholarly disciplines in determining how evidence is used in those fields. These processes are socially situated and learned through participation by members of communities of practice (Lave and Wenger 1991).

The field of science and technology studies (STS) has looked extensively at norms for data creation and use in the formation of knowledge claims. The overarching perspective on data practices within this literature is that the uses of data accepted by different scholarly fields, including what counts as data and how they are analyzed, are established and enacted through complex social processes within a discipline (Collins 1998; Knorr Cetina 1999; Hacking 1992 and 1996).

For Knorr Cetina, research group norms and practices sit within the framework of what she calls *epistemic cultures*: "those amalgams of arrangements and mechanisms – bonded through affinity, necessity, and historical coincidence, which, in a given field, *make up how we know what we know*" (Knorr Cetina 1999, p. 1, italics in the original). Knorr Cetina explores and compares the practices that shape knowledge production in high-energy physics and molecular biology, identifying three primary kinds of scientific work with different modes of creating data. The *simulation mode* uses a "*technology of correspondence*" in which the simulation is intended to correspond with events outside the laboratory. In the *experimental mode,* materials are processed in the lab in order to change their state in a "*technology of intervention*" (Knorr Cetina 1999, p. 37). In the third case, "*objects are signs*" for researchers, as in particle physics, where particle traces are detected and analyzed to attach them to "underlying causal events" (Knorr Cetina 1999, p. 39-40). The secondary use of museum objects and data aligns well with this final category, in which data are analyzed as objects signifying events; however, when museum data are used in simulation or experimentation, the picture becomes complicated. A biodiversity researcher using species occurrence records derived from museum specimens, for example, may be building or validating a model or simulation of the changes in species habitat over time. The occurrence records are valuable in this work because they operate as signs of the geographic range of a species at particular points in time, but the researcher uses them in a technology of correspondence, to create an understanding of their future range through simulation. The researcher analyzing the DNA of a herbarium specimen is involved in a technology of intervention, removing a piece of the specimen and changing its state to produce a string of DNA code. At the core of these uses however, is the persistence of objects as signs, of a particular object with a specific provenance that attaches the object to an event- the act of its collection.

Beyond epistemic culture, other more local factors influence the use of data by researchers. *Evidential culture* is a term Collins (1998) offers to describe the norms and beliefs a researcher or research team may have about the use of evidence. There are three dimensions of evidential culture. First, the spectrum from evidential individualism to evidential collectivism describes the degree to which researchers "believe that it is the job of the individual or individual laboratory to take responsibility for the validity and meaning of scientific results" as opposed to believing "that it is the job of the scientific collective to assess results from an early stage" (Collins 1998, p. 302). Where evidential collectivists might be willing to publish results that have a relatively unclear meaning in order to spark discussion in their community, evidential individualists would feel that results should have a clear meaning that can be explained in a publication. The second dimension, evidential significance, involves the statements researchers make based on their data and the interpretive risk they are willing to take with their findings. Claiming that observations are evidence of a particular phenomenon rather than simply observations is a claim for the evidential significance of one's data. Finally, evidential threshold concerns the amount of statistical risk a researcher is willing to take. This is largely determined by the standards of a journal or a field, which specifies the probability required to make findings statistically significant. Together, these factors account for many of the decisions researchers make as to whether to publish and how to portray their findings. By singling out evidential culture as a topic for analysis, Collins identifies an important way in which members of the same field may have different conceptualizations of the meaning, use, and value of particular data. Aspects of culture at other levels than the field may come into play as researchers assign meaning to data, aligning with research social worlds. While the qualities that characterize epistemic and evidential cultures may be drastically different between fields, these structuring factors for the researchers examined in this present study make them important topics for consideration.

Epistemic and evidential cultures are aspects of the information infrastructure in any discipline. They help individuals follow norms for what can be considered data and findings in their field, which in turn structure their interactions with information through the processes of data collection, description, and analysis. In interactions with museum information, these cultural elements come to bear first on the collection and description of objects as "data" by their original accumulators in their role as excavators or collectors, then on the work of museum staff to represent collections, and later on the selection of data and the uses to which they will be put by secondary users. The credibility of museum objects as data, determined by researchers in part through interactions with their metadata and other representations, is an important factor in their selection for new analysis.

2.6.1 Data Creation: Inscription

Latour and Woolgar (1986) use the term *inscription* to describe the practices of data collection and data reduction in their study of a biomedical laboratory. Inscription is a process by which data are made increasingly more amenable to the researcher's purposes. The laboratory members use resources like equipment ("inscription devices") to "transform matter into written documents" for data collection. The documents become the focus of attention rather than the matter from which they were created, which may be disposed of once that transformation has taken place. A document, such as an array of numbers, is eventually (perhaps after several intervening inscriptions) transformed into an inscription like a graph or a curve that is used as evidence to support a claim in a scientific paper. Each new inscription is "regarded as having a direct relationship to 'the original substance'" so that these transformations can be considered accurate representations (Latour and Woolgar 1986, p.51). The role of these transformations is to create order out of disorder as lab members choose "selectively to eliminate material from the mass of accumulated data" (Latour and Woolgar 1986, p.246).

With inscriptions, Latour and Woolgar provide a powerful model for understanding the creation and transformation of data. Their model can also be fruitfully applied to the representations of objects created by museum professionals. Curators, collection managers, and other museum staff capture information about artifacts based on a number of criteria that have already been established. By collecting the same kinds of metadata (such as creation date and place of origin) about a great number of objects, the museum makes these objects comparable with each other, normalizing them on the basis of these attributes. The process of deriving and recording information from museum objects in the course of research also creates inscriptions. The researcher selects attributes of the object that are relevant to their immediate research questions and goals and records that information as their research data. The boundaries between museum-created and researcher-created inscriptions are an important site of inquiry for this study, as museum staff identify researcher inscriptions as suitable or unsuitable for inclusion as part of the museum's representations of its collections.

While drawn from the field of Science and Technology Studies, I contend that the concepts presented in these studies of the function of data in scientific communities have broad applications outside of the sciences. The norms within an epistemic community delineate what constitutes data for members, as well as the ways in which data can be recorded, interpreted, and marshaled as evidence by researchers. The processes of data reduction through a series of inscriptions and the interpretation of those inscriptions explain the creation of data and ways in which data are used to form evidence. While the specific manifestations of epistemic and evidential cultures and the forms in which data are inscribed and interpreted can be expected to vary between communities of practice, these elements of knowledge formation are likely to be present across research communities.

2.6.2 Selecting Data for Reuse

The norms for data creation and knowledge claim formation in a given discipline are also relevant to the selection of data for reuse. At the end of this chapter, I explore these issues in the specific contexts of archaeological and botanical research. Here I discuss the concerns of data reusers as they chose data to reuse in their own research. A number of recent publications have explored how researchers select data for reuse. The major themes to emerge from this work are the secondary user's expertise and experience with methods (Zimmerman 2003, 2008; Knorr Cetina 1999); trust in data collectors (Van House 2002a, 2002b); and the availability of contextual information about the data (Faniel and Yakel 2011).

In her work on the techniques used by researchers for evaluating data created by others, Zimmerman (2003, 2007) finds that her ecologist-informants relied on their own knowledge of the data collection process in the course of data reuse, selecting data similar to those with which they were already familiar through their own experiences. Their professional experience and knowledge also helped them identify potential data sources. Zimmerman also identifies several factors that are central to the decision to use data created by other ecologists. First and foremost, the researcher must be able to understand the data -- particularly how they were created. This relies on the researcher's own experience collecting data and his or her ability to visualize the data collection methods used. Zuboff (1988) terms these abilities 'intellective skills,' which are "used to construct appropriate linkages between a symbol and the reality it means to convey" (p.

79). The knowledge a researcher gained from his or her own data collection experience was essential in the *reconstruction* of a data set, a term Zimmerman uses to refer to "all the processes ecologists employ to mentally reassemble the original collection of the data they seek to reuse" (Zimmerman 2003, p. 136). Opinions of the data collector's expertise and abilities, based largely on his or her reputation, were another factor in judging data quality, particularly in cases when "data are difficult to collect or tolerance for data uncertainty is low" (Zimmerman 2008, p. 646). Opinions based on contextual information about data collectors and their methods were crucial in determining the trustworthiness of data, implying that access to this kind of contextual information would be essential for these secondary users of data.

Similarly, in Knorr Cetina's analysis of physicists' practices, expertise gained through experience helps scientists know when data are trustworthy, to "discriminate plots that *are* correct from those that *look* correct" in the words of one of her informants. In this culture, experts are "those who have learned to engage with objects in reliable trust relationships and who, therefore, are trusted by colleagues who cannot engage in these relationships directly" (Knorr Cetina 1999, p. 135). The perceived expertise of individual data collectors is a proxy for trust, whether trust in the data set or the findings arrived at by researchers is required (Zimmerman 2003; Knorr Cetina 1999; Collins 2001).

An example of trust in using data gathered from a consortium illustrates the ways in which understanding the context of the creation of data is an important factor for establishing trust in that data. Van House's (2002a, 2002b) research on the CalFlora digital library, a repository for images and occurrence records tracking the presence of plants in different parts of California, addresses the trust issues that emerged in this community of amateur and professional contributors (which included museums). Data exchange that had taken place before the advent of CalFlora was on a person-to-person basis between researchers who shared a social network and were able to establish interpersonal trust, making data creators less wary of their data's misinterpretation and misuse by people with whom they shared it. Simultaneously, secondary data users were able to get information about the context in which data were captured directly from the person who collected them, increasing their trust in the data at hand. Once these exchanges were mediated by a database, trust became harder to establish. Van House describes trust as a "strategy of cognitive efficiency" which reduces the costs of verifying knowledge claims (Van House 2002a, p. 103). Trust is therefore an essential part of using information created by others, but is difficult to achieve, particularly in networked systems where interpersonal relationships between users may be limited or nonexistent.

Once the CalFlora collection became a prominent resource, users had to develop methods for deciding which data they could trust, because plant identifications can be difficult to make and are sometimes inaccurate. Trust in the data in this repository was often based on reputation, derived from users' knowledge of the background and abilities of the individuals who had contributed them. The factors that users took into account in establishing each other's credibility were "the skill of the observer, the observer's relationship to that which is observed (e.g., expertise in a particular taxon or geographical area), and his or her certainty in making this particular identification" (Van House 2002b, p. 236). Determining the credibility and expertise of data creators is a strategy also used by informants in several studies of data reuse (Zimmerman 2003; Zimmerman 2008; Van House et al. 1998). Clearly, indicators of expertise are used in many contexts to determine the credibility of people who are not known personally, but on whose judgment researchers rely. The CalFlora system helped users make these judgments by requiring that contributors create profiles detailing their background and relevant qualifications. By representing these aspects of an individual's experience, some of the trust lost when data sharing in this community became computer mediated could be regained.

> The qualities of the originator of information, then, are critical in assessing its credibility. This can be termed provenance: from where and from whom does the information come, and what do we know about the originators or guarantors? The question is not only whether we consider them competent, and honest, but 'virtuous'- whether or not they embody our values and view of the world and our standards for work. (Van House 2002a, p. 105)

Along with their knowledge of a data collector's reputation, secondary data users make use of other provenance information related to a data set as they assess its usability. In their study of proteomics researchers, Fear and Donaldson (2012) find that clear documentation of the experimental parameters and instrumentation used in the creation of a data set was essential information for reuse, and that a publication linked to a data set was an important resource for determining its authenticity. Writing as a group of archaeological specialists, Atici et al. (2012) reflect on their own reuse needs as zooarcheologists, finding that clear study documentation, detailed methodological background, and thorough contextual information are essential for reuse. The most important contextual elements are “time and place […] decoded data (or, at a minimum, use of a published code), and identification basics (taxon, element, portion, side, fusion, sex), as well as how identifications were derived (use of a physical reference collection, published studies used for determining age, etc.)” (Atici et al. 2012, p.8).

Yakel et al. (2013) examine the trustworthiness of a digital data repository itself as a factor in the data selection process. Their interviews with archaeologists and quantitative social scientists reveal that assurances of preservation and sustainability of data are of primary importance to archaeologists while social scientists emphasize institutional reputation. Archaeologists in particular value the transparency of a repository’s actions with regards to data, mentioning transparency twice as often as their quantitative social scientist counterparts. Trust, not only in a data set and its creator, but also in the repository offering data for reuse, is clearly an important factor in the selection process.

2.7 Research Use of Museum Data

This section reviews the secondary use of museum data in several disciplines and contexts. The use of data in museums has been analyzed primarily through the perspective of museum information professionals or museum visitors. The literature focusing on museum staff centers on their work as producers and users of information systems (Callery 2002; Gilliland-Swetland and White 2004) and in engaging audiences using new technologies (Marty 2007). From the visitor perspective, research has focused on the experience of casual users as they interact with museum resources (e.g., Galani and Chalmers 2008; Skov 2009). One area of study to emerge recently is social tagging of museum representations, which allows members of a broad public to contribute descriptive terms or narrative content about museum collections (e.g., Bearman and Trant 2007). Along with social tagging, use of other Web 2.0 capabilities and social media applications are having a broad impact on the relationship of many museums with their user communities (Bearman and Trant 2008). While these technologies present opportunities for museum engagement with users, the impact of this activity on use of museum data by scholarly researchers has yet to be demonstrated. This may be due, at least in part, to the separation of authoritatively derived information from that which has been contributed by members of the general public. Cameron and Mengler (2009) note that "while folksonomies, for example, appear on the web collections' interface as an alternative search mechanism, museums tend to manage these new interpretations by separating them from the record to maintain their curatorial integrity" (p. 199). Research use of museum data remains an under-explored topic in the museum studies literature.

2.7.1 Research with Museum Data

Research is widely considered to be a primary function of museums (Gunn and Prescott 1999; Anderson 2005; Dube 1990). The American Alliance of Museums includes research in its Code of Ethics for Museums, stating, "Museums serve society by advancing an understanding and appreciation of the natural and cultural common wealth through exhibitions, research, scholarship, publications and educational activities" (American Alliance of Museums 2000). Study and publication of collections is a traditional function of museums, generally carried out by curatorial staff, whose "primary responsibility is the production of high-quality research" (Novacek 1990, p. 354). Museum staff also facilitate use of collections by researchers not affiliated with the museum (Chambers 2001). In this section, I explore the literature on museum research addressing both internal and external users.

When performed by curatorial staff, research is sometimes referred to as the "inner museum function" with education serving as the "outer museum function" (Lane 1996, p. 539). While this view focuses on staff effort, rather than the totality of museum-based research, it does bring to the forefront the inward facing product of curatorial research: a greater knowledge of the museum collection, which can be used to augment object representations. Claims that current levels of internal collections research are inadequate pervade the literature on the subject, citing problems like cost (funding shortages combined with rising costs for research equipment), museum directors unsympathetic to research, and overburdened curators as the root causes (Anderson 2005; Graham 2005).

These issues manifest differently in various types of museums. In small museums, "collections research has often been regarded as something a curator did if he found time" (Fenton 2005, p. 225), highlighting the many demands on curators in addition to research, which may take their time away from that activity. In many university museums, curators receive faculty appointments, which come with their own research expectations. These appointments are a structural factor keeping research at the center of those institutions.

Many museums accommodate external researchers by answering their information requests, allowing onsite access to collections, equipment, and workspaces, and in some cases, providing them with titled research affiliations (Graham 2005). In other cases, particularly within the natural sciences, museums may arrange specimen loans between institutions so that researchers can examine them off-site.

Natural science collections can be considered a success story in museum research, receiving a great deal of research attention in contrast with archaeological museums. Because of their "long tradition of good collections management" and "networks of scientists and curators," natural science collections receive a comparatively great deal of research use, while in archaeology the "glamour of new discovery through excavation" means that "archaeologists do not have the benefit of a tradition of using excavation archives and finds that have been created by others" (Keene 2005, p. 56-57). These two types of museums and their research uses are discussed in depth in the following sections on archaeological and botanical research social worlds.

2.7.2 Museums and Data Consortia

Museums increasingly provide their content to data aggregators, which bring information from a number of sources together to meet the needs to specific research communities. Examples of cyberinfrastructure drawing together museum data with materials from other sources can be found in a number of fields (Rosenzweig 2007). The ARTstor digital library, for example, provides subscription-based access to digital images in the arts, sciences, and humanities drawn from museums, libraries, and photo archives

(ARTstor 2011). National consortia like the Canadian Heritage Information Network (CHIN) and the Collections Australia Network draw together digital representations of materials from cultural heritage institutions, including museums, throughout those countries. Participation in consortia benefits individual museums by providing them with standards and best practices, and often tools and monetary resources, for collection digitization and representation. As these consortia continue to add collections and tools for research and educational use, they give museum data a broader audience (Marty 2008a).

In botany, many herbaria participate in data consortium projects like the JSTOR Global Plants database, Integrated Digitized Biocollections (iDigBio) and the Global Biodiversity Information Facility (GBIF). In archaeology, some museums participate in consortia like the Global Egyptian Museum, bringing together collection databases from ten museums specializing in Egyptian artifacts, while other digital data sharing platforms often bypass museums entirely, working directly with the archaeologists responsible for a given data set (for example Open Context and The Digital Archaeological Record [tDAR] in the United States and the Archaeology Data Service in the United Kingdom). The move to bypass museums in building digital repositories for archaeological data is aligned with the conception that institutions focused on providing preservation and access to material artifacts and print-based records are not the best home for the preservation and management of digital data (tDAR 2013). To the extent that archaeological materials (including finds, records, and data) continue to be deposited at museums, they must remain involved in the management of these (often born-digital) materials.

In the natural sciences, scientists often turn to biodiversity consortia like iDigBio and GBIF, which bring together data from a number of sources (including museum collections) and multiple disciplines to map life on earth. Bowker (2000) reports that there are a several problems bringing together data from diverse fields in biodiversity databases. Naming practices can be different from field to field, so that multiple names exist for the same entities; the context of information is difficult to retain as it passes from field to field or as time passes; and integrating information from multiple fields or physical sites can be problematic (Bowker 2000, p. 649). With an infrastructure shared by many fields, the norms held by a single community of practice at a single point in time cannot be taken for granted as data are shared across fields and into the future. This is a particularly salient point with regards to museum data, where "despite early and ongoing efforts to create shared databases of digital surrogates […] most museums are still using their own unique systems with their own unique record structures, and even museums that use common standards and controlled vocabularies can face problems of sharing their information resources" (Marty 2008b, pp. 33-34).

As Trant notes, the use of museum information in cyberinfrastructure projects, including databases, comes at some loss of authority for museums concerning the interpretation of collections:

> It's not possible for museums to provide an interpretive wrapper around every work in every collection. Instead, other mediators are called upon to make meaning – teachers provide context for students, scholars provide new interpretation for their peers. The cyberinfrastructure provides a vehicle for others to make meaning about culture. Museums must be plugged into these grids, or they risk the well-being of their collections; they risk being bypassed by their core communities, simply out of ignorance (Trant 2008, p. 288).

Trant makes a compelling argument for the participation of museums in broader cyberinfrastructure, asserting that if museums do not participate, they will lose their scholarly and educational audiences. While some research has been done into cyberinfrastructure that includes museum data, an understanding of the research uses of museum data remains lacking. In order to build effective museum participation in cyberinfrastructure, this understanding must be developed.

This study explores these processes for two epistemic communities in the course of using museum data as evidence. In the following sections, I explore the social worlds of archaeologists and botanists and the acts of data creation and analysis within those worlds.

2.8 Archaeology: Social Worlds and Data

Archaeology is the study of human cultures through their material traces, including their objects, architecture, and impact on the landscape. Archaeologists survey and excavate sites inhabited by the people of earlier cultures, painstakingly recording the dimensions of structures they unearth, soil composition, and the three dimensional locations of objects they find, including architecture, artifacts, and human and animal remains, with the goal of forming a greater understanding of past cultures and social phenomena. They may create many types of data – numerical, image based, and CAD designs, as well as algorithms for quantitative models, depending on the specific research questions guiding a project and the work process itself (Faniel et al. 2013). In this section, I provide an overview of the work of archaeologists: a history of their discipline, paying particular attention to the major theoretical movements within the field, changes in methods and technologies in the field over time, and trends in archaeological data collection and management.

2.8.1 A Historical Perspective

Humans have long been interested in objects left behind by past cultures, beginning with prehistoric groups, who valued objects created by their forebears and used them as religious objects and relics of earlier times (Trigger 2007). Archaeology first emerged as "systematic antiquarian study of material artefacts as a supplement to written records," in the Song Dynasty (A.D. 960-1279) in China and the Italian renaissance in Europe (Trigger 1984, p. 356). Antiquarian activity is distinguished from the work of historians through its methods and its approach to objects. As the Italian historian Arnaldo Momigliano wrote in 1950:

> [T]he word "antiquary" suggests the notion of a student of the past who is not quite a historian because: (1) historians write in a chronological order; antiquaries write in a systematic order: (2) historians produce those facts which serve to illustrate or explain a certain situation; antiquaries collect all the items that are connected with a certain subject, whether they help to solve a problem or not. (Momigliano 1950, p. 286)

The emphasis on accumulation of historical objects and their categorization characterizes antiquarian activity during a time when historians were only beginning to consider objects as a source of evidence of the past, playing a far less central role than texts in their work.

The Italian Renaissance was an important milestone in the development of archaeological practice, bringing elite and government support to the collection and study of antiquities. As Trigger argues, "By the end of the fourteenth century A.D., the rapid social and economic changes that marked the end of feudalism in northern Italy led scholars to try to justify political innovations by demonstrating that there were precedents for them in earlier times" (Trigger 2007, p. 35). Scholarly interest in classical literature spread to art and architecture, while an appreciation for ancient Greek and Roman art among the Italian elite lead to their sponsorship of efforts to recover antiquities, although these efforts resembled treasure hunts more than they did modern excavation (Trigger 2007). Renaissance historians throughout Europe turned to the study of ancient monuments and other antiquities to learn about their national pasts, bolstered by infrastructural support including the appointment of a King's Antiquary position in England (established in 1533) and the founding of a Society of Antiquaries in London in 1572 (Trigger 2007, p. 47). This kind of support waxed and waned along with the political climates of these countries.

The collections of antiquities amassed and studied by researchers formed the basis of many later museums. In Denmark, for example, the collections of Ole Worm, which included documentation of ancient rune stones among other manmade and natural objects, formed the basis of the Kunstkammer ("Royal Collection") opened to public view in the 1680s (Trigger 2007, p. 49). Worm organized his collection into *natural* and *artificial* (human made) categories, the latter subdivided by the material type from which they were fabricated (Shelton 1994, p. 182). Aided by the publication of a catalog of his collections in 1655, Worm's collection is today cited as one of the earliest precursors to the modern museum, in part because his categorization of objects "recognized the necessity of ordered intentionality, the organization of museums into instructional venues for the transmission of knowledge" (Crane 2000, p. 73). The institution of the museum became an important resource for preserving the objects uncovered in archaeology.

Enlightenment thought brought about the next large shift in archaeological theory and practice, as antiquarians and historians joined their contemporaries in accepting an *evolutionary* view of human history. This idea suggested that cultural progress, encompassing technological, social, and political change, followed a relatively linear path bringing human societies ever closer to a state of perfection. Through the use of rational thought, its adherents contended, humans gain greater control over their environment and advance their societies. Antiquarians of the time shared this set of widely-held positivistic beliefs which shaped their work in comparing the artifacts of past civilizations with the activity of their own European cultures (Trigger 2007, p. 57-58). As eighteenth-century practitioners developed methods for excavating and recording finds, systems for the description and classification of objects and monuments, and methods for dating materials, they did so with the assumption of prior cultures' inherent inferiority to their own (Trigger 2007, p. 71).

A major shift in early archaeological theory in Europe, which came to be known as scientific archaeology, had its start in the introduction of the "Three Age System" by Christian Thomsen of the National Museum in Copenhagen. Thomsen organized the antiquarian collections in this museum into separate rooms, which he defined as periods of time based on the materials used to create human technologies. The Age of Stone referred to objects from a time when tools were made of natural material like stone, wood, and bone. The Age of Bronze referred to a time of early metalwork, when copper and bronze were the dominant materials. The Age of Iron followed this era, when that metal was introduced in tool making. Thomsen's development of the Three Age System was made possible by his access to vast groups of materials at the National Museum in Copenhagen, as well as original excavation information about them. He reasoned that materials excavated together could be similarly dated, using that knowledge to discern which materials had been in use concurrently, helping him form a chronology of materials (Trigger 2007; Maisels 1993). The Three Age System, introduced in print in 1836, gave historians a powerful paradigm for conceptualizing prehistory. The system has since been expanded upon and remains in wide use today.

The establishment of archaeology as a formal discipline did not take place until the 19th century, with the birth of several institutions dealing specifically with the study of prehistory. Gabriel de Mortillet published the first prehistory journal in France in 1864, followed shortly by German and Italian journals on the subject. 1865 saw the founding of the first professional society for prehistorians: The International Congress of Prehistory. By creating an international organization, Kaeser argues that its founders were implicitly blocking antiquarians, who generally studied cultures at a small geographic scale, from participation (Kaeser 2008). Museums also had an important role in the professionalization of archaeology according to Chapman, who calls them "the first professional homes for archaeology in that they actually paid archaeologists" (Chapman

1989, p. 152). In the nineteenth century, universities began to play an important role in archaeological infrastructure as well, as archaeologists were first hired to teaching positions (Trigger 1989, p. 149). The 19th century infrastructural foundations of archaeology, drawing on museums, universities, professional societies, and journals has remained remarkably stable since that time.

Given the massive scale and expense of most archaeological excavation, it has, not surprisingly, been largely associated with governments throughout the world. Trigger (1984) categorizes archaeological projects as nationalist, colonialist, and imperialist in terms of their function in meeting the goals of the sponsoring nation state within the world system. Nationalist archaeology became prominent in Europe in the post-Napoleonic era, as governments sought to consolidate power in part by creating national histories and identities for their people, appealing to a shared past. Archaeology continues to serve as a nation-building project in many countries, which excavate within their own geographic borders in order to learn about and to glorify their own national past. Colonialist archaeology has historically been a project initiated in European-settled territories, with the political agenda of proving the inferiority of the native populations they have sought to replace or subjugate, either by showing the lack of technological and cultural achievement of ancient people or by attributing their achievements to diffusion through interaction with people deemed to be more advanced. A few powerful nations performing research in other countries characterize imperialist archaeology. This strain of archaeological research has had explaining the predominance of the imperialist nation as its implicit political goal, through comparison with the histories of other nations, while adding to the glory of the imperialist nation through this work. While Trigger himself appreciates the reductive and non-mutually exclusive nature of these categories, I find them useful in illustrating the national character of archaeology and the way in which nationhood shapes archaeological projects worldwide (Trigger 1984). Using this typology, we can best describe American archaeology in the Near East during the 19th and 20th centuries (the context of the accumulation of the Kelsey's excavated collections) as imperialist, characterized and made possible by the international prominence of the United States. This is not, however, to ascribe explicitly imperialist motives to particular archaeologists, but to explain the role of this work in the context of international relations. It is this political context that defined the early collecting work of archaeologists at the University of Michigan; therefore it has some bearing on the research use of those collections today.

The evolutionary view of human history dominated archaeological work until the early 19th century, when a culture-historical paradigm, citing migration and diffusion as catalysts for change, slowly gained prominence. In the cultural evolutionary model, human civilizations were all on the same course of progress, but in different places along that course. In the diffusion model of change, however, interactions between groups of people spread technological and social developments among them. Under the culture-historical paradigm, archaeologists began to emphasize the specific features of human groups, rather than seeking to compare their development in some standardized way. Franz Boas was among the influential researchers of this era to promote cultural relativism and historical particularism, which advanced the ideas that the extent of development of cultures could not be compared and that each culture was shaped by its own historical experiences, caused in large part by contact with other people and the resulting diffusion of culture (Trigger 1989, p. 152). One notable development during this era of archaeological practice is the Midwestern Taxonomic Method, developed by W.C. McKern and several of his colleagues at institutions throughout the Midwest United States. This method for classifying objects in the archaeological record helped standardize the work of a large number of archaeologists studying the greater Mississippi Valley so that their work could be more easily compared and relationships between cultural groups would be more evident (McKern 1939). While archaeologists lauded the helpfulness of this tool, they also found some fault with it.

> It organized archeological materials into categories based on degrees of likeness of the assemblages being unearthed. Unfortunately, there was a tendency to regard classification as the end of research, and some archeologists who were obtaining long stratigraphic sequences, which in some cases showed gradual culture change, were hard put to classify these in Midwestern terms, although they continued for years to do so. (Caldwell 1959, p. 303)

In response to a situation in archaeology where "the emphasis was on archeological data as things in themselves rather than on the values offered by different ways of looking at them" (Caldwell 1959, p. 303), Processual Archaeology, then called "New Archaeology" emerged the late 1950s and early 1960s. Proponents of Processual

Archaeology argued that use of the scientific method could advance archaeology from a study of the ecology of earlier people in relation to their environment to a study of their ideology. Archaeologists were taking advantage of technological advances made during World War II, as archaeologist David Clarke later noted:

> [M]ajor technical developments of wartime introduced fresh archaeological potential, ranging from heavy mechanical excavators to new underwater and aerial equipment, through applied mathematics to operational research, computer electronics and atomic physics. A quantitative and qualitative technical and social revolution quietly transformed world archaeology in a series of almost imperceptible piecemeal changes. (Clarke 1973, p.8)

New tools for computational analysis and the invention of radiocarbon dating were particularly influential, the former bringing experimentation and simulation into archaeological practice, the latter drastically changing how archaeologists determine chronology (Clarke 1973). Processual Archaeology was the theoretical change that accompanied this shift in mechanical and computational methods, incorporating experiment, hypothesis testing, and simulation into archaeological practice.

Another important change to archaeological practice during this era was regulatory. The 1970 UNESCO *Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property* enacted stronger legal and ethical standards governing international archaeological excavation. The *Convention* essentially ended the export of archaeological finds from their country of origin, requiring stronger documentation for the movement of archaeological objects internationally and oversight of excavations, and requiring member nations to help repatriate stolen goods (UNESCO 1970). From this time onward, data became the main export resulting from archaeological research, rather than finds themselves.

The next major movement in the discipline is known as Post-processual Archaeology; a call begun by archaeologists in the United Kingdom during the 1980s for a reflexive archaeological practice, looking at the situatedness of archaeologists and their work. In response to the faith in the objectivity of scientific methods that developed under the Processual period, Post-processual writers contend that the prejudgments archaeologists bring to data have a major impact on their work, and must be acknowledged. As Hodder argues:

> Our prejudgements typically consist of definitions of terms (e.g. type series), criteria to identify which facts are significant, goals and expected answers, tools (from trowels to mass spectrometers), methods and skills […] and the social and political structures of the discipline, excavation team, etc. *The historical nature of knowledge* derives in part from the view that our prejudgements have a lasting effect. Our starting point influences our conclusions and the future trajectory of research. (Hodder 1999, p. 33 italics are in the original)

In order to practice a reflexive archaeology that acknowledges its biases, Hodder states that it is "necessary to foreground interpretation […] since interpretation determines excavation and sampling strategies" (Hodder 1999, p. 93). Interpretation should be documented as part of data collection and analysis in order to make the archaeological record comprehensible. Post-processual archaeology is the most recent of the theoretical trends outlined here, but it is not universally accepted, or even dominant, within the field. Processual archaeology has its adherents, who perceive their data as objective, as does cultural-historical archaeology. Because of its emphasis on reflexivity and interpretation, the concepts underlying Post-processual archaeology are very well aligned with the theoretical framework guiding the present study. Post-processualists have examined the data collection and interpretation processes in archaeology, and many of their ideas will be discussed in the upcoming section on archaeological interpretation.

2.8.2 Archaeological Specialization

Archaeology is a field of many specialties: temporal, geographic, methodological, and material (Harley et al. 2010). Archaeologists may study the human history of a particular time period (e.g., prehistoric, Paleolithic, Medieval), a specific geography (e.g., Egypt, the Near East, Greece, the Americas) or combine these concerns in a way that specifies both the time period and geography of interest. Classical archaeology (a field with which many of the archaeologists I spoke with identify) is a good example of this combination, narrowing its focus to ancient Greek and Rome and their surrounding civilizations. Two of many methodological specializations in archaeology are ethnoarchaeology, using archaeological methods to study living cultural groups of people, and experimental archaeology, using experiment to replicate processes used by prior cultures. Archaeological specialization can also relate to the type of materials being studied, for example, zooarchaeologists study the animal remains at archaeological sites to learn how animals were used by its inhabitants and archaeobotany looks at botanical remains found at those sites. Archaeologists may also specialize in certain types of artifacts produced by past people such as textiles, ceramics, metalwork, and architecture. Their knowledge of materials, construction techniques, and use patterns of particular types of objects in specific cultures add insight to archaeological investigations. These specializations function as social worlds for their members, who follow their specialization's norms for scholarly practice. As Harley et al. argue, "The sub-specialization of research in archaeology and its institutional and regional contexts influence publishing behaviors, criteria for advancement, mechanisms for keeping up to date, and practices of sharing and collaboration" (Harley et al. 2010, p. 30).

The interpretation of a given archaeological site often includes the participation of specialists in architecture, zoology, ceramics, textiles, and stratigraphy, to name only a few. These specialists examine the attributes of a site that fall under their area of expertise, but often do so off-site in laboratory settings, making their work far removed from the dig itself (Hodder 2003). A ceramicist, for example, will review the ceramic findings from a dig, examining their composition, stylistic attributes, and quantity in order to date when the ceramic finds were fabricated and to determine cultural influences on their creators. The knowledge of a site contributed by ceramicists may influence the work of other specialists interacting with the excavation in tasks like dating the time at which the site was inhabited and understanding how a site was used by earlier groups of people. Specialists contribute their interpretations to site reports composed by the team under the guidance of the project director and produce their own publications of their findings.

2.8.3 Archaeological Data and Interpretation

"Archaeological data can be defined as a set of dynamic, dialectical, unstable relations between objects, contexts, and interpretations." Objects and contexts are part of "a nested hierarchy of terms from attribute to artifact to assemblage to type to layer to feature to site to region" (Hodder 1999, p. 84). Thus what is considered the object and what is considered the context can be determined on a number of levels, each of which is decided through some interpretation, which is recorded in archaeological data as an object is identified or context determined. Objects and contexts define each other- in one of Hodder's examples, "the grouping of postholes into contexts depends on their interpretation as houses" (Hodder 1999, p. 86), an interpretation that might change as excavation proceeds, even as it changes the overall interpretation of the site.

Hodder discusses the role of individual archaeologists' knowledge in determining not only how archaeological information is recorded and interpreted, but how a site will be dug, calling this "interpretation at the trowel's edge." He explains,

> As the hand and trowel move over the ground, decisions are being made about which bumps, changes in texture, colours to ignore and which to follow. This is a practical bodily interpretation. It is influenced by one's interpretation of what is happening and by what one is finding. (Hodder 1999, p. 92)

Decisions made by the excavator about the meaning and value of what he or she finds directly influence the course of the investigation including what objects and information will be retained, how they will be categorized, and how the excavation will continue.

Holtorf (2002) illustrates this process as he traces a pottery sherd uncovered in an excavation from its initial discovery and identification through to its transformation into a museum object. From the undergraduate student who found it at a dig and identified it as a potsherd, to the more experienced excavation team members who classified it and other potsherds as either 'recent' or 'ancient,' discarding those deemed recent, to the ceramicist who identified, dated, and databased the potsherd and classified it as 'undiagnostic,' (meaning that it was not deemed worthy of further examination), analysis and interpretation determined the object's description and disposition at each step of the process. It was finally deposited in a local museum's storage as a "fragment of a large storage vessel of the Iron Age settlement on top of Monte Polizzo" (Holtorf 2002, p.62). Had it not been identified as "a potsherd," "ancient," and "undiagnostic," the object would have had a different fate in the archaeological process.

Archaeological interpretation, then, is central to the data collection process itself. The interpretation of a site determines how its characteristics will be identified, creating the context with which finds will be associated, (e.g. "the grouping of postholes into contexts depends on their interpretation as houses" in Hodder 1999, p. 86). Similarly, the interpretation of an object during excavation determines its eventual disposition, relying on factors like dating decisions and archaeologists' assessments of their usefulness in understanding the site.

2.8.4 Recordkeeping Practices

Throughout the archaeological research process, as a site is explored and interpretations made, archaeologists inscribe their data, detailing their research process, in a number of recordkeeping systems (McManus 2012). First, archaeologists use surveying equipment to plot the locations of site features and develop a grid which acts as a reference system to the site as a whole. Stratigraphy, the relationship between layers of excavated soil, is recorded in section drawings, which show the layers' vertical relationship. Stratigraphy allows archaeologists to identify temporal relationships between features uncovered in the same or different strata at a site. Section drawings are often accompanied by a Harris Matrix (introduced in 1973), which links the drawings in a site chronology. Plans map the location of structures, artifacts, and features unearthed at a site. Context sheets are textual descriptions of each archaeological context established by the team, based on stratigraphy and distinguishing features of that part of the site. They link each context to the site's grid, trenches, and vertical location while noting the kinds of materials found in that context and any images taken of the context (Grant et al. 2005). Photographs, drawings, field notes, and other written descriptions of features and objects at the site comprise the other primary types of data recorded at an excavation itself. Many other kinds of data are captured and recorded in the dig houses and laboratories where specialists examine excavated materials.

One classification system widely used in archaeology is *typological classification*, "where the numerous artifacts are clustered into discrete 'types', and the assemblage is sorted according to these pre-defined types" (Gilboa et al. 2004, p. 681). With ceramic vessels, for instance:

> Vessels are grouped together on the basis of similar features, and a single example is illustrated which thereby represents all the others. The type vessel need not come from the same site as the others – it may come from a museum collection which represents sherds from an excavated collection. (Orton et al. 2013, p.191)

By grouping similar artifacts by shape, contour, fabric (physical composition), and style, archaeologists can more easily sort through massive quantities of finds. A single archaeological site may use separate typologies for ceramics, glassware, marble, brick, or any other group of materials. Type series are generally not established anew for archaeological projects, unless one does not already exist (Orton et al. 2013). Indeed, "part of the necessary equipment for any archaeologist desiring to do survey or excavation in a region is a mastery of the local artifact typology" (Whittaker et al. 1998, p.131). Typologies developed by prior archaeologists working in a region become part of the information infrastructure for continuing archaeological work in that area.

Project or dig directors are the people in charge of determining a method for representing the overall work at an excavation site, which will tie together the data produced by team members. They may decide to use a combination of print and electronic methods of data capture, including project databases for onsite data recording, or print-based recordkeeping with records scanned at the end of each season and added to a project database. Historically, the data from digs has remained within a small group of researchers, as Kansa and Kansa explain:

> In the past, primary data was typically developed to serve the limited audience of the project director and a few specialists. Primary data had little role outside of a project, so it tended (and still tends) to be informally developed, maintained, and validated. (Kansa and Kansa 2011, p.87)

Dig directors are also responsible for creating a project report at the conclusion of the dig. Huvila (2008) describes the project report as a well-defined genre containing a "description of investigation process, a survey of related literature and an interpretation of the results of the investigation. The description is followed by a catalogue of finds unearthed during the project, a list of photographs, plans, drawings and samples. The most important findings are often summarised in a separate short introductory chapter in the beginning of the report" (Huvila 2008, p. 6). The report is an important part of archaeological practice: its successful completion is a requirement for future permission to undertake archaeological projects. In his study, Huvila's 25 Swedish and Finnish archaeologist informants said that reports were "primary sources of archaeological information on any particular excavation and site [… while] secondary publications such as journal articles were often seen as abridgements, which do not give enough information on the subject matter" (Huvila 2008, p.6). The archaeological report, then, is a major source for learning about excavations, and considered to be more comprehensive than other publications originating from archaeological research. By including a catalog of finds and lists of data sources like photographs and site plans, the report also serves as an overview of data generated by the project.

While the project report can serve as a key to finding the data from an excavation, it will most likely not describe the extent of the data recorded at that site in its entirety. Several authors have argued for the importance of retaining all archaeological data from a given project in a manner that eases future understanding of the data (Aitchison 2009; Brown 2007). “Archaeological archives” consist of “all parts of the archaeological record, including the finds and digital records as well as the written, drawn, and photographic documentation” (Brown 2007, p. 3). The importance of good recordkeeping in archaeology is difficult to overstate. As one author put it, “The process of investigating the archaeological resource will often diminish the quality of that resource- excavation cannot be repeated, as once deposits have been excavated they are gone- and so the archive remains the primary record of what was there before” (Aitchison 2009, p. 67). Since excavation destroys an archaeological site, all researchers have left for analysis and reconstruction is the archaeological record.

2.8.5 Archaeological Data Practices

Historically, archaeologists have considered formal publication to be the primary means for information dissemination, through monographs and papers that detail an archaeological project and its findings (Babeu 2011). Traditionally, some selection of data used in writing these publications is included as evidence for the authors’ claims, subject to the spatial constraints of print publication (Kansa and Kansa 2011). As technology for information sharing has changed, however, new possibilities for sharing the data underlying archaeological findings have come to the forefront. A call for data sharing to enable interpretation by stakeholders outside the excavation team, including the local populations in dig areas, is emerging (see for example, Hodder 2003).

Archaeological data from a dig are generally owned and stewarded by the excavation director, the person who coordinates the dig, and the specialists working in its various components. Jones argues that the post-excavation period is characterized by fragmentation and decontextualization of the finds, as specialists examine material in laboratories far removed from the excavated context. "[F]eatures, objects, and their context are gradually prised apart in order to understand them. However in doing this we affect a process in which our interpretations of the site become ever less grounded on the primary observation of the site itself" (Jones 2004, p. 43). Archaeological recordkeeping is now the only tie between the objects and their excavated context.

While the director oversees some aspects of specialists' work, he or she "does not tell the pottery specialist how to construct a database for the pottery. The director will watch over the utility of the end product, not the details" (Eiteljorg 1998, p. 22). The excavation director must walk a fine line between ensuring data longevity and maintaining the relative autonomy of specialists on the dig. Furthermore, Harley et al. report that archaeological data management practices:

> are defined by varied criteria such as the nature and scope of the site itself, the training and interests of the lead researcher, the nature of data and the methods involved in their collection and preservation, and the influence of various stakeholders (e.g., funding bodies, universities, museums, governments, and/or local authorities). (Harley et al. 2010, p. 31)

The propensity to archive one's data is sadly not a given in archaeology. In her recent study of archiving in the personal digital image collections of archaeologists and art historians, Boudoin (2011) finds that these researchers tended to save only the images they saw as unique. Furthermore, they did not have systematic practices to preserve their collections, and had a hard time seeing how they might be useful to others. They were generally unaware of the available institutional repositories that might help them preserve their image collections and saw their own research as so highly specialized that it would be unlikely that their images would interest others in their field.

Archaeologists are not only creating digital data, but also using digital tools to interpret those data and communicate them to archaeological and lay-audiences. One example comes from the Kelsey Museum itself, which presented 3D modeling of the site of Antioch to visitors to its 2006 exhibit "Building a New Rome: The Imperial Colony of Pisidian Antioch." Creators of the immersive 3D model of the site used photographic records and architectural drawings from the University's 1924 expedition (held in the museum's archives) along with their own digital photographs to reconstruct a model of the city. One product of this work is a series of 15 second movies that "show the fragmentary remains of the building that are still on site being transformed into a reconstruction of the complete monument, allowing the viewer to see the alignment of the semi-transparent reconstruction with the on-site remains" (Harrington 2011, p. 176). While these movies have clear educational value for users in showing them what the site may have looked like, the process of their creation had a research value as well. Researchers building the model were able to prove that prior measurements and reconstructions were faulty when the data they provided could not be fit into the new three-dimensional model (Harrington 2011, p. 174). This brief overview of archaeological data practices highlights both the heterogeneity of data and some of the hurtles in incentivizing these researchers to share their data, including selective retention of some types of materials (Boudoin 2011), the individualized nature of recordkeeping practices, even within a single dig (Eiteljorg 1998), and the decontextualization of data that takes place during the analysis of archaeological finds by specialists (Jones 2004).

2.8.6 Sharing Archaeological Data

Given the different disciplinary backgrounds and the relative autonomy of archaeological specialists, these researchers produce very heterogeneous datasets, which makes describing data for future retrieval and use a difficult task (Khazraee and Khoo 2011; Atici et al. 2012). Within a single excavation, diverse datasets are linked by loci, the physical contexts relevant to the data. Geographic Information Systems (GIS) are widely used by archaeologists to associate their data with a precise physical location, but GIS does not deal with the z coordinate, depth, which is essential in defining stratigraphic relationships in archaeology (Harley et al. 2010). In this way, GIS is a necessary tool, but not a sufficient one, which helps explain the growth of three-dimensional modeling in this discipline.

Due to the collaborative and interdisciplinary nature of archaeological research, a great deal of within-project data sharing already takes place. Archaeologists use web hosted, password protected databases to share information and analyses between project members while keeping others out of the data. Fear of being scooped, worry that data are not ready for public consumption, lack of institutional reward, and a dearth of data standards in the discipline are some of the barriers to open sharing of archaeological data

(Harley et al. 2010). These concerns have kept a majority of archaeologists from publicly sharing full datasets prior to publication of their own analyses (or at all), but a small number of archaeological projects have forged ahead by making data accessible on the web as they are amassed. One notable project, the excavation at Çatalhöyük in Turkey, offers public access to the project database and diary entries kept by researchers there, providing an example of site-specific data sharing (Çatalhöyük Research Project 2013). Such resources can support the casual interests of visitors to the website and the more defined information needs of archaeologists (Czyrnyj 2011). As Kansa et al. note, however,

> Most Near Eastern archaeological projects take place in smaller research programs with less funding and research support than Çatalhöyük. These smaller projects have less capacity to develop their own customized, web-accessible database solutions. They may develop rich bodies of documentation, but without Internet dissemination much of the material will never see publication simply because this vast amount of content cannot be accommodated by print publication. (Kansa et al. 2007, p.189)

A research project's access to resources is an important factor in the extent of its information infrastructure and the likelihood of that infrastructure to enable data sharing with a public audience.

While not without its own difficulties, sharing data obtained from a single research site is a trivial problem in comparison with sharing and analyzing data between multiple projects, for purposes like regional analysis of cultural and economic trends. Because data are not described uniformly, reconciling them between projects and making them amenable to aggregated analysis is very difficult. In several parts of the world (including the United States and much of Europe) where a good deal of archaeological work is done as contract archaeology or cultural resource management, carried out by private companies rather than academically affiliated archaeologists, incentives for open data sharing are even smaller than they are among academics. These projects are contracted by private developers who are required by government mandate to determine the archaeological value of a site prior to building on it. In most of these cases, data are not required to be described, managed, curated, or deposited in any way (unlike some government funded projects that require data management as a condition of the grant) (Harley et al. 2010). In several countries, however, data from these projects *are* required to be deposited in government run data repositories. These repositories release guidelines to depositors requiring adherence with metadata standards such as Dublin Core (Data Archiving Networked Services 2013), standards for specifying provenience (Parks Canada 2005), and preferred data formats (Archaeological Data Services 2012).

Similar attempts at defining data structures for the deposit of data sets are taking place outside of the government arena. Open Context, a data publication service in the United States, offers a number of fee-based services to depositors, including editing of data sets and peer review, guidelines for deposit, and advice for creating data management plans in grant proposals to the National Science Foundation and National Endowment for the Humanities. Open Context accepts data in Microsoft Excel and several other common formats and converts them into ArchaeoML, an open format for specialized archaeological metadata (Open Context, n.d.). Open Context has experimented with linked data and used the ontology from the Encyclopedia of Life to describe its zooarchaeological data. Another, similar project, The Digital Archaeological Record (tDAR) offers many of the same services to depositors, including acceptance of multiple format types, assistance with data management plans, and options for setting permissions to access portions of a data set. tDAR is noteworthy for its attempts to build a faunal ontology for the zooarchaeological data is supports by convening a meeting of American and British Faunal Working Groups of archaeologists, to come to an agreed upon set of concepts to which zooarchaeological data can be mapped. Its system allows data providers and users to map datasets onto ontologies to aide cross-dataset analysis (Spielmann and Kintigh 2011).

The archaeological community as a whole has yet to develop a formal ontology for the description of data. One pre-existing tool is the CIDOC Conceptual Reference Model (CRM), created by the International Committee for Documentation (CIDOC) of the International Council of Museums (ICOM). This model, in development since 1996, has gained the status of an international standard as ISO 21127:2006, "Information and documentation -- A reference ontology for the interchange of cultural heritage information." CIDOC CRM defines the logical relationships between database elements used in cultural heritage documentation, making databases from various sources interoperable through this standardization. It does not, however, "define any of the terminology appearing typically as data in the respective data structures," a task undertaken with the introduction of controlled vocabularies in archaeology and other fields (ICOM/CIDOC Documentation Standards Group 2011, p. i). As Faniel et al. (2013b) note, however, CIDOC CRM was created with the needs of museum staff in mind, not the needs of those working with archaeological field data, reducing its usability for the latter group.

Khazraee and Khoo (2011) argue that ontologies organizing archaeological data are inadequate for understanding how the data were created. They call for ontologies that capture a "categorization for understanding" rather than ontologies that facilitate only storage and retrieval of data. They state that, "categorization for understanding is an inductive approach to codification. Archaeologists categorize things in different schemes to make sense of data and find a fitting scheme that can accommodate their data. Accordingly, this categorization has a dynamic nature and evolves through time and improves by development of our understanding." These authors emphasize "practice-based ontologies" to account for and record the meaning-making that accompanies archaeological work (Khazraee and Khoo 2011, p. 384). Their call to document the interpretive process in archaeology echoes Hodder. The latter author wants to document decision making "at the trowel's edge" in order to open the process up to non-archaeologist stakeholders while making the interpretive process more transparent to future users of the data. While Kharzee and Khoo propose metadata as a solution, Hodder favors the addition of more representations of data, in the form of videos, blogs, and other materials archaeologists would create during their work in the field (Hodder 2003). Esteva and her colleagues, in contrast, are developing a system that records transformations made to archaeological data to make the decisions made in data analysis visible to future users (Esteva et al. 2010). While each of these systems takes a different approach to documenting the interpretation process in archaeology, none have gained the status of a standard in that field.

In studies of archaeological data reuse, adequate contextual information has emerged as one of the most important factors considered by potential reusers. Archaeologists need to know how a study was conducted, what tools and instrumentation were used in data collection, and the criteria used by data creators as they sorted data into various interpretive categories (Atici et al. 2012; Faniel et al. 2013b). When such information is unavailable, archaeologists turn to site reports and field documentation created by the data collectors to glean that contextual information (Atici et al. 2012). In the next section, I discuss these issues in relation to archaeological records held by museums.

2.8.7 Archaeological Material in Museums

Museums are the predominant repository for archaeological data, which includes "[t]he body of finds, environmental samples, paper, photographic and digital records and other material arising from an excavation, together with any analytical reports" (Merriman and Swain 1999, p. 250). Archaeological data in museums, however, appear to receive a relatively small amount of research use. In a 1998 survey of English museums, 29 percent reported that they had received no research visits or inquiries in the preceding year (Merriman and Swain 1999). These findings are echoed in another, more recent survey of museums holding archaeological data in England, where researchers found that among the nineteen respondents, "the highest proportion of visitors to archaeological collections in store was from volunteer workers (45%), followed by members of the public (20%), private researchers (14%), university researchers (10%), and special interest or community groups (6%)" (Edwards 2012, p. 29). Only 24% of visits to these museum collections were for research purposes.

The lack of use of archaeological collections may, in part, be due to the value placed on discovery of objects in archaeology, with analysis of previously excavated materials an undervalued research method (Keene 2005; Merriman and Swain 1999). Museum and collection reputation appear to be an important factor in research use, as Merriman and Swain found that "it tends to be the larger museums, which often have important collections and an academic reputation, which are most used, but even here the majority of enquiries are by specialists" (Merriman and Swain 1999, p. 260).

In archaeology, records showing the *provenience*, or detailed excavation location of collections, are an essential element. "The integration of these records with the objects and specimens" is what makes the objects useful for research and interpretation (Sullivan and Child 2003, p.2). In accordance with this emphasis on records, Callery (2002) found that archaeological records in museums were quite detailed in comparison with records pertaining to natural history museum collections, speculating that this was due to the destructive nature of research in archaeology:

> Both anthropology and archaeology tended to have detailed descriptions in the accession records. Perhaps since both destroy the environment that they are studying, archaeologists and anthropologists are particularly dependent upon the records of those that have preceded them in the field. Site maps, level markers and photographs of objects in situ are necessary additions to field notes and other measurements and descriptions of the isolated objects. (Callery 2002, p. 200)

In contrast, however, Faniel et al. (2013b) report that archaeologists using museum collections expect (and often receive) less contextual data in museum records than in other field archaeology data sources. They attribute this to changing practices in museum collecting over time, acknowledging that purchased artifacts that have entered museum collections have much less specific provenance information.

Indeed, museum staff rely to a large degree on the information submitted with objects when creating their own descriptions of objects. "Archaeological cataloging is usually begun by the repositing archaeologist, who records basic information […] and that information which is necessary for his or her research. The repository collects and records the basic information […] using either data supplied by the repositing archaeologist or creating it" (Winter 1996, p 93-4).

Because of their traditional focus on artifacts, most archaeological museums are not perceived as well equipped to handle the born-digital data currently being produced by archaeologists.

> Currently, most RFPs, SOWs, contracts, and agreements do not specify the requirements for digital curation. As a result, digital data, such as field records, images, laboratory records, data sets resulting from field and laboratory analyses, and Geographic Information System (GIS) maps, are stored on CDs or other digital media within a curatorial facility that focuses on curating material remains. The digital records are treated the same as paper records and artifacts. Such curation practices neither preserve digital data nor make it accessible; CDs and other digital media degenerate over time, are not readily accessible to users, and will eventually become obsolete as computer hardware and software change. (tDAR 2013)

Unless archaeology museums can develop reliable systems for ingest, preservation, and dissemination of data, the discipline as a whole risks the separation of artifacts from the records describing their context, a major archaeological concern (Simbulan 2013).

With this brief introduction to archaeological research, I now turn to botany, to conduct a similar investigation of the history, research methods, data practices, and role of herbaria in the work of that field.

2.9 Botany: Social Worlds and Data

Botany is the branch of biology concerned with plant life. The study of botany encompasses the ecology, anatomy, morphology, and genetics of plants. Botanists collect and study plants, deposit them in herbaria, and use herbarium specimens as objects for comparison. They publish descriptions of new species, guides to the flora of a geographic region, reports on the relationships between plants and their environment, and treatises on plant families. In the process of their work, botanists create many kinds of data including field notebooks, specimens and specimen labels, photographs, drawings, genetic code, spreadsheets, databases, and models of species distribution patterns. In this section, I explore the work of botanists: a history of the discipline of botany, methods and technologies that have influenced botanical work over time, and issues in botanical data collection and management. I pay particular attention to the subfield of systematic botany, with which many members of the Herbarium staff and its researchers identified.

2.9.1 A Historical Perspective

The history of botany can be traced to a number of sources of concern about plants. Humans have always been interested in plants, as food and as medicinal and economic resources. It took quite a while, and a confluence of social forces including technological and theoretical advances, for these interests to coalesce into the discipline of botany. In this section, I discuss the development of botany as a field from these and a number of other sources. The role of governments, universities, amateurs, and botanical societies in shaping this profession will be discussed in the sections below.

While the legacy of botany is no doubt traceable to prehistoric practices, its written history can be traced to ancient Greece, where specialists collected and sold root plants for magical and medicinal purposes (Greene 1909). During this period, Hippocrates (460-357 BCE) authored descriptions of medicinal plants and Theophrastus

(371-287 BCE) the “Father of Botany” classified plants based on their characteristics. Plant classification at this time, however, was largely restricted to specific properties, particularly the root, and did not often consider the whole plant (Eames 1941).

In the early 16th century in Europe, interest in ancient writing on botany, as on many subjects, experienced a revival. Beginning in Germany, a movement of self-stylized Herbalists sought out ancient Greek texts on medicinal plants while collecting their own specimens in herbaria and botanical gardens and publishing classifications and descriptions of a large number of species in texts they called herbals (Sharp 1941). Also during this era, Luca Ghini (1490-1556), a professor of botany at the University of Bologna, became the first person to press plants to dry them and then mount them on paper, the basic practice still used to preserve plant specimens (Bridson and Forman 1999). At this early time, then, some of the major characteristics we now associate with botany were already in place: plant collecting, in both dried and living forms, description and classification, and publication.

One important historical source of botanical activity has been the colonial efforts of European governments. The Spanish government’s motivation in funding the Columbus expeditions was in part the retrieval of spices, a motivation that continued to inform Spanish colonial efforts in the Americas and the Philippines the 16th and 17th centuries. De Vos describes these activities as economic botany: “the practice of studying the botanical properties of plants that may be of use to human society and cultivating them for profit” (De Vos 2006, p. 400). In colonial contexts, this involved both the discovery of plant species in new locales and the introduction of species to colonial territories for the purpose of cultivation. This work often included cooperation with botanical gardens and herbaria, as in the case of

> English naturalists who collected “exotic” plants from far-off lands, and sent seeds and seedlings to Kew Gardens where they were cultivated and studied, then shipped off to a part of the empire where they could be best grown in large quantities. (De Vos 2006, p. 404)

These resources were often explicitly government supported. For instance, Cook (2002) notes that,

> French naturalists enjoyed considerable organizational and financial support from the crown. In 1706, for example, the Nantes apothecary garden became an official

> naturalization garden, with ships' captains required to deposit overseas seeds and plants there. (Cook 2002, p. 186)

Botanical discovery, description, and management has been a common goal to most colonial projects, including the colonization of North America, as the colonizing government sought to catalog and exploit the resources of the new territory.

Botanical floras, a major part of the information infrastructure of botany, also emerged in this era, benefitting from the growth in overseas exploration and colonial activity (Sharp 1941). Floras serve as references to the plant life of an area. These publications describe the plants growing in a particular geographic region, habitat, or climate and usually include dichotomous keys that help botanists make a series of judgments about the characteristics of a plant in order to identify its species. Floras both codify the current knowledge of the plants of an area and function as manuals for botanists trying to identify specimens (Singh 1999).

Biological surveys sponsored by government agencies continue to provide a basis for decisions regarding natural resource management in the United States, while simultaneously providing specimens for the natural history collections where those objects are deposited (Lane 1996). Schiebinger and Swan (2005) note that while botanical historiography has emphasized the growth of standards in this era, governments played an important role in establishing botanical infrastructure.

> A resilient and long-standing narrative in the history of botany has characterized its rise as coincident with and dependent on the development of taxonomy, standardized nomenclature, and "pure" systems of classification. Indeed, the late seventeenth and eighteenth centuries witnessed key developments in the systematization of many fields. But to isolate the science of botany is to overlook the dynamic relationships among plants, peoples, states, and economies in this period. […] [E]arly modern science and especially natural history, of which botany was a subfield, remained strategically important in global struggles among emerging nation-states for land and resources. (Schiebinger and Swan 2005, p.3)

The early modern period was important in terms of the growth of infrastructure for botany, including government participation in collecting and propagating specimens and the development of standards for botanical practice.

The 18th century in Europe saw the rise of a number of competing identification and classification systems for plants. As botanists sought to identify plants, understand new species, and determine their relationship to previously described plants, many individuals proposed their own systems. The first dichotomous keys, systems for identifying plants based on their physical features, emerged during this time. A key uses a series of questions about the features of a specimen to help a botanist determine its identification. Using a "step-by-step approach," keys

> presented readers with pairs or small sets of descriptive phrases. A user would choose the description that best applied to the specimen at hand, then follow the associated instructions about which descriptions to read next. In this way, users could narrow down the possibilities applicable to their specimens by choosing appropriate description after appropriate description, until they reached the specimen's name. (Scharf 2009, p.88)

Dichotomous keys can be used by novices and experts to identify specimens, and are still an important tool in botany. They have grown from text-based to textual and visual systems, and are now developed in electronic environments as well, including mobile applications (Leggett and Kirchoff 2011).

The degree to which 18th century keys and other plant identification systems grouped plants that were physically similar determined whether they were considered "natural" or "artificial" systems. In his widely adopted sexual system of plant identification, the Swedish botanist Carl Linnaeus proposed an "artificial" system whereby the naturalist counts the stamens and pistils (male and female sexual structures) on plants to determine their class and order, then reads genus and species descriptions to pinpoint their identification. While the system was easy to use, focusing solely on one aspect of the plant's physiology, with far fewer steps than keys, the results did not always reflect the "natural" relationships between plants, since plants' sexual similarity is not always commensurate with their physical similarity in other dimensions (Scharf 2009). Identification systems have continued to evolve in botany to encompass images in addition to text and to reflect their authors' theories of the distinguishing characteristics in various plant groups.

Linnaeus is widely remembered for another major contribution to biology: binomial nomenclature. Prior to the Linnaean system, plant names were descriptive and often unwieldy, sometimes consisting of five or six words (Nicolson 1991). With binomial nomenclature, Linnaeus developed a system that includes classification as a part of naming. By consisting of a genus name followed by a species name, binomial classification both groups species (under the genus name) and specifies them. As Stearn explains:

> In botany and zoology the term binomial nomenclature refers to that system of naming associated with Linnaeus whereby a species of plant or animal is designated by a two-word name (binomen, bi-nomial), e.g., *Homo sapiens*, consisting of a generic name, e.g., *Homo*, followed by a one-word specific epithet (trivial, trivial name), e.g., *sapiens*. The same generic name covers all species, living and extinct, put in the same genus. The two-word specific name applies to only one species but covers all the individuals classified in that species. A specific epithet has precision only when associated with a generic name; standing by itself it may be without meaning. Generic names and specific names have to be linked to descriptions of genera and species. In other words, the binomial system of biologists derives from a very old and widely used system of naming in general and is based on the assumption that the organisms to be named can be classified into genera and into species, i.e., into entities of different rank (or taxa as they are now called). (Stearn 1959, p. 5)

Binomial nomenclature is an important standard in botany, coordinating the work of botanists around the world. With a single naming system, botanists can be assured that they are all referring to the same thing. As the International Code of Nomenclature for Algae, Fungi, and Plants (the international standard for plant naming) states, "The purpose of giving a name to a taxonomic group is not to indicate its characters or history, but to supply a means of referring to it and to indicate its taxonomic rank" (International Association for Plant Taxonomy 2012, Preamble).

As Stearn states above, "Generic names and specific names have to be linked to descriptions of genera and species" (Stearn 1959, p. 5). Publication is a central tenet of botany- species descriptions in the published literature establish nomenclatural additions and determine priority- who may claim to have named a new species. A shared botanical standard, the International Code of Nomenclature, deals with authorship, priority, and the ways in which botanical practice recognizes them.

The code is derived from the International Botanical Congress, which first convened in Paris in 1867 to develop professional norms for the practice of botany. Nomenclature was a particularly important issue for this group given widespread synonymy for botanical groups- different names given to the same taxa by various botanists (Daston 2004). Local botanical clubs adopted the codes with their own modifications, often suggesting changes that informed later versions of the code

(Nicolson 1991). In the eleven subsequent versions of the code, each named for the city in which the Congress took place, standards for naming, authorship, and publication priority for plant species have developed. Each Congress has changed the code over the years to reflect botanical practice, with modifications in the 2012 version that permit electronic-only publication of species names and remove the requirement that new plant descriptions are written in Latin, accepting English as well (International Association for Plant Taxonomy 2012). Through more than 100 years and numerous iterations, the International Code of Nomenclature continues to be a core standard of botanical practice.

Botany is one of many biological fields that were greatly influenced by Charles Darwin's 1859 publication *On the Origin of Species.* Darwin theorized that species evolve through natural selection, the process through which populations inherit biological traits according to the reproductive success of organisms with those traits in their environment. Darwin's concept of evolution became a central tenet of biology, influencing the practice of botany, so that concepts of plant classification needed to have an evolutionary component to gain acceptance. As Adolf Engler, the German botanist who developed a method for plant classification still widely in use today, stated,

> [I]t is not simply the task of scientific systems to unite forms marked by common characteristics into groups of a lower or higher order, but to strive towards the goal of allowing the genetic development, or at least the morphological gradation, to express themselves in the arrangement of plants. (Engler 1897, p. 358 quoted in Stevens 1984, p. 190)

While evolution was a concept that had to be accounted for in classification schemes, historians have argued, "ideas about evolution affected only the way in which classifications were explained, rather than the way in which they were constructed." (Stevens 1984, p. 183) Phylogeny, the evolutionary history of taxonomic groups, became a central concern of botany.

Throughout this history of botany, the importance of travel to botanical practice is clear: someone must actually collect a plant in its original habitat before it can be studied, cultivated, or used. Because travel can be difficult and expensive, botanical networks of exchange have always been a part of practice in this field, with botanists exchanging specimens with their colleagues. In addition, botanical practice often included enlisting non-botanists to collect specimens from far away locales. In post-colonial America, for instance, botanists in the eastern states would solicit specimens from westerners (Lewis 2005). Cooperation between professional and amateur botanists helped both groups advance their work, in part through specimen exchange. While amateur involvement in botany is ongoing, Keeney (1992) explains that professionalization of the field cut out amateurs from central roles in the study of plants in the 19th century.

Keeneys' depiction of the amateur spectrum of botanical work in the United States begins in the 1820s, when botanizers, as some amateur botanists of the time called themselves, and professional botanists shared a network for the exchange of specimens and knowledge. Members of both groups collected plant specimens, often sending them to other botanists and botanizers to identify. Amateur botanists were largely physicians and clergy, with interests in the medicinal qualities of plants: *materia medica* (Stannard 1966). In their botanical pursuits these amateurs were not very different from their professional counterparts. They read the same journals, joined the same organizations, and corresponded with each other to exchange specimens and make identifications. At the beginning of the 20th century, however, this network shifted, favoring professionals to the exclusion of their botanizer counterparts. Keeney explains that a host of factors contributed to this professionalization at the expense of amateur access. Pre-formulated medicines gained prominence at the end of the 19th century, reducing the need for doctors to have knowledge of the medicinal properties of plants. National scientific societies like the American Association for the Advancement of Science emerged, with predominantly professional and academic leadership, who "struggled to impose professional standards and ideals of scholarship and documentation upon the papers given at meetings and published in the proceedings," alienating amateur members and keeping them from full participation (Keeney 1992, p. 31). In the 1880s and 1890s, a shift in focus from natural history to biology in botany, using experimentation along with observation and emphasizing physiological and ecological issues, allowed professional botanists to define the terms of the field, largely to the exclusion of amateurs. An orientation towards laboratory work requiring specialized equipment shut out amateurs without access to these resources from full participation (Keeney 1992, p. 127-8). During this era, botanists used microscopic technology in anatomical studies to identify plant tissues at the cellular level and made a major discovery in chlorophyll and its role in photosynthesis. Both developments were rooted firmly in laboratory work.

Twentieth century botanical practice was greatly influenced by advances in chemistry and the advent of molecular biology. In the early 20th century, biochemists using thin layer chromatography were able to examine and identify the molecular activity of plants, and, with the advent of DNA extraction in 1944, botanists were increasingly able to study the genetic factors related to plant characters. By the late 20th century, botanists were using genetic information to determine taxonomic relationships among plants, no longer relying solely on physical traits. In the mid 20th century, ecological and biogeographical studies became a focus of study for some botanists, examining plant communities and the relationships between organisms within their ecosystems. Transmission and scanning electron microscopy, which emerged during this time, allowed a closer look at plant structures while developments in computing brought about the practice of numerical taxonomy, applying algorithms to large data sets to come to taxonomic conclusions. Cladistics, an approach to biological classification grouping organisms with common unique characteristics from a recent shared ancestor, also emerged during this era, taking advantage of computational phylogenetics to analyze molecular sequencing data and determine species ancestry (Morton 1981). Now, in the 21st century, botany is a field of many methods, both field and laboratory based, contributing to an ever-growing understanding of the plant kingdom.

2.9.2 Botanical Specialization

A number of specializations in botany define the research interests, questions, and methods that botanists use to approach their work. They function as smaller communities of practice among botanists, who may more closely identify with the other practitioners of their sub-discipline than with botanists as a whole. In this section, I describe the major areas of botanical specialization, which primarily run along taxonomic, methodological, and geographic lines.

Taxonomy and systematics deal with the identification and elaboration of species and their classifications. Taxonomy "is a science that includes identification, nomenclature and classification of objects, and is usually restricted to objects of biological origin; when limited to plants, it is often referred to as systematic botany." (Lawrence, quoted in Bridson and Forman, 1998, p. 2). Systematics has been defined as "a science that includes and encompasses traditional taxonomy, the description, identification, nomenclature, and classification of organisms […] that has as its primary goal the reconstruction of phylogeny, or evolutionary history, of life" (Simpson 2005, p. 9). These definitions highlight the closely linked nature of taxonomy and systematics in botanical work—both definitions refer to the other term. Following Simpson, taxonomy is considered a subset of systematics in the present study, with the latter's focus on evolutionary history considered to be the major differentiation. Ultimately, however, self-identification by botanists as systematists or taxonomists guide the use of these terms here. Botanists working with plant systematics may use specimens they collected themselves, herbarium specimens, or specimens received from exchange. They may perform morphological and anatomical analysis (including microscopy), chromosome or chemical analysis, numerical taxonomy, and cladistics to do their work of mapping plant families (Singh 1999).

Botanists often specialize in a particular plant group, for instance fungi, algae, mosses and liverworts, ferns, or fossil plants (paleobotany), devoting their careers to developing expertise in a particular plant family. Botanists may take morphological approaches to their work, studying the physical characteristics of plants and their anatomical structures. They may also take a genetic or chemical approach to analysis. Some botanists, particularly those that author flora, guides to the plant life of a geographic region, may be specialists in the plant diversity of a geographic area. Practical applications of botany may also guide a botanist's specialization, including plant pathology, economic botany, and ethnobotany (Robinson 2002).

In addition to using plants to perform their research, botanists may also make use of data about plants, collected by themselves or others. While computational phylogeneticists and practitioners of cladistics analyze the genetic information from large numbers of plants to determine the relationships between genetic expression and morphological traits, botanists studying biogeography, ecology, and biodiversity may correlate specimen locality data with climate and habitat related data sources (Morton

1981). Sharing research goals and methods with others within their area of specialization, these smaller communities of practice shape the norms of botanical sub-disciplines.

2.9.3 Botanical Data Practices

Given the wide range of research methods in botanical practice, it is not surprising that data in this discipline may take a number of forms. In this section I discuss the forms of botanical data, norms for recordkeeping, and data practices in botany, including data sharing. I begin with the field notebook, the primary recordkeeping system for plant collectors, which also functions as the source for specimen label information in herbaria.

For botanists working in the field, collecting or otherwise examining plants in their natural habitat, the field notebook is a widely used tool for data collection and recordkeeping. Field botanists use notebooks to record details about specimens they collect, including the species name, the date and location of the collection, and other information about population counts, measurements of plants, and descriptive notes about the plant's habitat. As the professional literature advises,

> For each collection, data to be recorded include the date, names of collectors present, location (including geographical coordinates and altitude if equipment permits), ecological notes such as habitat type and population size in natural populations, and all information about the plants themselves that may not be evident from the dried specimen (e.g., flower or bark color, distinctive odor, or the habit and size of a large plant). (Hildreth et al. 2007, p. 14)

Botanists often collect multiple plants of the same species from the same site, in order to exchange them with other collectors and herbaria. Each specimen is given a number by the collector: "a unique number from the collector's single running number sequence, which should start at 1 and continue ± unbroken" (Bridson and Foreman 1998, p. 206). Specimens must be carefully dried by the collector, and are usually frozen for a period of time upon herbarium deposit in order to reduce the chances of insect infestation (Hildreth et al. 2007).

Through deposit in herbaria, botanists use specimens as vouchers for claims made in publications. Frank and Perkins explain, "A voucher herbarium specimen is a pressed plant sample deposited for future reference. It supports research work and may be examined to verify the identity of the specific plant used in a study. A voucher specimen must be deposited in a recognized herbarium committed to long-term maintenance." (Frank and Perkins 2007). As the home to voucher specimens, then, herbaria are central to the botanical research process. Even botanists who do not use herbarium collections in their own studies use them as repositories for the specimens they used in their research.

The data derived from specimens can take many forms, depending on the botanist's research goals and methods. Botanists studying plant morphology may make drawings and photographs of the specimen and its anatomical details, taking measurements of these characteristics and using statistical techniques to compare them in plant populations (e.g., Ortega-Olivencia and Catalán 2009). Phylogenetic researchers extract DNA from specimen fragments, amplify them through techniques like polymerase chain reaction (PCR), use computer programs to assemble, align, and edit the sequences, and perform statistical techniques to isolate the relevant gene sequences distinguishing one species within a genus from another (e.g., Yang and Berry 2011). Biogeographic botanists and ecologists use plant occurrence records (often derived from herbarium specimens) along with climate variables derived from other data sets to model the distribution of species (e.g., Loiselle et al. 2008). In each of these cases, botanists create a series of inscriptions – instantiations of their data at different stages of processing – but they all fundamentally rest on the specimens themselves, which botanical norms dictate must be deposited at herbaria in order to serve as vouchers.

2.9.4 Sharing Botanical Data

While voucher specimens must be deposited at a herbarium, most of the other forms of data created by botanists do not share this mandate. Data sharing mostly takes place informally, between collaborators, although several venues have emerged for sharing the data underlying published articles. In this section, I review the state of data sharing in botany.

Along with voucher specimens, genetic sequences are a form of botanical data that is routinely shared. Phylogenetic researchers publish genetic sequences in the database GenBank, receiving a GenBank accession number that they can cite in publications as a reference back to the sequences (Benson et al. 2003). In part because "DNA sequences are easily transferred electronically, and the language of their four constituent bases is nearly universal," sharing sequences in botany and other biological sciences is relatively easy (Chase and Cox 1998, p. 216). References to GenBank accession numbers, associated with the specimens from which they were derived, are common in botanical publications dealing with genetic data.

Some botany journals provide mechanisms for authors to make supplementary data available to readers. One example is the journal Taxon, which states that it is "providing authors the opportunity to store in electronic form supplementary data too bulky or too technical to be included in the printed version of their article. All such data will be maintained as separate files in the online version of Taxon" (International Association for Plant Taxonomy 2011). Such offers from journals are one important way that botanists can make their data sets accessible to their colleagues, while maintaining connections to the publications produced from the data.

Data sharing during the research process is prevalent in botany as well, in part because of the collaborative nature of many botanical research projects. As Harley et al. (2010) note,

> Society's "grand challenge" questions, such as climate change, disease prevention, food production, or sustainable fuels, demand that multiple disciplines converge around large topic based questions because no one discipline has the expertise to tackle the problem. (Harley et al. 2010, p. 289)

Botanists working on these vital issues may find themselves in large, interdisciplinary collaborations. In botany as well as other biological sciences, "discussions about data tend to be done by circulating data files by email, desktop sharing, and uploading files to shared workspaces" (Harley et al. 2010, p. 296). Data moves between collaborators through the use of information technologies that allow them to compare, combine, and analyze datasets over large distances (Endersby 2001). Data can be discussed and questions answered between individuals.

At the institutional level, Darwin Core has become the most widely used standard for biodiversity data, aiding data sharing in botany. Beginning in 1999, and leading to its ratification as a standard in 2009, the Darwin Core Task Group of the Taxonomic

Databases Working Group developed this standard, based on the Dublin Core Metadata Initiative. As Wieczorek et al. (2012) describe:

> The terms are organized into nine categories (often referred to as ‘‘classes’’) […], six of which cover broad aspects (event, location, geological context, occurrence, taxon, and identification) of the biodiversity domain. The remaining categories cover relationships to other resources, measurements, and generic information about records. (Wieczorek et al. 2012, p. 2)

The standard has been met with broad acceptance from the natural science community, with help from large projects like the Global Biodiversity Information Facility, which publishes biodiversity information from over 340 organizations around the world and has developed toolkits to help organizations work with Darwin Core (Wieczorek et al. 2012). As providers of biodiversity data, Darwin Core has become an important standard for herbaria.

2.9.5 Botanical Material in Herbaria

In addition to serving as a home for voucher specimens deposited by botanists, herbaria function as resources for a range of botanical research purposes. A herbarium is a "collection of preserved plants built up over a long period of time" (Bridson and Forman 1999, p. 4), making it an important resource for botanists, who consult plant specimens collected by their colleagues, past and present. Botanists use herbaria for a number of reasons, from taxonomic and systematic study to sources of ecological data regarding the prevalence of species in a given geographic region over time (Boyle 2011). In this section, I discuss the role of herbaria in enabling botanical research.

A primary user group for all natural history collections, including herbaria, is biologists involved in taxonomy and systematics (the former is concerned with naming and describing new species while the latter is concerned with determining the evolutionary relationships between species). "Systematic biologists base their studies on genomic data (arrays of genes or whole genomes) and phenomic data (features extrinsic to the genome that include proteins, cell structure, anatomy, and many other characters)" developing phylogenies, tree-like maps of the relationships between species (Novacek and Goldberg 2013, p. 412). By examining some subset of the genes, proteins, cell structure, anatomy, and other characters of a number of plant specimens, systematic botanists come to conclusions about the relationships between species. Natural history collections also act as institutional homes to "the greatest concentrations of experts devoted to taxonomy and systematics" – collection curators (Novacek and Goldberg 2013, p. 412). In terms of taxonomic and systematic uses of natural science collections, then, curators of these collections are their own largest user group, suggesting a research network highly entrenched in its collecting institutions.

The relevance of herbarium collections to the systematic and taxonomic study of plants is clear. Bebber et al. (2010) show that 84% of new flowering plant species described between 1970 and 2010 were based on specimens that had been collected more than five years prior, "with nearly one-quarter of new species descriptions involving specimens >50 years old" making herbaria, as the institutions responsible for the long-term preservation of these specimens, essential resources for taxonomists (Bebber et al. 2010, p 1). Consulting herbarium specimens along with the taxonomic literature is suggested best practice for reliably determining the identification of specimens, a core activity of botanical systematics (Singh 1999).

Genetic, genomic, and phenomic study are a second major research use of natural history collections. These techniques, including molecular systematics and DNA barcoding, use specimens from natural science collections to compare portions of genomes to derive analyses (Novacek and Goldberg 2013). As these techniques gain prominence in natural science fields like botany, there is some concern about the relationship between molecular and traditional systematics. While some authors promote the switch to a DNA-based taxonomy within biology, based on samples retrieved from type specimens, they recognize that:

> this will be impossible in most cases, either because types are not available or because they cannot be used for DNA extraction. In such cases, DNA taxonomy will have to be based mainly on sequences from newly collected individuals, which are assessed by experienced taxonomists to determine their identity. (Tautz et al. 2003, p. 71)

Even with the growing dominance of molecular studies, then, morphological taxonomic and systematic experts are needed to provide a reliable determination for a specimen, making them indispensable to biology. Following larger trends in biology towards genetic analysis, however, there is some concern that natural science museums are moving away from systematic work and may not have the on-staff expertise needed to identify and curate specimens (Anderson 2005). Tautz et al. (2003) also underline concerns about the suitability of herbarium specimens for molecular studies: not all specimens will yield a reliable genetic sample- in some cases, the specimen's age and condition make genetic analysis impractical.

The third major use of natural science collections is biogeographic and environmental study, which uses specimen data to map species distribution, layering it in Geographic Information Systems with other location-based data like climate, topography, and other parameters. Through these analyses, researchers can draw correlations between species distribution and environmental factors and model future distribution (Novacek and Goldberg 2013). These researchers may not need to access a specimen physically in order to use it in their analysis, and they may find that data consortia meet their needs for specimen data. The research uses of herbaria are discussed and elaborated upon with data from the present study in chapter 5, which addresses the experience of researchers in a herbarium in comparison with those in an archaeological museum.

2.9.6 Herbarium Practice

Specimens and related data enter herbaria in several ways: through field collections directly deposited by botanists (particularly those who have some association with the institution), exchange with other herbaria, acquisition of a historical collection from a botanist or herbarium, gifts for determination, and temporarily, through loans (Nevling 1973). New specimens that enter a herbarium's collection are frozen or fumigated (for insect control), identified by staff, accessioned, mounted along with their labels on a herbarium sheet, and stored with other examples of its species within the collection (Bridson and Forman 1999). In order to use the specimens, researchers visit a herbarium onsite and retrieve them from the collection (or make a loan request to herbarium staff) and then review them in groups for comparative analysis. As Latour wrote of herbarium research, "Once classified, specimens from different locations and times become contemporaries of one another on the flat table, all visible under the same unifying gaze" (Latour 1999, p. 38).

Loans and other research requests between herbaria work through institutional channels, where one collection manager or curator contacts another on a researcher's behalf. This is a pragmatic measure: "The main reason for inter-institutional rather than inter-individual arrangements is […] due to the glacial time-scales of systematic botany. Individuals may move, retire, or die, but institutions only rarely do any of these things" (Swales 1998, p. 47). Herbaria frequently establish exchange relationships as well, where they send duplicate specimens to other herbaria that may wish to grow their collections in a given genus. They maintain records of exchange balances with other institutions to ensure reciprocation (Ferguson et al. 2012). One form of specimen exchange arranged between herbaria, called "exchange for identification" or "gift for identification," is used to request identification of a specimen by staff at the receiving institution. In this case, a staff member of the receiving herbarium with expertise in that taxon will return their annotation of the duplicate specimen to the gifting institution, so that both collections are authoritatively identified (Ferguson et al. 2012). Gifts for identification are often made in cases where staff at the receiving herbarium has taxonomic knowledge that the gifting herbarium does not.

In order to use natural science collections, including botanical specimens, a researcher must have access to both a specimen and its label. Lane (1996) eloquently describes the relationship between the two, showing that both are essential to using a specimen.

> Natural history collections have always contained a wealth of data: genetic and phylogenetic information stored as an inherent part of the samples of organisms themselves and biogeographic, ecological, and biographical information stored in the labels that are affixed to them. Together, a preserved organism and its label are a scientific specimen that has great intrinsic value. Separately, the label is a piece of paper with meaningless inscriptions on it, and the plant, spider, microbe, mushroom, or bird, though carefully preserved, is just so much dead organic matter. (Lane 1996, p. 536)

The label provides essential descriptive information about the specimen, without which it would be incomplete (Frank and Perkins 2007).

While label information is needed to provide context to specimens, herbarium staff rely on collectors to provide that vital data. Accordingly, they may provide guides to potential contributors specifying the information needed in order to deposit a specimen. As one such guide states,

> Only the collector knows fully the circumstances of collection, and thus bears responsibility for sharing (on the label) what he or she knows about the locality, habitat, appearance, and attributes of the plant—whatever cannot, years later, be determined from the pressed, dry carcass. (Voss 1999, p. 57)

The label contains information that cannot be gotten from any other source. Without a high-quality label, the specimen itself may be considered worthless.

Keeping a good field notebook and writing useful specimen labels are two aspects of fieldwork that are taught to students as they learn botany. Field notebooks are often the source material for labels, tracking the same collection information but allowing the author to add growing conditions and other details that might be too lengthy for a label. Field notebooks preprinted with a form can also be used to prompt the collector to record the name, locality, habitat, altitude, and other important pieces of metadata (Singh 1999).

As numerous researchers use a herbarium specimen over the years, they will attach annotation slips to the herbarium sheet to leave a record of their assessment of the specimen's identity. Annotation labels, also called determination slips, are additive – rather than changing the original label, a botanist adds his or her own new label in conversation with the collector and previous annotators. Along with an updated species identification, determination labels provide the date and name of the annotator, leaving a useful history for future researchers (Singh 1999).

The most important kind of specimen in natural history collections is the type, "a particular specimen chosen to be the 'name bearer' of a species" (Novacek and Goldberg 2013, p. 412). Types are routinely deposited in natural history collections as a physical record of biology that can be consulted by future researchers. The International Code of Nomenclature specifically recommends deposit of type specimens in herbaria, as quoted below:

> It is strongly recommended that the material on which the name of a taxon is based, especially the holotype, be deposited in a public herbarium or other public collection with a policy of giving bona fide researchers access to deposited material, and that it be scrupulously conserved. (International Association for Plant Taxonomy 2012, Section 7A.1)

Because of the taxonomic role of types, as physical evidence for a nomenclatural decision, these specimens are particularly important to botanists, and are often stored separately within herbaria (Bridson and Forman, 1999).

Authoritative guidelines for these and other aspects of herbarium practice have been published by the Royal Botanic Gardens, Kew in an extensive handbook (Bridson and Forman 1998) and by the American Society of Plant Taxonomists (ASPT) in a brief document entitled *Desirable Procedures in Herbarium Practice and Ethics*. The latter document was first published in 1958, revised in 1973, and a new edition is now being prepared for publication by a group of herbarium curators. While the newest edition has not yet been finalized, a draft document states that it was needed, “Because the number of practicing taxonomists trained in classical methods has declined, making it more likely that non-systematists may find themselves in charge of a collection, and since many new methods and challenges have arisen since 1973” (Ferguson et al. 2012, p. 1). These documents are remarkably succinct, outlining procedures for loans, exchange for identification, visitors, and requests for information in approximately four pages (Kobuski et al. 1958; Nevling 1973; Ferguson et al. 2012). The Kew Gardens *Herbarium Handbook* and the ASPT *Desirable Procedures* document outline best practices in herbarium management and provide advice to herbarium staff as they fulfill their duties. The quotation above from the *Desirable Procedures* document suggests a change to the social world of herbaria, where taxonomists using classical methods are a declining population. The implications of this change will be discussed in chapters 4 and 5, dealing with staff and researcher interactions with collections. In the present context, it is a reminder of the changing landscape of research communities, as well as the interrelated nature of herbarium and botanical practice.

2.10 Conclusion

This chapter has delved into a number of topics related to the research use of museum collections in botany and archaeology including the representation of museum objects, the creation of data and knowledge claims, information infrastructure, and the decision to use data created by someone else. Here I will conclude with several important points of comparison between botanical and archaeological practice concerning the identification of objects by their collectors, the basis for future museum description and researcher access.

In botany, the identification of specimens is fairly straightforward: the collector notes the species name they feel is appropriate when they collect the specimen itself. This identification may be disputed or overturned by later botanists through the annotation process. Botanists record these changes on the specimen sheet itself by adding annotation labels. Several standards make this process work. Rules for nomenclature specified in the International Code of Nomenclature for Algae, Fungi, and Plants, the taxonomic system that has been adopted by biologists worldwide, and norms for data collection in field notebooks and their translation into labels, expressed in professional and educational publications, all help to ease specimen naming. Standards are well established and members of this social world understand how to use them. The prevalence of molecular studies further removes the guesswork from specimen identification, where matching a genome to a previously sequenced species can yield an ostensibly objective identification.

In contrast, archaeological determination of an object's identity is highly contextual. During the excavation process, archaeologists decide whether an artifact is collected, what information about it is recorded, and what its disposition will be through an interpretive process. Where an artifact was found, what was found in the same physical context, and the prevailing understanding of the site itself all shape this interpretation. In a publicly facing museum catalog record, the artifact is presented without its full context, making the subjective nature of its identification invisible to users.

Data collection practices in archaeology and botany are largely understood, as are the processes by which the objects collected in these fields enter museums. What remains to be seen, however, is the ways in which these objects form the basis of later research, once they have become part of a museum. While researchers have explored the extent and character of collection metadata in museums (Callery 2002; Gilliland-Swetland and White 2004; Trant 2008) the relationship between collection metadata and research use of museum collections remains to be discovered. Similarly, while some work has been done into the ways in which scholars repurpose data created by others

(Van House 2002a; Zimmerman 2003 and 2008), research into the processes by which they come to select, use, and understand museum data is an underexplored area. In the following chapter I outline the design of the present study, intended to address this gap.

Chapter 3

Methodology

In this chapter, I describe the methods used in this study to investigate the practices surrounding the research use of museum collections. The chapter begins with a discussion of my research questions. It continues with a justification of my research design, a comparative case study, including the selection of case study sites, participant recruitment, and the specific data collection and analysis methods employed.

3.1 Research Questions

In chapter two I explored the data reuse and museum studies literature, identifying significant gaps in our understanding of the museum research process. While quantitative studies address the amount of research use received by collections (e.g. Merriman and Swain 1999), qualitative studies exploring the research process in museums are lacking. In particular, the relationship between museum practices for managing and representing collections and researcher practices for finding, accessing, and using museum data is currently unknown. In this section I explain my research questions in relation to the gaps I identified in the literature.

The major research question guiding this study is *What is the relationship between museum objects, their representations, and research use?* With this question, I define the scope of the study: museum objects and their representations, staff practices that make those materials amenable to research and other uses, and the practices of researchers to make use of those materials as research data. As I discussed in chapter 1, what functions as data may be a heterogeneous assemblage of resources, and is defined by an individual researcher in a specific context (Wynholds 2011), subject to the norms of a particular research social world. This question deals with the function of museum representations as boundary objects, coordinating the work of staff and researchers. It links museum staff and researcher practices through the management of objects and the production of representations, including databases and documentation, and their use in research.

The following sub-questions define the specific areas that comprise researchers' practices with regards to museum data for the purpose of my study:

- How do researchers find and access museum data?
- What are the characteristics of the data they receive?
- What information about the data do researchers require in order to use the data?
- How do researchers assess the quality and relevance of the data they receive?
- How do researchers analyze museum data in the course of their work?

Following the emphasis in the data curation literature on the need for adequate metadata (e.g. Atici et al. 2012; Fear and Donaldson 2012), and the work of curators to make data amenable to reuse (Daniels et al. 2012), I argue that one major factor influencing research with museum collections is the work of museum staff to organize collections, describe them, and manage access to them. Therefore, a second research question focuses on the practices of museum professionals in managing resources for the museum: *What factors influence the practices of staff members as they describe and manage museum data?*

In addition, the following sub-questions define the specific areas that comprise staff members' practices with regards to museum data for the purpose of my study:

- How do staff members accession and organize museum data?
- What qualities of the data do they choose to represent in public and internal information systems, and how do they make those decisions?
- How do museum staff members develop and represent new understandings of the objects in their collections?

- How do museum staff members manage and facilitate the research process?

To explore these questions I investigated the structures of two social worlds: 1) researchers, who make meaning and form new knowledge based, in part, on the use of museum data, and 2) museum staff, who create, modify, manage, and interpret representations of museum objects while providing access to them. Many staff members at museums, particularly curators whose work involves augmenting and understanding collections, actively pursue their own research agendas using museum data. Because their relationship to museum data, as expert custodians, offers them a different kind of access to collections, I examine researchers among museum staff as a particular category of user. Their position as a member of both museum and disciplinary social worlds is an important distinction to consider in examining the practices of this group, discussed in greater detail in the upcoming section on participant recruitment and selection.

3.2 Qualitative Approach

I chose a qualitative approach to this research because I sought an in-depth understanding of the behavior of museum staff and researchers in their interactions with museum data, focusing on why and how they engaged in particular practices. A qualitative approach is appropriate to these goals because it seeks "answers to questions that stress *how* social experience is created and given meaning" (Denzin and Lincoln 2011, p. 8) through interactions with participants engaged in the activities in question.

The qualitative data generated from this study provide a rich description of the experiences and motivations of participants. However, the data do not allow me to make causal claims about the museum research process, a goal outside the scope of this study, which would require an entirely different approach to data collection and analysis. In addition, the data are context specific and do not permit generalization to other contexts. As Creswell states, "The intent in qualitative research is not to generalize the information […] but to elucidate the particular, the specific" (Creswell 2013, p. 157). By providing an in-depth understanding of particular instances of the museum research process, I do not claim that these instances are representative of all museum-based research, or that they depict the full range of museum and research practices. Instead, I assert that many of the practices seen in these instances are likely to emerge in the experiences of other museum-based researchers and museum staff, indicating value for the theoretical propositions generated from this data.

3.3 Comparative Case Study Design

To investigate museum-based research, I employed a comparative case study of the users of two museum collections. In this section I argue for the suitability of the case study approach to this research. The case study is a well-known social science research methodology providing depth of understanding and rich description of a phenomenon in a particular setting (Mohr 1985). Through methods such as interviews and observations, focused at a particular site over a period of time, the analyst is able to develop a nuanced and layered picture of the case under investigation. Given the specificity of case studies, the ability to generalize one's findings is not a goal of this methodology; however, successful case studies suggest applicability to other cases with similar characteristics (Lincoln and Guba 2002). Yin argues that case studies are "generalizable to theoretical propositions and not to populations or universes" (Yin 2009, p. 15). The goal of this study is to expand and generalize theory about the research use of museum collections, a goal for which the case study is an appropriate method.

A case study methodology allows flexibility in the research design, permitting observations made in the case to direct research methods and goals as the work progresses (Fidel 1984). The exploratory nature of case studies permits the researcher to engage in an iterative process of gaining understanding of the case and refocusing observation as meaning is gathered from the specifics of the case (Stake 1995, Zach 2006). This flexibility allows knowledge of the individual case to guide inquiry as the study progresses. Furthermore, the selection of two cases for study and replication of methods between cases:

> allows the researcher to identify possible patterns in the data and explore them by returning to the field for more data. Conscientious application of these techniques ensures that explanations for the phenomena under study developed from the data are verified during the course of the research process. (Zach 2006, p.13)

Through iterative data collection and analysis between two cases, the researcher is able to gain a deep understanding of each case, verifying findings within and between the cases.

3.4 Case Study Site Selection

I designed this study as a comparative analysis of the research use of materials at two university museums serving different scholarly communities. In this section, I justify my selection of university museums in general and two museums at the University of Michigan, in particular. In choosing to conduct a comparative case study at two sites, I have selected a maximum variation purposive sample designed with sufficient variability in several areas: the research communities served, the kinds of materials available to researchers at each museum, the type and degree of public access to collections at the two museums, and the variety of research use of the collections. Patton explains that maximum variation sampling:

> aims at capturing and describing the central themes or principal outcomes that cut across a great deal of participant or program variation. For small samples a great deal of heterogeneity can be a problem because individual cases are so different from each other. The maximum variation sampling strategy turns that apparent weakness into a strength by applying the following logic: Any common patterns that emerge from great variation are of particular interest and value in capturing the core experiences and central, shared aspects or impacts of a program. (Patton, 1990, p. 172)

Through maximum variation sampling, then, this study was designed to reveal both common patterns in research practices at the two museums and areas of divergence. In the following sections, I address the areas of variation that I used as selection criteria for the case study sites.

3.4.1 University Museums

First, I chose to limit my sites to university museums. As on-site resources for the members of a particular academic community, university museums contribute to the scholarly infrastructure of those institutions. University museums are generally subject-oriented, containing collections derived from the research activity of academics within the larger institution. They frequently treat their collections as research archives, keeping the majority of objects in storage rather than on public exhibition until a researcher requests some subset of them for use (Keene 2005). Their curators often have academic appointments, requiring them to conduct research as part of their ongoing duties. Because of their strong research orientation, university museums are an appropriate group for examination in this study.

In order to understand the range and extent of museums at universities with high research activity in this country, I conducted an analysis of the websites of the seventy-three public universities in the United States classified by the Carnegie Foundation for the Advancement of Teaching as RU/VH: Research Universities (very high research activity) (Carnegie Foundation for the Advancement of Teaching 2010). This search of university websites reveals a wide range in the types of museums on research university campuses and in the number of museums per university. Eight of the seventy-three universities did not appear to have museums on campus while forty had between one and three museums. Nineteen of the universities had four or five museums on campus, while six of the universities had six to twelve museums on campus. These results may not reflect the full number of museums at each of the universities—some university museums may have a limited web presence. However, they do indicate which of the universities sharing the RU/VH: Research Universities (very high research activity) designation within the Carnegie classification have museums that are easily findable on the university's website.

My web search revealed that science and art museums were the most common museum types among universities in the United States with Carnegie's very high research activity classification. Fifty-one of the seventy-three universities had at least one art museum while thirty-seven had some type of natural history or science museum. In the latter case, there was quite a bit of variation in the organization of natural history museums, which may account for the range of number of natural history and science museums (between zero and ten museums of this type). Some universities, like the University of Oregon, highlight each of their natural history collections separately (including Fisheries and Wildlife, Bird, and Mammal Collections and a Geological Collection), although they do not seem to represent organizationally distinct museums. In contrast, the University of Michigan's Museum of Zoology has six separate collections organized by specimen type but kept under the same museum umbrella.[8] Archaeology and anthropology museums were at the other end of the spectrum of museum type: of the 73 universities designated RU/VH by the Carnegie Foundation, only 19 have archaeology and anthropology museums. By selecting a natural history museum and an archaeology museum as case study sites, this research examines both the most and least common university museum types.

In Table 3.1, I summarize my findings for museums at public universities bearing the Carnegie classification of having very high research activity. I separately list the University of Michigan, the home to both museums selected in this study, for comparative purposes. While the American Alliance of Museums provides a typology of 18 types of museums in its directory, I grouped these into the four categories shown below (American Alliance of Museums 2011). Some collapsing of categories was necessary to better compare museums in this data set. For instance, I included arboreta and botanical gardens, such as the University of Michigan's Matthaei Botanical Gardens and Nichols Arboretum, in the category "natural history or science" while historic houses and structures, such as the University of Michigan's Detroit Observatory, were added to the "history museums" category. Also included in this category are specialized historical object collections, such as the Sindecuse Museum of Dentistry and the Stearns Collection of Musical Instruments, both listed by the University of Michigan as campus museums. Although many universities included art galleries in their museum listings, I did not include them in my count, limiting my scope to collecting institutions.

Table 3.1. Museums in RU/VH Carnegie classification public universities compared with the University of Michigan

Total Number of museums	**Number of universities**	**Archeology or Anthropology museums**	**Art museums**	**Natural history or Science museums**	**History museums**
0	8	0	0	0	0

[8] Oregon State University "Museums, Galleries, and Collections." Accessed June 10, 2011: http://catalog.oregonstate.edu/ChapterDetail.aspx?key=17#Section3461 and University of Michigan "Museums & Galleries." Accessed June 10, 2011: http://www.umich.edu/museums.php

1-3	40	4	43	17	14
4-5	19	11	27	27	19
6-12	6	4	5	34	11
12	**University of Michigan**	**2**	**1**	**6**	**3**
Total 0-13	*73*	*19*	*75*	*78*	*44*

3.4.2 University of Michigan Museums

I selected both sites for this study from the museums at the University of Michigan. While this limitation in selection confined the study to the context of a particular research university, the narrowing of context provided several benefits. As mentioned above, one benefit emerges due to the museums' association with a research university. Because of their university affiliation, the museums serve constituent communities of scholars from both within and outside the university and promote research use of their collections. A second benefit in selecting museums at the University of Michigan relates to the depth at which I was able to study research activities in these institutions. Researcher visits to museum collections were generally scheduled in advance with museum staff, but sometimes with only a few days notice. My geographic proximity to the collections gave me the flexibility to collect data on short notice when necessary. Since this research design required maximum participation from individuals using the museum collections, flexibility in scheduling meetings with participants on my part was vital. Researchers' time with collections is generally limited, and it was important that I adjust data collection to coincide with researcher schedules, something I would not have been able to do with museums at a long distance away. Because of my own affiliation with the University of Michigan and the frequency with which I was able to visit onsite, I was also able to establish ongoing relationships with museum professionals that were an essential component of participant recruitment.

One final consideration regarding the selection of museums at the University of Michigan concerns a new initiative to move all museum catalogs within the College of Literature, Science and the Arts (LS&A) to a shared system for content management and digital asset management. The adoption of a shared system raised the collection managers' attention to existing descriptive cataloging systems and cataloging practices. My study benefitted from these individuals' articulation of their generally tacit processes.

As the University makes steps towards purchasing and implementing a shared system, which should make collection information more widely accessible to users, this study has the potential to impact that process. By providing insight into the practices of researchers at two of the museums within LS&A, this dissertation addresses use of the information systems already in place, which can inform future system development.

The University of Michigan has twelve museums. After corresponding and meeting with staff at four museums at the University of Michigan, I selected two sites for this study: the Kelsey Museum of Archaeology at the University of Michigan ("the Kelsey") and the University of Michigan Herbarium ("the Herbarium"). I selected these two sites on the basis of several relevant criteria. Important differences between the two museums include the scholarly communities served by their collections, the type and degree of public access to the collections, and the amount of external research activity they receive. One vital similarity between the sites, guiding their selection, is their shared commitment to supporting research activity.

I selected museums with collections serving two different research communities (botany and archeology) in order to explore the use of museum data and knowledge generation in two different disciplinary contexts. This aspect of the study helped me identify factors related both to museum practice and the particular norms within the scholarly communities the museums serve. It offers depth to the research question *What is the relationship between museum objects, their representations, and research use?* by providing two disciplinary contexts in which to compare museum staff and researcher practices. As I discussed in the literature review, the research methods prominent in these two fields use a range of quantitative and qualitative analytical strategies from computational phylogenetics in botany to an examination of the physical characteristics of a group of objects in archaeology. This variation lends itself to an analysis of the role of disciplines in shaping researcher work in museums.

The University of Michigan Herbarium and the Kelsey Museum are also representative of the most and least common types of museums found at universities with very high research activity in the United States (as seen in Table 3.1, above). While natural history museums are the most common type of university museum in this group, archaeological and anthropological museums are the least common. The selection of these two museums provides another kind of variation in the context of university museums.

The disciplines of archaeology and botany have rather different relationships with the museums holding collections related to their work. As I discussed in the literature review, both fields use museums as repositories for the materials they produce in the course of research. Archaeological data, including finds, records, and reports, are routinely deposited in museums, but receive relatively little research use after deposit (Merriman and Swain 1999, Edwards 2012). The addition of finds in archaeological museums that collect objects from outside their own nation's borders has slowed considerably since the 1970 UNESCO *Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property*. Still, archaeological data held in museums present unique opportunities for researchers interested in ancient objects and the cultures from which they originated.

As the primary specimen repositories in their field, herbaria serve an important role for botanists, who both deposit voucher specimens at these museums in order to cite them reliably and use them to examine collections made by other researchers. Herbaria are major resources for the study of plants, used frequently in the description of new species (Bebber et al. 2010). Because natural history museums tend to receive more research use than archaeology museums (Keene 2005) selecting a herbarium and an archaeology museum for this study provides variation in the centrality of museum resources to the research practices of the two fields.

The objects collected by archaeology museums and herbaria are different as well, providing another source of variation between the sites. Botanical specimens are samples of plant life treated as examples of their species. They may have special evidential value as type specimens and embody morphological differences due to factors like habitat or the time of year at which they were collected, but members of the same species are considered directly comparable by botanists as representatives of the same taxonomic group (Singh 1999). This is not the case with archaeological artifacts, which are considered unique to the site from which they originate (Hodder 1999). A ceramic bowl excavated in North America is not seen by archaeologists as comparable to one unearthed at a dig in Egypt because of the vastly different contexts in which they were found. In addition, botanists routinely collect multiple specimens from the same species for distribution to various researchers, giving them the same collector number and metadata, and treating them as equivalent objects. The relative rarity of archaeological artifacts in comparison with botanical specimens, along with the differences in commensurability between objects within each museum, provide interesting points of comparison between the two sites at the level of the museum object.

Another source of variation concerns the extent of records documenting collections at the two sites. Callery (2002) found that the archaeological records in museums were far more detailed than those kept by their natural history counterparts. As she explained, "Site maps, level markers and photographs of objects in situ are necessary additions to field notes and other measurements and descriptions of the isolated objects" for the interpretation of archaeological artifacts (Callery 2002, p. 200). In alignment with her findings, the collector-supplied records available at the Kelsey are much more complex than those held by the Herbarium. At the latter site, documentation is, in many cases, limited to the label accompanying each specimen, although the Herbarium does own field notebooks, notes, drawings, and photographs created by many of the researchers who have contributed to its collections. The use of these auxiliary materials in the research process is an important element of this study: variation in the type and extent of research records and other representations of objects at the two museums permitted a comparative analysis of the role of records in museum-based research.

Both the Kelsey and the Herbarium have a strong institutional commitment to supporting research. The University of Michigan Herbarium describes itself as

> home to some of the finest botanical collections in the world. The 1.7 million specimens of vascular plants, algae, bryophytes, fungi, and lichens combined with the expertise of the faculty-curators, students, and staff provide a world-class facility for teaching and research in systematic biology and biodiversity studies. The organismal and genetic resource collections such as those in the Herbarium provide the best tangible record we have of life on Earth and constitute a crucial resource for use in research and education benefiting science, society, and the university. (University of Michigan Herbarium 2011a)

This phrasing reveals the importance of research uses of the museum's collections to meeting the goals of the institution. The Kelsey Museum also emphasizes the importance of research to its organizational mission, stating:

> The mission of the Kelsey Museum of Archaeology is to serve the international academic community, the University of Michigan, and the public through research, conservation, and exhibition of its collections of artifacts from the ancient and medieval cultures of the greater Mediterranean region and through fieldwork. As a public resource the Museum has a corresponding commitment to sharing the knowledge gained through our fieldwork and other research with the general public of all age levels and in all walks of life. (Kelsey Museum of Archaeology, n.d.)

Research on the museum's collections of artifacts is a major part of the museum's mission, as is sharing the knowledge gained through research with the general public. Both museums state their commitment to research in these passages, demonstrating that research activity is central to their work. By selecting study sites that explicitly emphasize research as a core part of their mission, I expected that the museums' activities, including the representation of collections, would be influenced to a large degree by research concerns.

While both museums state the importance of research using their collections, the number of researchers who actually use the collections in person in a given calendar year varies between the sites. At the Kelsey approximately 20 researchers, drawn from staff and students at the university as well as outside users, visited the collection in 2010 (Interview with Collection Manager AS1). In contrast, the Herbarium visitor log showed 40 visitors in 2010. While all visitors may not have gone to the Herbarium for the purpose of conducting research, I was pointed to the visitor log as a general indication of the quantity of outside research use. These numbers have several limitations: neither of them includes research use of the collection by individuals affiliated with the museums (internal researchers) and both offer estimates of research use rather than hard numbers. Also, Herbarium specimens can be borrowed by other museums for use by their researchers. The visitor log does not reflect this use.

The museums I selected for this study are both active in a larger community of similar institutions. The Kelsey is a member museum in the American Alliance of Museums although the Herbarium is not (American Alliance of Museums 2011). The

Herbarium regularly works with other herbaria, facilitating specimen loans between institutions and offering specimens collected by staff to other institutions as appropriate. Botanists routinely collect extra specimens of a given species specifically for the purpose of exchange between researchers, and the University of Michigan Herbarium staff frequently engages in this kind of trade with other herbaria. In addition, Herbarium staff members participate in professional organizations like the Society for the Preservation of Natural History Collections, developing and sharing best practices for collection preservation.

The Kelsey Museum is also actively engaged in its community, serving as a Museum Partner for the Archaeological Institute of America and collaborating with other archaeology museums and academic departments throughout the world. The Kelsey works with a number of other archaeological organizations in the fieldwork it sponsors at archaeological sites internationally. For example, the Gabii Project (active in Italy since 2007) features a collaboration between researchers at the University of Michigan and at the Intercollegiate Center for Classical Studies in Rome, University of North Carolina at Chapel Hill, the University of Arkansas, Brown University, and other institutions (Gabii Project 2011).

One major difference between the two case study sites is the type and degree of public access they offer to their collections. An important aspect of the Kelsey is its exhibition space and ongoing public programming. A recent renovation of the museum building added an exhibition wing, which opened to the public in 2009, greatly increasing the already substantial space devoted to exhibition. This aspect of the museum is in sharp contrast to the Herbarium, which does not have public exhibition of its collections. Although it is open to visitors, the Herbarium does not offer displays or exhibits of the collection. This distinction shows that while both the Kelsey and the Herbarium enable research use of their collections, for the Herbarium research is the primary raison d'être. The Kelsey's substantial exhibitions denote an emphasis on public education and entertainment and the representations of museum objects created at the Kelsey include things like exhibition text, while the Herbarium's do not. Although exhibition text is not a resource used by any of the researchers I interviewed, it is a major concern of curators and other staff involved with exhibit preparation. In addition, collections research for the purpose of exhibition is a major use of the Kelsey by internal stakeholders, as chapters four and five illustrate. This difference in the two museums' public orientation creates a distinction that adds to the diversity of the two case study sites.

While this section has introduced the two case study sites, I explore their histories, organizational structures, and representational strategies in chapter 4, which deals with staff at the two museums and their work practices. The following table summarizes the dimensions of variation between the two sites that are relevant to this study:

Table 3.2 Characteristics of the Case Study Sites

Museum	**Material collected**	**Primary research community**	**Number of staff members**	**Exhibition mandate**	**Number of external on-site researchers in 2010**
Herbarium	Plant specimens	Botany	24 (includes 7 curators, current and emeritus; 4 collection managers; 5 graduate students and post-doctoral fellows; and 8 staff in administrative, lab technician, plant mounting, and graphic design roles)	Does not physically exhibit collections	40
Kelsey Museum	Archaeological artifacts and records	Archaeology	25 (includes 7 curators; 2 collection managers; 2 research scientists; and 14 staff in administrative, security, exhibit design, and outreach roles)	Dedicated exhibition space	20

In order to gauge the interest of museum staff in participating in the study and determine the appropriateness of their museums as study sites, I conducted three preliminary 1.5 hour interviews with staff members at the museums selected for the study. These meetings served several purposes, allowing me to pilot and revise my semi-structured interview protocol for use with staff members (see Appendix A for the interview protocol), gain an understanding of the research uses of the museum collections, and ascertain that they receive enough research use to warrant inclusion in the study. Another important component of these meetings was securing an agreement to participate from key staff members, including museum directors, collection managers, and curators. In addition to agreeing to be interviewed themselves, several staff members from each site offered to assist me with participant recruitment among other museum staff and external researchers. In section 3.6, following a discussion of my data collection methods, I explain my participant recruitment strategy.

3.5 Data Collection Methods

In order to learn about the work practices of museum staff and researchers, I designed and implemented a semi-structured interview protocol and performed non-participant observations of members of each group as they worked with museum data. I supplemented these data collection methods with archival research in order to gain a historical perspective on collections management and research practices at both museums. In this section, I describe and justify these data collection methods.

3.5.1 Semi-structured Interviews

My primary data collection method in this study was the semi-structured interview, conversations with museum staff and researchers ranging from one to two hours in duration, using the protocols in Appendix A and B to guide the questions I asked. I selected this method for its utility in learning about people's perceptions and interpretations of events and its flexibility in tailoring the interview session to the participant, pursuing lines of questioning that emerged as the interview progressed (Weiss 1994).

I developed my semi-structured interview protocols in several sections. They began with an introduction and background section orienting the participant to the interview process and eliciting baseline information about the kinds of work in which the participant engaged, focusing particularly on their use of museum data. In the protocols, I used the term "museum materials" in lieu of "museum data" in order to avoid confusion about the boundaries of what might be considered "data" in museum contexts, and to allow participants to consider a broad range of resources with which they interacted. The staff interview protocol then covered the topic of collection and data management processes, addressing my research question *What factors influence the practices of staff members as they describe and manage museum data?* by asking about their work creating representations of the collections, standards and practices in place at the museum, and how those norms were developed or adopted. The protocol then moved to the topic of research use of museum data, asking questions about researcher interactions with the museum, the resources needed by researchers, and their methods of accessing content.

The researcher interview protocol followed a similar pattern. After introducing the participant to the study and learning about their professional background and research interests, I asked how they identified, selected, and gained access to the museum data they used in their research. I then asked about their use of the materials: how they analyzed and derived information from them. These topics address my research question, *What is the relationship between museum objects, their representations, and research use?* by prompting the researcher to reflect on the role of particular museum resources in the research process. Aligned with the social worlds framework of this study, I asked about the research methods in their field as well: how they learned to conduct museum-based research and how that type of work is received in their discipline. Both the staff and researcher protocols ended with an opportunity for the participant to make any remaining comments about the museum research process and a request to observe the participant as they conduct their work with museum objects and representations.

While semi-structured interviews provide direct accounts of individuals' experiences of events and their interpretations of them, there are several drawbacks to this data collection method. Interviewees will often "place themselves in the best light possible and tell what they think the interviewer wants to hear" bringing the validity of interview data into question (Chenitz 1986, p. 88). In addition, retrospective interviews, as many of mine were (with researchers who had already completed their interaction with museum objects), are subject to memory decay as individuals reflect on their experiences after the fact (Tourangeau et al. 2000). On the part of the researcher, there is a danger "when the subjective bias of the interviewer affects the interpretation of the data in ways that misrepresent the subjects' reality," a problem that can be mitigated by using a structured or semi-structured interview protocol rather than an unstructured one

(Newman and Benz 1998, p. 68). These and other issues can introduce bias into interview data. To mitigate these concerns, I coded across interviews, noting and analyzing themes that emerged in multiple people's accounts. In addition, I conducted nonparticipant observation, when possible, to triangulate my data from reported accounts with observed behavior. I describe that method in the following section.

3.5.2 Nonparticipant Observation

Nonparticipant observation is considered a key tool in qualitative data collection, through which the researcher notes the details of a phenomenon in its field setting (Creswell 2013). Nonparticipant observation is a valuable technique because it "provides unique, contextualized insights into events and activities and the meanings that they hold for members of the setting" as the researcher observes, but does not participate in, these activities (Liu and Maitlis 2010, p. 609-610). In my nonparticipant observations, I asked researchers and museum staff to walk me through their activities in the museum, explaining their process in working with museum data. This method gave greater depth to my understanding of museum representation practices and researcher work with museum data.

With museum staff, I performed nonparticipant observation as a collection manager at the Herbarium (HS2) worked with a student to evaluate specimens and create their representations during the accessioning process. A similar observation at the Kelsey was not feasible, however, because the museum does not regularly accession new objects as a result of the 1970 UNESCO *Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property* (UNESCO 1970).

My nonparticipant observation with researchers was more extensive. In preparation for each of the ten interviews with researchers that I conducted face to face during a museum visit, I asked them to allow me to observe them as they worked with museum data. Five of the interviewees agreed, resulting in three one-hour observation sessions. I observed three researchers at the Kelsey (working as a group on a shared research project, in a single observation session) and two researchers at the Herbarium (research collaborators who were working separately, in two observation sessions). I observed these participants in their examination of museum resources, requesting that they do a "think-aloud" process, verbalizing their thoughts as they analyzed the materials. Hevey states that "think-aloud" methods "provide a basis for investigating the mental processes underlying complex task performance and can provide rich data on such cognitive processes" (Hevey 2010, p.2). While this method has been criticized for its potential to change participants' thought processes through the act of reporting them, Ericsson and Simon (1993) have persuasively argued that concurrent articulation does not alter thought processes. One other limitation to the method, that it does not address automatic processes in the participant's behavior, remains valid, but in the context of this study, understanding participants' interpretations of their decision making is a major goal, making those automatic processes a minor concern (Hevey 2010).

3.5.3 Historical Research

The final data collection method I used in this study was research with historical records, performed at the Bentley Historical Library, which houses the records of the University of Michigan, and within the organizational records held onsite at the two museums. This aspect of my research addresses the question *What factors influence the practices of staff members as they describe and manage museum data?* Through an examination of organizational records from the two museums, particularly the papers of museum directors and curators, I was able to find documentation of some of the collection management practices of the early museum staff (particularly at the Kelsey Museum), along with correspondence showing the decision making process leading to the adoption of those practices.

I took two approaches to finding and selecting these materials. At the Bentley Historical Library, I examined the finding aids for two collections—one containing the records of the Kelsey Museum, the other holding the records of the University of Michigan Museums unit, which oversaw the Herbarium along with other University museums between 1863 and 1976 (Bentley Historical Library 1983; Bentley Historical Library, n.d.). Using these finding aids to pinpoint curators and museum directors (collection managers were not listed in the finding aids) from the museums during those time periods, I selected boxes from the subgroups related to those individuals that appeared to contain relevant folders. My selection of archival sources was guided by mentions of correspondence with other museum personnel and references to accessioning and collections in the finding aids.

My search through these materials followed what Lytle has termed "the provenance method of subject retrieval of archives." As he stated, "since agency functions determine the subjects of the records, provenance-related information about archives can be used to gain intellectual control over bodies of records without examining or indexing them" (Lytle 1980, p.70). I used my knowledge of the functional responsibilities of individuals within the two museums, gained in part from the finding aids for the two collections, to narrow my search to specific subgroups of records within the finding aids. I then analyzed the descriptions of those subgroups to determine which sections of the records would be most relevant to my research question, working my way through those materials to find pertinent records.

Within records held by the museums themselves, my sources included card catalogs, ledgers, field notebooks, and excavation records. To the extent that they were available, I also analyzed documentation of museum procedures for accessioning, processing, and describing new collections used over time for this work. In these instances collection managers guided me to the resources I used. The totality of this material was invaluable for understanding the norms for data description followed by researchers and museum staff at various points in time. It contributed greatly to my understanding of the representational histories of the two museums, discussed in chapter 4.

3.6 Participant Recruitment

I conducted interviews with museum staff members and researchers who had used the museums' materials for research, or were in the process of doing so. Because the former group managed the latter group's access to the collection, I used a snowball sampling method to discover and recruit both staff and researcher participants. As Morgan explained, "The typical process for a snowball sample begins with interviewing an initial set of research participants who serve as informants about not only the research topic but also about other potential participants" (Morgan 2008, p. 816). At the end of each interview with museum staff members, I asked who else I should speak with, receiving names of staff, students, and outside researchers whose work included either managing museum objects and representations or using them in research. In this section, I describe that process and explain my participant selection strategy.

3.6.1 Museum Staff Members

Within both museums, I began my data collection with semi-structured interviews with collection managers. As the people most directly aware of and responsible for researcher visits to the collection, they were key to my identification of other potential participants among museum staff, students, and outside researchers using the collection. They were able to inform me of recent and ongoing research projects undertaken by curators, which helped me identify individuals to recruit from this group as well. I supplemented the information they provided about curator research with names of individuals I selected from both museums' websites on the basis of the individual's area of curatorial responsibility, in order to ensure that the sample of curators reflected major areas of each museum's content. Because curators both manage the collections and conduct research using them, I used both the staff and researcher interview protocols in these meetings, in order to learn about both their work as researchers and their work managing museum collections. Several of the collection managers also conducted their own research using the collection for which they were responsible, and I asked these individuals about both aspects of their work as well.

The museum staff members of interest to this study were primarily curators and collection managers. Individuals in both roles were engaged in growing museum collections, creating policies for objects held in those collections, and bearing responsibility for their safekeeping. Beyond these activities, the two roles traditionally have different responsibilities in museums. According to the Bureau of Labor Statistics Standard Occupational Classification, the work of curators is to "Administer collections, such as artwork, collectibles, historic items, or scientific specimens of museums or other institutions." They also "may conduct instructional, research, or public service activities of [the] institution" (Bureau of Labor Statistics 2010a). The government organization does not have a classification listing for museum collection managers, but describes some of their duties in the occupational group “museum technicians and conservators” who “Restore, maintain, or prepare objects in museum collections for storage, research, or exhibit.” These individuals “may identify and record objects or install and arrange them in exhibits […]” (Bureau of Labor Statistics 2010b).

Within the University of Michigan, the central human resources unit outlines the basic function, responsibility, and characteristic duties of many job roles across the university in a series of “classification descriptions.” The document pertaining to curators specifies that their function is “To provide scholarly or scientific and technical leadership in the design and conduct of the research programs on the collections committed to his care in one of the recognized divisions of the several museums; and to provide comparable leadership in the utilization of those collections for educational purposes” (University of Michigan 1979). The characteristic duties listed for curators are:

- Identify and define problems, the solutions to which are related to the study and acquisition of research collections.
- Identify and clarify barriers to understanding which affect solutions to research problems as well as specific items of knowledge which are required.
- Develop hypotheses to be tested and ways of doing so.
- Develop devices of various types for empirical studies, including hardware, software, statistical methods and the like.
- Plan and execute field work or comparable object centered study problems related to the hypotheses that have been developed.
- Evaluate data to establish relevance to the problem or problems being evaluated.
- Prepare seminars, talks, lectures and the like to dissemination of knowledge particularly the results of research undertaken.
- Maintain the collections of art objects, artifacts, or specimens acquired in the research programs, arrange for their proper preservation, and, if appropriate, for their display; supervise maintaining accurate cataloging records of all information relevant to the collections.
- Participate in determining research priorities and planning programs of research.
- Train student investigators and support personnel and conduct continuing education for research personnel at all levels.

- Participate in the acquisition of works of art, artifacts, or scientific specimens for the museum collection keeping in mind the nature and scope of existing collections and the needs of teaching and research programs.
- Prepare research results for dissemination in scholarly exhibitions, exhibition catalogues, interpretive label texts, reports, papers, journals, books and other media. (University of Michigan 1979)

The document pertaining to collection managers is titled "Coordinator Museum Collections," providing the basic job function "To plan and implement procedures for the accession of specimens, artifacts and photographic slides" (University of Michigan 1983). The characteristic duties listed for coordinators of museum collections are:

- Develop, update and implement systems for the classification, cataloging and storage of specimens, artifacts and photographic slides.
- Inspect and test specimens and artifacts to determine methods and procedures for restoration and preservation.
- Research, develop, implement and record methods and procedures for the restoration and preservation of artifacts and specimens.
- Appraise specimens and artifacts to determine appropriate insurance coverage.
- Develop and coordinate procedures for the circulation and loan of specimen and artifacts.
- Coordinate the development and maintenance of a museum collection data base.
- Estimate job requirements, including staffing, equipment and supplies.
- Hire, train and evaluate support staff.
- Provide reference and orientation services to student, faculty and other users of the collections.
- Prepare statistical and other periodic and special reports.
- Assure compliance with affirmative action and safety programs.
- Process collections and preparing, classify and catalog specimens and artifacts.
- Research information needed to catalog collected items.
- Apply appropriate methods and procedures to restore and preserve specimens and artifacts.
- Answer reference requests by phone or correspondence.

- Organize and maintain storage of specimens and artifacts in an appropriate environment. (University of Michigan 1983)

A comparison of these two lists shows different responsibilities in research activities and work with collections between the two roles. While curators are responsible for conducting research related to the collections, including determining research priorities, planning and conducting research projects, and disseminating the results of research, their role in collection management is primarily supervisory ("arrange for […] proper preservation […] supervise maintaining accurate cataloging") (University of Michigan 1979). In contrast, the role of museum collection coordinator involves direct responsibility for the care of objects, record keeping, and policy development regarding the collection. Research in this position is limited to "information needed to catalog collected items" and developing "methods and procedures for the restoration and preservation of artifacts and specimens" (University of Michigan 1983).

The prominence of activities related to research and scholarship on the list of curator duties is notable, and well-aligned with the work performed by curators at the Herbarium and the Kelsey. As they "identify and define problems, the solutions to which are related to the study and acquisition of research collections," curators do work that may change the representation of objects in the museum's information systems. However, as they "classify and catalog specimens and artifacts" collection managers are most often the people who update those representations. These activities related to research and management of museum collections make both groups essential participants in the study.

I interviewed people who were accountable for the collections to learn about the flow of materials into them as well as decisions made about metadata and other information representation issues that affect ongoing use of the collections. These interviews were intended to help answer my research question, *What factors influence the practices of staff members as they describe and manage museum data?* by learning about the work of museum staff as they transform artifacts and collections into data.

While these individuals manage museum collections, they (particularly curators) often also act as internal researchers, contributing to their field's understanding through their interpretation of museum objects. Because research with collections is a part of the curatorial role, the research practices of this group are particularly important to the study. The research that takes place as part of curation is addressed in chapter 5, which analyzes the experiences of individuals conducting museum research.

Given the many roles staff members play at the museums and the central interest of this project: the relationship between the representation of museum objects and their subsequent use in research, I targeted my interviews with staff members at both sites to people involved primarily with the description and research use of collections, both in their own work and in facilitating research using collections which is done by others. I interviewed six staff members at the Kelsey (24% of the total staff) and eight at the Herbarium (32% of the total staff). In terms of job title, these people were primarily collection managers, curators, and research scientists. I did not interview personnel with chiefly administrative roles within the museums. I outline my staff informants in Table 3.3.

Table 3.3 Characteristics of staff participants.

Respondent number*	Museum	Staff role	Number of years at museum	Disciplinary background
AS1	Kelsey	Collection manager	8	New World Archaeology
AS2	Kelsey	Associate Director and Curator	24	Classical Archaeology
AS3	Kelsey	Exhibition Coordinator	10	Graphic Design
AS4	Kelsey	Curator	17	Egyptology
AS5	Kelsey	Curator	37	History of Art
AS6	Kelsey	Curator	8	Egyptology
HS1	Herbarium	Curator	30	Botany
HS2	Herbarium	Collection manager	14	Botany
HS3	Herbarium	Collection manager and Research scientist	26	Botany
HS4	Herbarium	Research scientist	7	Botany
HS5	Herbarium	Collection specialist	1-2	Botany (undergraduate degree)
HS6	Herbarium	Director and Curator	7	Botany
HS7	Herbarium	Collection manager	20	Library science
HS8	Herbarium	Curator	7	Botany

*AS refers to staff at the archaeological museum (the Kelsey) while HS refers to Herbarium staff. I numbered the participants consecutively, in the order in which the interviews took place.

My interactions with staff members, through observation and interview with participants, were instrumental in my understanding of the practices surrounding collection representation and research access to museum collections.

3.6.2 Researchers

At each museum, I engaged in conversations with collection managers and curators to identify researchers to interview about their experiences using the museum. Collection managers alerted me to upcoming visits to their collections by researchers, whom I contacted by email prior to their visit with a request to interview them about the process of examining museum data (and in several cases to engage in non-participant observation of that process). In order to meet my recruitment goal of 15 researcher interviews per museum, I supplemented these concurrent interviews with retrospective discussions with researchers who had used the collections during the past year. I recruited this group with the help of collection managers, who reviewed their email correspondence with researchers to discover recent users. Entries in the visitor log at the Herbarium supplemented collection manager HS3's memory as he helped me identify potential participants from visitors over the prior twelve months.

My interviews with researchers were focused on their experience using museum data for their own research purposes, asking how they discovered and gained access to the materials, what aspects of the materials were useful to them, and how they analyzed those materials. While participants in retrospective interviews may experience memory decay as they reflect on their research experience after the fact (Tourangeau et al. 2000), my interviews with this group were useful for understanding their research experience in a broader context, as they reflected on the relationship between that instance of museum research and their own broader research goals and experiences.

I interviewed 15 researchers at the Herbarium and 16 researchers at the Kelsey using the museums in their work. Of the botanists, 14 have an ongoing professional affiliation with a herbarium, as curators, postdoctoral researchers, and students. In contrast, most of the archaeological researchers did not have an ongoing affiliation with an archaeology museum, with the exception of one research scientist and four students who worked closely with the Kelsey itself. Table 3.4 provides a description of the individual interviewees, providing the respondent number I use to refer to each person throughout the dissertation, the museum at which their research took place, and information about their professional role and disciplinary background. In the final column, I state the research method/s used with each participant and the interview's temporal relationship to the research we discussed. The interview was either concurrent to a research project (in the case of ongoing research), or retrospective, describing finished work.

Table 3.4 Characteristics of (non-staff) researcher participants.

Respondent number*	Museum	Professional role	Organizational Affiliation	Number of years in role	Disciplinary background	Method
AR1	Kelsey	Adjunct Professor	Public university (US)	6	Egyptology	Interview, retrospective
AR2	Kelsey	Doctoral Student	Public university (US)	7	Egyptology	Interview, concurrent
AR3	Kelsey	Doctoral Student	Public university (International)	7	Archaeology	Interview, retrospective
AR4	Kelsey	Doctoral Student	University of Michigan	8	Archaeology	Interview, concurrent
AR5	Kelsey	Associate Professor	Public university (US)	16	Classical Studies	Interview, concurrent
AR6	Kelsey	Research Scientist	University of Michigan	2	Archaeology, Ancient Near East	Interview, retrospective
AR7	Kelsey	Doctoral Student	Public university (International)	2	Egyptology	Interview, retrospective
AR8	Kelsey	Doctoral Student	Public university (US)	7	Art History	Interview, retrospective
AR9	Kelsey	Professor	Public university (US)	25	Anthropology, Classical Studies	Observation and interview, concurrent
AR10	Kelsey	Assistant Professor	Public university (US)	2	Art History	Interview, retrospective
AR11	Kelsey	Doctoral Student	University of Michigan	5	Archaeology	Interview, retrospective
AR12	Kelsey	Doctoral Student	University of Michigan	6	Archaeology	Observation and interview, concurrent
AR13	Kelsey	Doctoral Student	University of Michigan	5	Archaeology	Interview, retrospective

Respondent number*	Museum	Professional role	Organizational Affiliation	Number of years in role	Disciplinary background	Method
AR14	Kelsey	Masters Student	Public university (International)	2	Archaeology	Interview, concurrent
AR15	Kelsey	Independent Researcher (Master of the Arts graduate)	Independent researcher (International)	5	Egyptology	Interview, retrospective
AR16	Kelsey	Doctoral Student	University of Michigan	6	Archaeology	Observation and interview, concurrent
HR1	Herbarium	Doctoral Student	University of Michigan	2	Plant Systematics	Interview, concurrent
HR2	Herbarium	Doctoral Student	University of Michigan	6	Plant Evolutionary Biology	Interview, concurrent
HR3	Herbarium	Post-doctoral Researcher	University of Michigan	3	Plant Systematics	Observation and interview, concurrent
HR4	Herbarium	Post-doctoral Researcher	Government research organization (International)	5	Plant Evolutionary Biology	Observation and interview, concurrent
HR5	Herbarium	Research Scientist	Large botanical garden (US)	23	Plant Systematics	Interview, retrospective
HR6	Herbarium	Undergraduate Student, Research Assistant	Public university (US)	1	Botany	Interview, retrospective
HR7	Herbarium	Associate Professor	Private university (US)	15	Molecular Plant Systematics	Interview, retrospective
HR8	Herbarium	Botanist	Conservation evaluation company (US)	19	Botany	Interview, retrospective
HR9	Herbarium	Professor, Herbarium Curator	Public university (US)	21	Botany	Interview, retrospective

Respondent number*	**Museum**	**Professional role**	**Organizational Affiliation**	**Number of years in role**	**Disciplinary background**	**Method**
HR10	Herbarium	Herbarium Curator	Public university (US)	30	Botany	Interview, retrospective
HR11	Herbarium	Herbarium Curator	Natural history museum (US)	42	Botany	Interview, retrospective
HR12	Herbarium	Landscape Ecologist	Ecological consulting company	9	Ecology	Interview, retrospective
HR13	Herbarium	Research Scientist	Public university (International)	22	Plant Systematics	Interview, retrospective
HR14	Herbarium	Professor, Herbarium Curator	Public university (US)	34	Plant Systematics	Interview, retrospective
HR15	Herbarium	Herbarium Curator	Public university (International)	50	Plant Systematics	Interview, retrospective

*AR refers to researchers at the archaeological museum (the Kelsey) while HR refers to Herbarium researchers. I numbered the participants consecutively, in the order in which the interviews took place.

In table 3.5, I summarize the interviews and observations I conducted at each site. In total, I conducted 45 interviews with 14 staff members and 31 researchers. I conducted six non-participant observations with five researchers and one staff member.

Table 3.5 Interview and observation participants at the two sites

Method	**Museum staff**		**Researchers (non staff)**	
Museum	Herbarium	Kelsey	Herbarium	Kelsey
Semi-structured interviews	8	6	15	16
Non-participant observation	1	0	2	3

The University of Michigan Behavioral Sciences Institutional Review Board (IRB) has reviewed this study and has determined that it is exempt from IRB oversight. Prior to conducting my interviews and observations, I requested permission from museum staff and researchers to audiotape our meetings and to photograph the artifacts they used in their work. I assured participants that they were welcome to skip any questions with which they felt uncomfortable, or to terminate the interview at any time. To protect the identities of participants, I have adopted respondent numbers to refer to them throughout the dissertation. In addition, I have carefully reviewed transcripts, memos, notes, and reports of my data to remove identifying information that might link participants to the study.

3.7 Data Analysis

My data analysis consisted of iterative thematic coding of interview transcripts and observation notes using the qualitative coding software nVivo. As my theoretical understanding of the cases developed, I created memos analyzing the codes, which I used to make sense of the material and to identify areas for further data collection (Miles and Huberman 1994).

In order to judge the validity of my coding, I recruited a second coder, a doctoral student in the information science field, who has conducted research on the topic of data reuse. She and I reviewed the codes together, discussing their application to the transcripts, and independently coded the same transcript, using nVivo to ascertain our level of agreement. The first round of coding did not reach a suitable level of agreement, so the coder and I met again to review the codes and discuss our application of them in the first transcript, paying close attention to areas of disagreement. We then did another round of coding and intercoder reliability testing on a second transcript, reaching a reliability coefficient of 0.81 using Scott's Pi, a statistic measuring inter-rater reliability for coding textual data (Scott 1955). Once we had reached this level of reliability, I continued to code the remainder of the interviews and observation notes using the coding guidelines we developed. The purpose of this intercoder reliability testing was to ensure that I applied the codes logically and consistently throughout the process, using principles that had been reviewed by a peer familiar with the issues addressed by this study (Miles and Huberman 1994). The code list is included as Appendix C.

3.8 Methodological Limitations

Although the methods I have selected for this study have the benefit of producing rich data based in the words and activities of my participants, there are several issues related to the reliability and validity of these methods that I will address before proceeding. Simply stated, "'reliability' is the extent to which a […] procedure yields the same answer however and whenever it is carried out; 'validity' is the extent to which it gives the correct answer" (Kirk and Miller 1986, p. 19). The two concepts are interrelated: reliability is a precondition for validity (Lincoln and Guba 1985). In qualitative research, there are "no straightforward tests for reliability and validity" (Patton 1990, p.372), instead, those assessments are derived from the robustness of the study design and from the credibility and authenticity of the analysis as determined by readers and study participants (Miles and Huberman 1994). While these qualities cannot be directly measured, numerous researchers have produced guidelines for improving the reliability and validity of qualitative studies, several of which I have incorporated here.

I sought to enhance the reliability of my research design by using semi-structured interview protocols to guide the interviews. These protocols were derived from my research questions and from factors identified in the data reuse literature as important to the data reuse process. By using one protocol for each of the two groups of interviewees (researchers and museum staff), I ensured a degree of consistency across these meetings in order to elicit information about the same issues from a range of individuals. Consistency in the protocols helped me check for consistency in my data across subjects, an activity that is associated with greater reliability of interview data (Newman and Benz 1998). To determine the reliability of the interview protocols themselves, I pilot tested them with museum staff members and researchers early in the data collection process (Creswell 2013). Noting hesitance or comprehension problems in response to some questions in the initial protocols, I reviewed those questions with participants at the conclusion of the interviews, making adjustments to the questions to increase the likelihood that they would be easily and correctly interpreted.

I used my ongoing communications with several museum staff members to do periodic member checking, to gauge the validity of my data and interpretations (Newman and Benz 1998). In these instances, I discussed my preliminary findings with staff members who elaborated or corrected my understanding from their own perspective. These conversations indicated areas where I needed to collect more data or reconsider my analysis. To further increase the validity of the study, I used my interview and observation methods to triangulate data between the two sources, finding that evidence and themes were consistent between the two methods (Miles and Huberman 1994).

As I discussed in the previous section on data analysis, I used inter-coder agreement to verify the reliability of my analysis. Because the data coding process is highly interpretive, reaching appropriate standards of reliability with a second coder provides an external check on the quality of interpretations (Creswell 2013). This step helped me establish a level of consistency in my coding that was beneficial throughout the study.

The case study approach I selected for this research, while valuable for forming an in-depth understanding of the study sites, poses problems for the study's external validity: "the extent to which the results of the research study can be generalized to other settings or groups" (Newman and Benz 1998 p.33). Due to the specificity of case studies to the contexts they examine, it is not appropriate to generalize from case studies to other populations, decreasing their external validity in this sense. That said, the researcher may generalize case studies to theoretical propositions (Yin 2009) and the reader may infer the *applicability* of a case study to his or her own context (Lincoln and Guba 2002).

In the following two chapters I present the findings and analysis I derived using these methods. Chapter 4 addresses the work done by museum staff to manage and create representations of collections. In Chapter 5, I discuss the research process from the researcher's viewpoint, exploring their interactions with collections, their representations, and the museum staff who make materials accessible to them.

Chapter 4

Museum Staff: Curating Details

In this chapter, I discuss the work of museum staff in organizing and representing collections. I address my research question: *What factors influence the practices of staff members as they describe and manage museum data?* by looking at the work staff members do to make collections useful. I examine the processes they use to represent and manage collections and the priorities embodied in those practices. Throughout this chapter, I maintain that the social worlds to which these staff members belong, including the world of museum practice and the disciplinary worlds to which they are accountable, structure the work of these individuals in creating representations and managing collections.

The staff members I describe have layered identities and roles—many identify as museum professionals, and a good number of them (particularly curators) are also researchers themselves, using the collections for which they are responsible to do their own scholarship. They identify with particular research subworlds: art history, classical archaeology, and Egyptology at the Kelsey; systematics, ecological niche modeling, and molecular genetics at the Herbarium (to name only a few). Strauss discussed the segmenting of social worlds into specifiable subworlds, saying the formation of subworlds within a social world, "signifies not only new activities, sites, technologies, and organizations, but also signifies new universes of discourse" within a social world (Strauss 1978, p. 123). As individuals work within intersecting and changing subworlds, they navigate multiple identities as they struggle to address (sometimes competing) goals. Often these layered identities caused what I am terming *identity frictions*: discrepancies between how things were done in the past and how they are done now; conflicts between the research methods used by a member of one subworld and the methods used by another. Identity frictions reveal the impact of changing social worlds on their members, as the needs of members of various subworlds are balanced in museum practices. I discuss identity frictions throughout my findings as moments of contrast that delineate the goals, values, and practices of members of subworlds.

I begin this chapter with an overview of the staff composition of each of the two museums, continuing with a discussion of the collections for which they are responsible. Here I present a historical view of the two museums, focusing on their representation of materials over time. I then describe the process of accessioning collections at the Herbarium, a process I was not able to observe at the Kelsey, because accessioning new materials is no longer a regular occurrence there. Next, I discuss the implications of collection source for the later representation of objects in the multiple representation systems at use in the two museums. Then I look at the information dissemination practices in place at the two museums, exploring which information is made public, and in what manner. Finally, I bring the discussion back to the topics of social worlds and information infrastructure to analyze the chapter in light of the theoretical framework guiding this study.

4.1 Staff Composition

The Kelsey Museum of Archaeology has 24 staff members. The majority of them (13 people) are full-time staff, working exclusively for the Kelsey in roles like Museum Exhibition Coordinator, Community Outreach Supervisor, Senior Conservator, Museum Collections Manager, and Administrative Specialist. The other staff members are in curatorial roles, with titles like Associate Curator of Graeco-Roman Egyptian Collections and Associate Curator of Dynastic Egyptian Collections. Curators divide their time between work at the museum and tenure-track faculty roles in University departments. The Herbarium has 25 staff members, likewise divided into staff positions like Administrative Specialist, Research Museum Collection Manager, and Plant Mounter and curatorial roles like Curator (Vascular Plants) and Assistant Curator (Fungi). The curatorial roles at both museums are specific to particular segments of the collections: Graeco-Roman Egyptian, Dynastic Egyptian, Hellenistic and Roman, Greek and Near Eastern as previously noted in the Kelsey; vascular plants, algae, bryophytes, fungi, and lichens in the Herbarium. At the Herbarium, collection managers are also aligned with these specific collections, reflecting the organization of the collection and its storage needs. This is not the case at the Kelsey, where collection managers maintain responsibility for the collection as a whole. These differences in staff roles, between curators and collection managers, reflect a difference in the kind of expertise expected of them. In relationship to the collections, their expertise is primarily *content-based,* corresponding to a deep and thorough knowledge of some section of the museum's objects and the research practices of a related research subworld (in the case of curators) or *systems-based,* referring to a facility with the information systems in use at the museum (for collection managers).

At both museums, curatorial staff members have half-time appointments. The majority of curators also teach classes as tenure-track faculty in university academic departments: Herbarium curators teach primarily in the Department of Ecology and Evolutionary Biology (EEB) and curators at the Kelsey museum teach in the departments of Near Eastern Studies, Classical Studies, and History of Art. All of these departments are part of the College of Literature, Science and the Arts, an administrative unit that houses a large number of academic programs within the University of Michigan and currently oversees both museums, although both museums have been organizationally situated in several different departmental arrangements since they were founded. Given the curators' split responsibilities, they must balance museum work with their other academic duties. This can be tricky, as curators are ultimately accountable to their home academic departments. AS5, a curator with over 30 years of experience at the Kelsey, explained that many departmental deans, to whom curators must communicate the value of their work, do not understand museum curation as an academic activity, per se.

> You know obviously the College of Literature, Science, and Arts is about teaching and research, and museums are seen still, to this day, as a kind of amenity. But ultimately, if push came to shove, disposable.
>
> Interviewer: But you mentioned the Special Exhibits Program that incorporates research and teaching into exhibitions.
> AS5: It does, but try to tell a dean that. [chuckle] If you don't participate in the life of the museum and understand what it takes to put some thing into a gallery and present it to the public and to students in a way that makes sense, you have no idea. It looks easy. It looks like putting a vase of flowers on your coffee table, but

> that's not what it's about. [laughter] I mean seriously, there are so many steps because you're responsible for the objects. There are ethical considerations. There are standard practices and best practices in the profession. Conservation has to be involved. The registrar's office has to be involved. The preparator has to be involved. Everything goes through multiple stages of review and, not to mention, the research, the concept, the writing, the design and bringing all of that together. It's an enormously complicated team effort, and it doesn't quite transmit to an academic person who has no contact with that world as a research project. It doesn't communicate to them the same kind of effort.

In addition, as this curator told me, "Museums are not tuition-generating units at the university and they don't have much priority in the scheme of things." Juggling the demands of academic departments and museums is a difficult part of the curator's role at academic museums, which AS5 has managed to address by combining teaching and curatorial duties through the aforementioned Special Exhibits Program she developed. In this program, undergraduate and graduate students enrolled in her classes spend the semester researching objects in the Kelsey's collection, culminating in an exhibition at the museum. These classes increase the museum's knowledge of the collection, provide new exhibition content for the museum, give students curatorial and exhibition experience, and help curators meet their teaching requirements. For curators like AS5, subworld memberships including instructor, curator, and researcher, with responsibilities to an academic department as well as a museum, created an identity friction, which she resolved by combining her curatorial and research duties into her instructor role.

Although superficially the staff composition of the two museums is quite similar, there are large differences in their duties. Perhaps the greatest distinction between the museums is the amount and type of public facing activity, which is reflected in their staffing. The Kelsey museum has a large exhibition and outreach component; the Herbarium does not. Since it began, the Kelsey has engaged in exhibition of collections, from display in the Classical department in the 1890's to the current two-level dedicated public exhibition space it currently enjoys. Accordingly, a number of staff members at the Kelsey have positions related to the exhibition of materials, including Museum Exhibition Coordinator, Curator for Academic Outreach and Exhibits, and Community Outreach Supervisor. In addition, a doctoral program is housed at the Kelsey, the Interdepartmental Program in Classical Art and Archaeology (IPCAA). IPCAA emphasizes both archaeological fieldwork and museum-based research, and one staff member, the Graduate Program Coordinator, oversees this dimension of the museum. The Herbarium also hosts numerous graduate students in their work, but in a less formalized relationship than that at the Kelsey. Doctoral students are affiliated with faculty in EEB and use the herbarium collections as research data. The Kelsey also sponsors a number of ongoing archaeological excavations in the Near East, which are led by several curatorial staff and the two research scientists affiliated with the Kelsey. These are grant-funded projects applied for and managed by University faculty. At the Herbarium, which has never had an exhibition mandate for its collections, its function as a research collection is the organization's largest priority. Accordingly, a large part of the Herbarium's staff are engaged directly and primarily in research roles, including curators, research scientists, project coordinators and research fellows associated with specific grant-funded initiatives, and several professors emeritus, who have retained their affiliation with the Herbarium after retirement.

Staff members at the two museums have a range of relationships to the collections, reflecting their functional roles. Curators are responsible for planning exhibitions (at the Kelsey) and for content knowledge in their area of specialization, whether this encompasses specific plant families at the Herbarium or temporally and geographically delineated archaeological materials at the Kelsey. Their content expertise is central to their interactions with the museum collections, which they work to authoritatively identify, augment through their own collecting (at the Herbarium) and which they study and publish interpretations of at both museums. They are also responsible for teaching, applying for grants, and other aspects of their work as faculty, aside from their museum responsibilities. Collection managers at both museums also have content expertise but it is primarily their expertise in information systems that they bring to bear in their work with collections. These individuals are responsible for the physical care of collections, the pragmatic details of researcher access, and working with information systems to update the representations of collections held by the museum. While the collection managers at each museum had deep knowledge of the research processes related to their collections, often obtained through their own experience as researchers in the relevant field, few of them had the specific content expertise in their collections to make their own research with museum data an ongoing part of their work. I will go into greater depth in my discussion of these distinctions in the coming pages.

The staff composition of the two museums frames the following section in which I focus on the collections held by the two museums, emphasizing the methods and frameworks that the staff members working with collections and their representations bring to that work. Throughout the remaining pages, I will return to the social worlds and communities of practice of these individuals, investigating the ways in which these individuals' professional and educational backgrounds influence their perspectives on work with museum objects.

4.2 Collection History: The Kelsey Museum

There are several common themes in the collecting histories of the Kelsey and the Herbarium. The seeds for both collections were sewn in the 19th century by professors affiliated with the University of Michigan who did their own collecting and donated the objects they amassed to the University. In both cases, their collecting was related to exploration, of the Near East and the state of Michigan. While both collections continued to grow after their founders passed on, those initial collections form the basis of the materials currently held at each museum. In this section I describe those histories and important characteristics of the collections today.

The Kelsey Museum's early collection management practices were marked by several themes: the development of practices for collection management, the management of information about the objects derived from their provenance, and the use of the collection by researchers. Each of these topics will be discussed at length in the following sections.

4.2.1. Building the Collection

The first objects owned by the Kelsey Museum were obtained for the University by faculty studying the classical world. In particular, Francis Willey Kelsey was most active among faculty obtaining archaeological objects from the Near East for the University. Kelsey joined the University's Latin department in 1889 and was appointed its head after the death of Henry Frieze, the previous department head, later that year (Pedley 2012, p. 39). During his tenure at the University, from 1893 to 1927, Kelsey amassed a large number of archaeological artifacts, through excavation and purchase from antiquities dealers. In recognition of his role in building the archaeological collections, the museum was renamed the Kelsey Museum of Archaeology in 1953.

The physical placement of the University's archaeological collection changed several times in its early history. Initially kept near Professor Kelsey's office in the Library, when he moved to Alumni Memorial Hall in 1910, they moved with him, winding up in a basement space designated as the faculty "Club Room" (Pedley 2012, p. 165). Collections were eventually dispersed throughout the building, which also housed and displayed the collections of the Department of Fine Arts. After Kelsey's death, in 1927, the collections were moved to their current location, Newberry Hall, which became the Museum of Archaeology.

While Kelsey was a great collector of Near East archaeological objects, the majority of his collecting should not be interpreted as personal. With the exception of collections donated to the University by his family after Kelsey's death, material he obtained was sold to the University of Michigan, not to Kelsey himself. His interests shaped the collection, but it was always intended as a resource for the University rather than a privately held group of artifacts.

The museum's first curator, Orma Butler, appointed in 1928, described the research materials available prior to Kelsey's collecting. "The members of the Classical staff were dependent upon a scanty supply of casts, a few small objects in the private ownership of different members of the Faculty, and such illustrations as a limited Library could furnish" (Butler 1930, p. 3). Butler recounts the growth of the collection in 1893, when Kelsey was on a leave of absence in Europe. In Carthage that year, Kelsey befriended the Reverend R.P. Delattre who sold him 109 "duplicate specimens" of lamps, vases, and building materials from him own Musée Lavigerie, which held the fruits of his excavations at that site. Additionally, on this same trip, Kelsey purchased 1096 other objects from antiquities dealers in a number of European cities. One object among those purchased from Reverend Delattre was considered particularly valuable by Kelsey, a fragment of a Roman lamp, "the discovery of which in [Delattre's] early days at Carthage led him to undertake his valuable excavations." Butler writes that "This piece by reason of its historical significance bears the number 1 on our Accessions Catalogue," a record originally entered by Professor Kelsey, where he detailed the circumstances under which he obtained each object (Butler 1930, p. 3).

Butler's history of the collection attributes the majority of its growth to Kelsey's work, although other University faculty, particularly members of the Classics department, played a role in the acquisition of artifacts. Acquisition was largely at a lull, however, between Kelsey's 1893 trip abroad and his later travels in 1919-1921. During his "First Expedition" travels in 1919-1921, Kelsey scouted locations for potential archaeological excavations to be conducted by the University, while simultaneously building relationships with local dealers of antiquities which resulted in the collection of a great number of new artifacts (Butler 1930). Through Kelsey's efforts, the University conducted excavations at three sites in the Near East: Antioch in Pisidia in Turkey, Carthage in Tunisia, and Karanis, Egypt. While the Michigan excavations at Antioch and Carthage only lasted for one season each (the summers of 1924 and 1925, respectively), the Karanis excavations continued for twelve seasons, from 1924 to 1935. Material from Karanis is viewed by many of today's curators and collection managers as the most valuable of the collections at the Kelsey, due to the length of the excavation, the amount and detail in the excavation records providing context to the collections, and the range of material excavated documenting the everyday lives of Egyptian villagers over generations of habitation.

In 1924, the Near East Research Fund was established at the University to fund excavation projects. Prior to this time, Near East archaeological artifacts had been purchased with earmarked donations or given to the University, but the Near East Research Fund enabled the University to begin its first excavation at Antioch in Pisidia in 1924. While still originating from private donation (most notably a $100,000 donation from Horace H. Rackham), the Near East Research Fund was pooled from donations organized, in large part, by Kelsey (Butler 1930, p. 8; Robbins 1958, p. 1463). Later that same year, faculty at the University began the excavation at Karanis, yielding a shipment in 1926 of approximately 500 objects to the University. The Near East Research Fund, overseen by the informal Advisory Committee on Near East Research (consisting of the University President, several deans, and a number of faculty members including Kelsey), was an important part of the University's archaeological research infrastructure, providing excavation funding which, in turn, helped the collection grow. Following Kelsey's death in 1927, this group was formalized by the Board of Regents as the Committee on Near East Research and given oversight of the excavation program (Robbins 1958, p. 1464). New objects procured from excavations, gifts, and purchases continued to grow the collection so that by 1929, 5949 objects had been accessioned (Butler 1930, p. 9).

4.2.2 Formalizing and Institutionalizing the Museum

Given the growing collections and lack of public access to them, four professors, Winter, Bonner, Boak, and Waterman, each of whom had a role in the excavations, met with the University's Director of Museums in fall of 1928 to propose a new museum. "As a result of their conference," Orma Butler reported, "it was decided to create a new Museum of Classical Archaeology and to ask that the lower floor of old Newbury Hall be made over into exhibit rooms for a part of the material. The Regents granted the request, and were generous in their provision of funds for the purpose" (Butler 1930, p. 10). Four exhibition rooms were established to showcase different aspects of the collection.

As previously noted, Orma Fitch Butler was appointed the first curator of the Museum of Classical Archaeology in 1928, the year following the death of Francis Kelsey, with whom she had worked in the University's Latin department since 1912. In 1928, Butler received the titles of Assistant Professor of Latin and Curator of Archaeological Collections, which she held until her death in 1938 (University of Michigan Faculty History Project 2011). In her letter to the museum's director, J.G. Winter, accepting the position as curator, Butler wrote: "Since I have been [in] such close contact with the collections for so many years I feel that I can be of real help in getting matters straightened out." She continued, pragmatically discussing her plans for cataloging the museum's holdings:

> I do think that the time is ripe for a catalogue of our Collection to be made. If this is done no one person can do all that work, and it seems to me that we might

> well be considering how the field can be subdivided among the members of the Staff to get this done. With a view to such a possibility, I am planning when the objects are being shifted from their present quarters to put lamps together without respect to their numbers, and other objects of which we have a large number will be gathered into one group. A card catalogue will make them accessible at any time, time, [sic] and the convenience of having them brought together will be of untold value.[9]

Butler's emphasis on the creation of a single catalog for the collection was to guide the work of several staff members who built the catalog in a piecemeal fashion by reviewing and describing artifacts by type.

One concern of Butler's pertained to fitting the Archaeology museum's practices into those used by other university museums at Michigan. This was achieved, in part, through the use of forms adapted to the new museum from the Museum of Zoology. Nine days after accepting her appointment as curator, Butler wrote to Winter, "Yesterday after our conference with Dr. Ruthven[10] Miss Thompson and I went into the whole subject of office supplies for the work on the new Classical Museum. In order to make things clear we also went into the subject of records so as to see how the present system used by the Museum, into which we shall of course be expected to fit, could be adapted to our needs. In order to have a clear record of all of our plans I am sending you this list of the various things which we figured out as desirable for our work." She then lists such items as a typewriter, general office supplies, loose leaf binders, office furniture, and most relevant here, a list of six forms in use in the University Museum System, which she calls "forms for the proper keeping of records," attaching samples to her letter.[11] In her letter she describes the forms and the quantities she thinks would be appropriate for the new museum,

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[9] Letter from Orma Fitch Butler to John G. Winter, December 13, 1928, Blanks. [museum] folder 3, box 6, Orma Fitch Butler Papers, 1913-1938, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

[10] Alexander Ruthven was the first director of the University of Michigan Museum of Zoology, appointed in 1913.

[11] Letter from Orma Fitch Butler to John G. Winter, December 12, 1928, Blanks. [museum] folder 3, box 6, Orma Fitch Butler Papers, 1913-1938, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

A. “Possibly not needed, but part of the University Museum System, if thought useful only a few of form 1----200 [12]

B. Form 2 used for the record of all additions to the collections and as a basis of the yearly report which each Curator is expected to make yearly. Also a Museum form----5,000

C. Form 3 suggested for our work as a means of keeping location of the various objects in the two spots where the collection will be located as well as of the objects which will have to be packed away. Absolutely necessary for the work in the Laboratory course. Two catalogs really needed, one in Newberry and one in Angell----15,000[13]

D. Form 4, not needed unless we plan to do loan work. If thought necessary only a few say[14] ----200

E. Form 5, Absolutely necessary to make lists by classes of objects, a Museum form adapted to our use. Such lists will bring into classes our widely scattered objects and make it possible to arrange them by kinds, ----1,500

F. Form 6, Valuable as a first step toward the making of a complete Catalog of the Collections. By this system any object that had been studied by any member of the Staff could be written up and filed in numerical order by classes of objects against the day of publication. This is my own idea but will prove I think most useful----10,000

Forms 1, 4, 5 and 6 should be printed on a good quality of paper, and nos. 5 and 6 should be perforated for binding in a Moore Loose Leaf Binder. Forms 2 and 3 should be printed on a <u>good</u> quality of cards, a stock that will not crumble with age or discolor since there is no reason why this work should ever have to be done over.”

---

[12] A form titled “Notification to the Accession Officer” from the Museum of Zoology for reporting a new accession and its source.

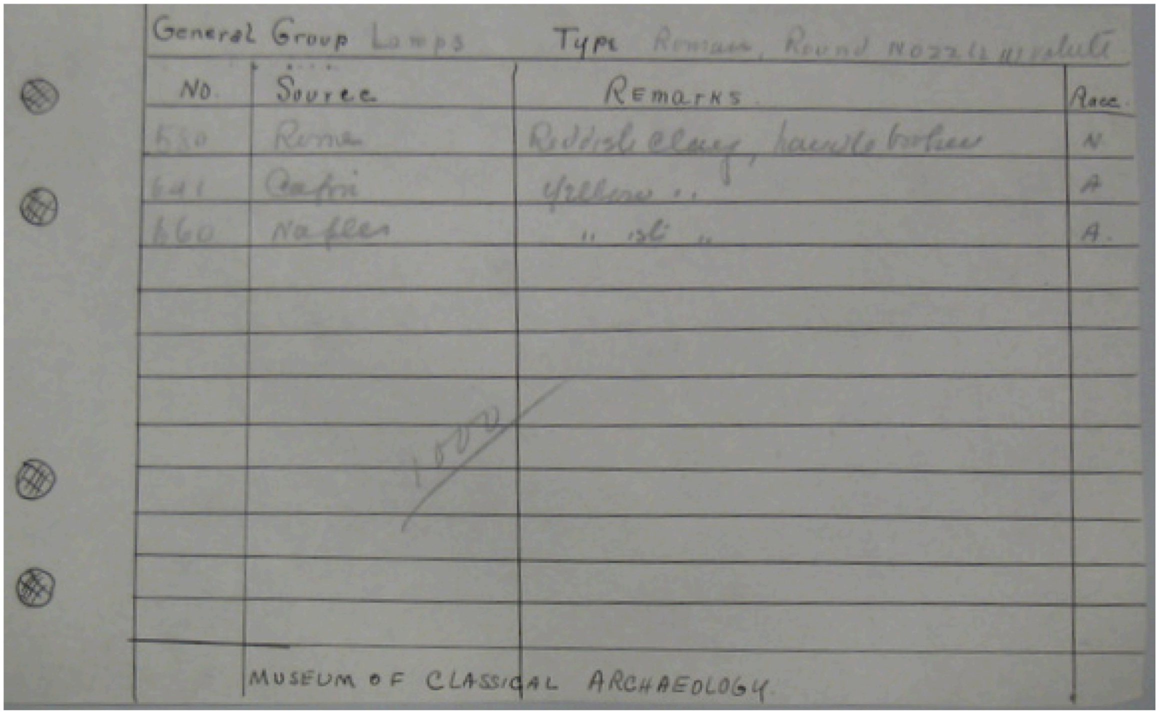
[13] At the time, these buildings were the two primary locations of the museum’s artifacts. The collections were later moved in their entirety to Newberry Hall.

[14] A form titled “Specimens Loaned, Exchanged, or Presented to Other Institutions.”

Winter returned Butler's letter with marginal notes giving his response. Form 1 was marked "Not Needed- No"; form 2 with the number 300, a much smaller amount than Butler suggested; form 3 was annotated "No- Wait For"; form 4 with the words "Not needed"; form 5 was not annotated and form 6 received the determination "Wait." Form 2 then, was the only one to receive a definitive immediate approval by Winter for use in the new museum. By selecting form 2 and not the others, Winter was emphasizing the need to record information about each object in a card catalog while minimizing the importance of reporting new accessions internally (e.g. form 1, "Notification to the Accession Officer" which was marked "not needed"). Butler suggested the latter function could be fulfilled with form 2, when she wrote that it would be "used for the record of all additions to the collections and as a basis of the yearly report which each Curator is expected to make yearly." Form 3 largely duplicates form 2 as an object catalog- both are card based and allow for the same object information to be recorded. The major difference is the prominence of the location field on form 3, emphasizing its use as a tool to track the location of objects. By deciding not to use form 4, an acknowledgment receipt, museum staff clearly de-emphasized loans between museums as an important function of the new museum. Butler's letter suggests that loans are not important to the museum in the words, "not needed unless we plan to do loan work." With his response, "Not needed," Winter agreed that loans were not something in which the museum would frequently engage. Form 6, also not selected, would have allowed the museum to record publication information about the objects in a listing by object type. While Winter's verdict was "Wait," suggesting that this form would be useful later in the museum's progress, it does not appear to have been adopted. Instead the object cards and files came to hold this information.

Form 5, which was not annotated by Winter, has no direct correlate in the museum today (Figure 4.1). It was essentially a means for the museum to list objects by group so that they could be easily located regardless of accession number or location. It would have functioned as a guide to objects grouped by type (in this case Roman lamps with a round nozzle). Aside from group and type, the only other information that would have been recorded here is accession number, source, remarks (allowing for a brief description) and the mysterious column "Racc" supplied with the codes N and A.

Assuming that this form was never adopted, this choice shows that while the ability to list objects by type was desired, it was not a major priority for the museum at this time.



General Group Lamps Type Roman, Round nozzle ...

No.	Source	Remarks	Race
550	Roma	Reddish clay, handle broken	N
641	Capri	yellow "	A
660	Naples	" " "	A.

MUSEUM OF CLASSICAL ARCHAEOLOGY

Figure 4.1 Form 5, General Group and Type. Accessions, folder 3, box 6, Orma Fitch Butler Papers, 1913-1938, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

Another form that was not adopted bears mention here. Figure 4.2, below, shows a form that was designed to be a House Catalog for the dig at Karanis. Listing house number, location, and year, it would associate information about the house to the objects found in each one.

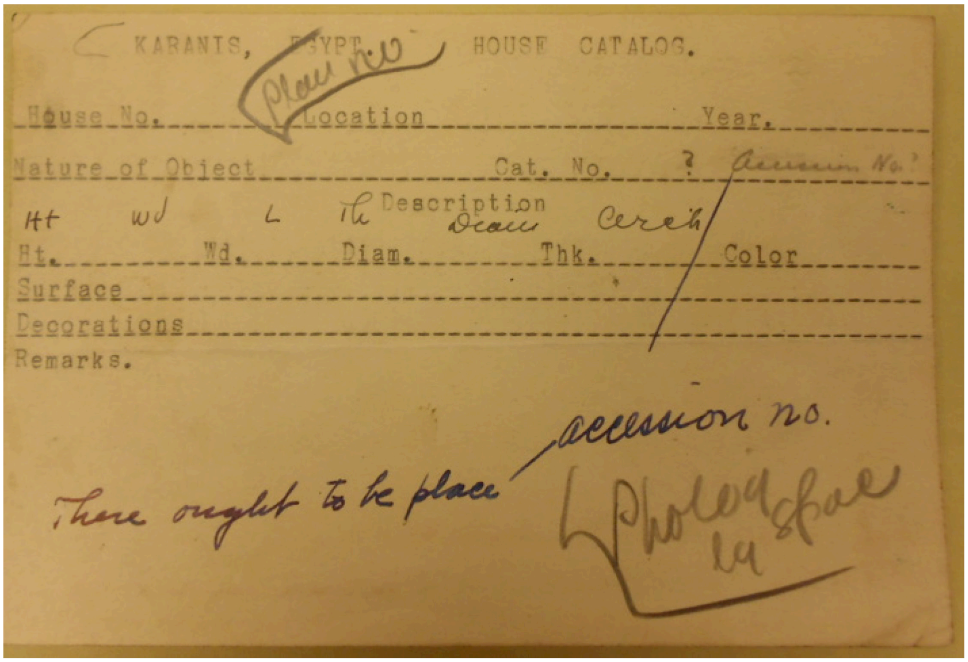
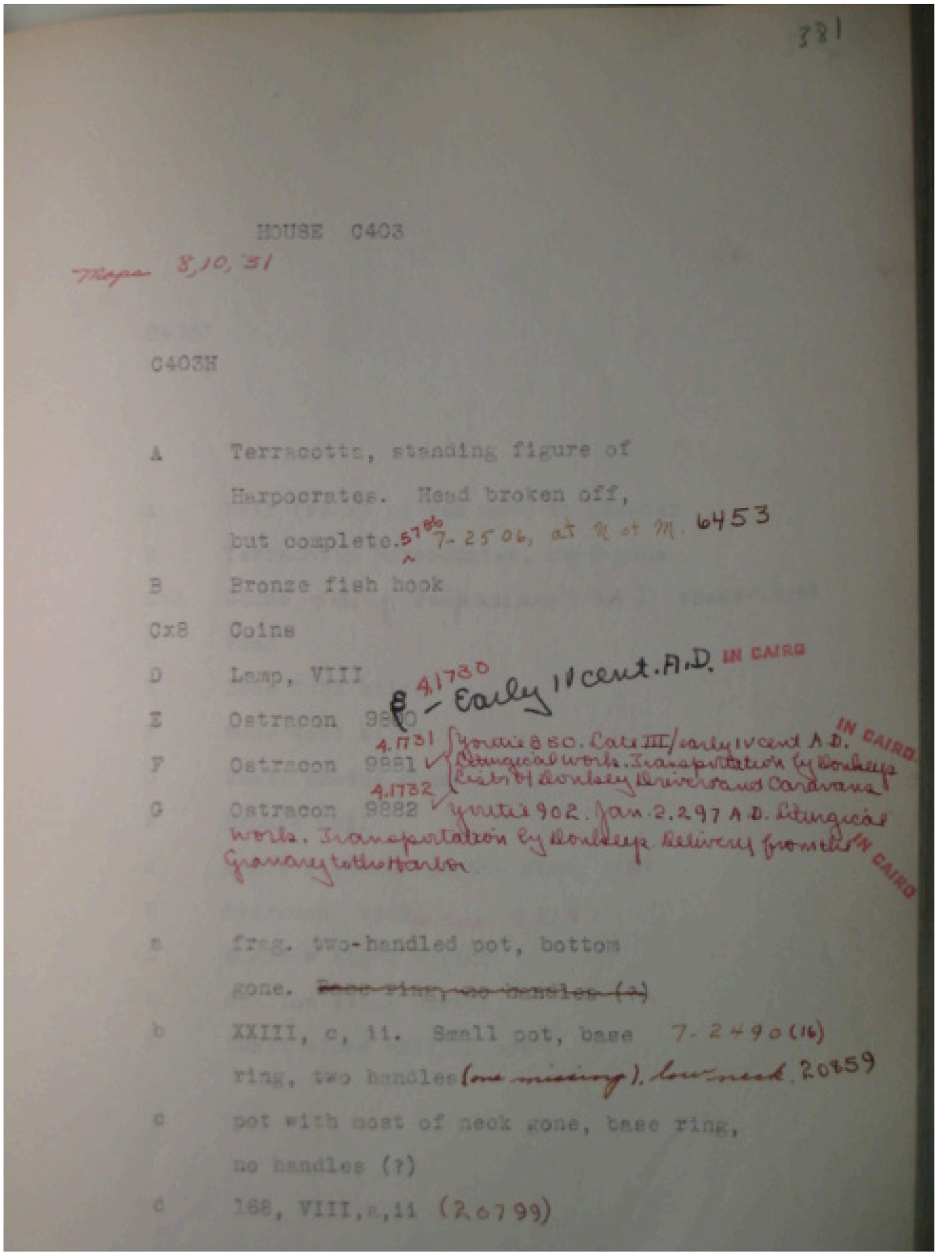

KARANIS, EGYPT HOUSE CATALOG.
House No. Location Year.
Nature of Object Cat. No. ? Accession No.?
Ht wd L Th Description
Ht. Wd. Diam. Thk. Color
Surface
Decorations
Remarks.
There ought to be place accession no.

Figure 4.2. Karanis, Egypt House Catalog, 1928. Accessions, folder 3, box 6, Orma Fitch Butler Papers, 1913-1938, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

This form may not have been adopted because of duplication in the Records of Objects from each excavation, which are part of the Kelsey's research materials, located today in the registration office (Figure 4.3). These typed books contain lists of finds from each structure excavated by the University, listed by the layer in which they were unearthed. Handwritten and stamped annotations denote what happened to the object ("in Cairo" or "at U of M"), give accession numbers for objects that became part of the museum's collection, and indicate available photographs of the objects. With information about the structure and layer from which excavated objects came, the museum is able to provide basic provenience for each object listed in these books.



381

HOUSE C403

Thopa 8,10,31

C403H

A Terracotta, standing figure of
Harpocrates. Head broken off,
but complete. 5786 7-2506, at N of M. 6453

B Bronze fish hook

Cx8 Coins

D Lamp, VIII

E Ostracon 9880 4.1730 - Early IV cent. A.D. IN CAIRO

F Ostracon 9881 4.1731

G Ostracon 9882 4.1732 IN CAIRO

IN CAIRO

a frag. two-handled pot, bottom
gone. ~~base ring, no handles (?)~~

b XXIII, c, ii. Small pot, base 7-2490 (16)
ring, two handles ~~(one missing)~~, ~~low neck~~. 20859

c pot with most of neck gone, base ring,
no handles (?)

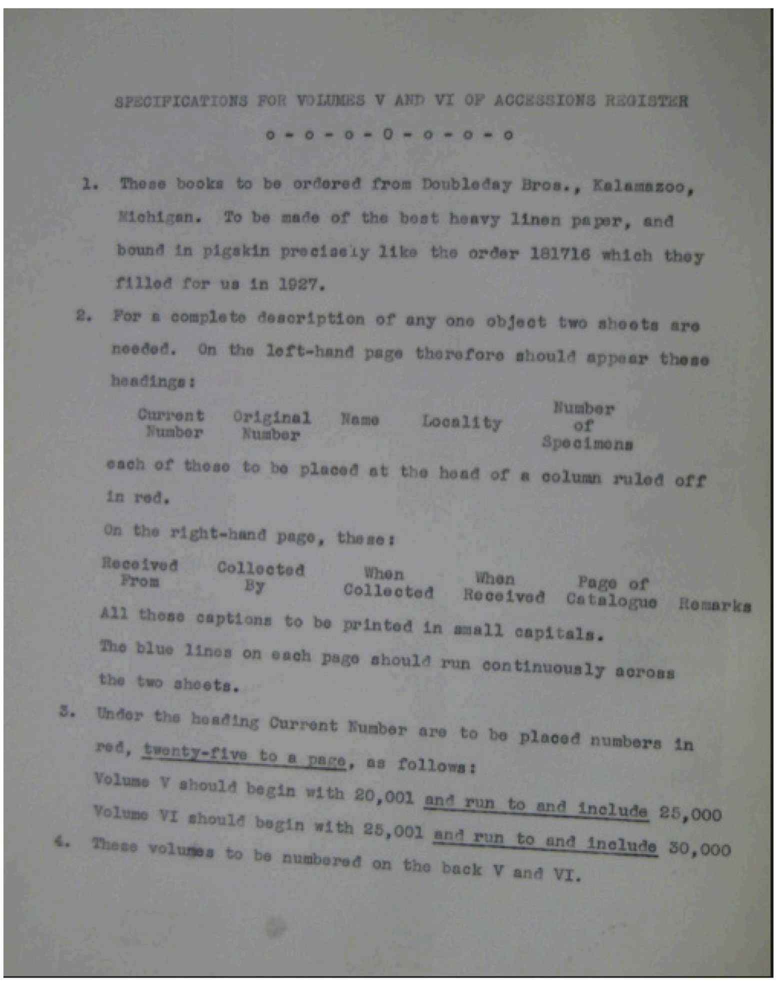
d 168, VIII, a, ii (20799)

Figure 4.3. Karanis Record of Objects, Season 1933-1934, page 381, Kelsey Museum.

By proceeding with Form 2 and neglecting others, Winter and Butler prioritized the comprehensive description of the collection, implying that other museum functions like loans and reporting new accessions were less important. Form 2 and its evolution to today's catalog is discussed in the next section. While they doubtlessly engaged in these other museum functions (loans are mentioned several times in their correspondence and Bulter's 1930 *Report of the Museum of Classical Archaeology* reported the museum's accessions) they were not deemed important enough to merit their own forms at the museum's start.

4.2.3 Early Museum Representations

One important part of the collection management process had already been established before Winter and Butler's appointments. The Accessions book had been ordered from Doubleday Bros. in Kalamazoo Michigan and would begin its fifth volume with the acquisition number 20,001, per Butler's specifications in 1928. The categories specified in this volume, a continuation of those that had been ordered in the past, were Current Number, Original Number, Name, Locality, Number of Specimens, Received From, Collected By, When Collected, When Received, Page of Catalog, and Remarks. Together, these categories provide basic information about the source of new objects entered into the collection.


SPECIFICATIONS FOR VOLUMES V AND VI OF ACCESSIONS REGISTER

o - o - o - 0 - o - o - o

1. These books to be ordered from Doubleday Bros., Kalamazoo, Michigan. To be made of the best heavy linen paper, and bound in pigskin precisely like the order 181716 which they filled for us in 1927.
2. For a complete description of any one object two sheets are needed. On the left-hand page therefore should appear these headings:

   Current Number | Original Number | Name | Locality | Number of Specimens

   each of these to be placed at the head of a column ruled off in red.

   On the right-hand page, these:

   Received From | Collected By | When Collected | When Received | Page of Catalogue | Remarks

   All these captions to be printed in small capitals.

   The blue lines on each page should run continuously across the two sheets.
3. Under the heading Current Number are to be placed numbers in red, twenty-five to a page, as follows:

   Volume V should begin with 20,001 and run to and include 25,000

   Volume VI should begin with 25,001 and run to and include 30,000
4. These volumes to be numbered on the back V and VI.

Figure 4.4. Specifications for Volumes V and VI of Accessions Register, 1928, Accessions, folder 13, box 5, Orma Fitch Butler Papers, 1913-1938, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

Accessioning of the collections was done by object type, following a system established by Kelsey. Butler wrote,

> Professor Kelsey's policy, which I have followed, was to set aside a certain section for one thing. In this way I have held nos. 5001 to 7000 for glass. We are now up to 6300 and there are lots of fragments to be entered which have not yet come to us. In like manner I am holding 9000 to 10000 for the new ostraka. I have a leeway of about 1250 numbers yet between 7001 and 8999, but there is material to fill most of that which I am entering as I have time.[15]

Butler's method of accessioning by reserving groups of numbers for various types of artifacts had benefits and drawbacks. First, because accessions in the museum were processed by individuals working with a given type of artifact, all of the objects given a subset of these numbers would have been accessioned by the same person. That person's job was simplified while the work could be easily traced to the person who did the accession. Because objects were not numbered sequentially according to their date of accession, however, the potential for skipped numbers was high. The system in place at this time was geared towards the ease of the person doing the accessioning, who processed objects by type, rather than a potential user, who might assume that an object with a smaller number had been at the museum for a longer time. From the user's perspective, the distribution of accession numbers could also potentially complicate their understanding of the object's provenance. Rather than accessioning all objects from a specific excavation locus together, for example, accessioning by type might cause a user to assume that objects were unearthed together when that was not the case. From the point of view of museum staff, though, this method helped ensure that the same accession number was not given to two objects while multiple staff members were involved in the process. This concern is echoed in a letter from Butler to Winter which reads, "Miss Van

[15] Letter from Orma Fitch Butler to John G. Winter, May 27 1932, Correspondence with John G. Winter 1934-1935, folder 8, box 5, Orma Fitch Butler Papers, 1913-1938, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

Ingen will give me the material by numbers for the Accessions Book. I have given her the series 15000 on so there is no risk of confusion."[16] The division of labor used by the museum in the accessioning process, grouping accessions by object type, also reflects specialization within the field of archaeology, where a researcher may have expertise with a specific kind of material through their specialization as a ceramicist, for example.

While organization of accession numbers took place by object type, another priority was to keep materials from a given site altogether in one group. As Butler wrote to Winter, "It seems to me that it would be an excellent plan to get the fourth volume [of the Accessions ledger] now, and after the figurines are done, those are the things which I have assigned to the 14,000's, go on in the new volume, keeping the Seleucia material by itself."[17] Thus we see that the numbering system for accessions was useful to the museum in separating groups of objects, whether grouped by type or by origin. It was a means of controlling workflow as well as managing information.

Early on in their positions as museum director and curator, Winter and Butler set creating a catalog of the entire collection as a high priority. Winter wrote to Butler,

> I want a complete catalogue prepared of all the objects in the collection: the cards should be rushed through. In addition we need, as soon as possible, a catalogue card for every coin in our Collection. The assistants are provided with the understanding that they do actual museum work: furthermore we need the work done.[18]

The catalog at this time was a card-based system, with a card for each object in the collection. The basic format of the card was derived from form 2 in the correspondence between Butler and Winter discussed above. Form 2, sketched by Butler in Figure 4.5, was for a card catalog of objects in the collection giving an object description, location in the collection, accession and catalog numbers, locality, when received, and remarks.

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[16] Letter from Orma Fitch Butler to John G. Winter, October 6, 1932, Correspondence with John G. Winter 1934-1935, folder 8, box 5, Orma Fitch Butler Papers, 1913-1938, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.
[17] Letter from Orma Fitch Butler to John G. Winter, December 1, 1932, Correspondence with John G. Winter 1934-1935, folder 8, box 5, Orma Fitch Butler Papers, 1913-1938, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.
[18] Letter from Orma Fitch Butler to John G. Winter, October 14, 1931, Correspondence with John G. Winter 1934-1935, folder 7, box 5, Orma Fitch Butler Papers, 1913-1938, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

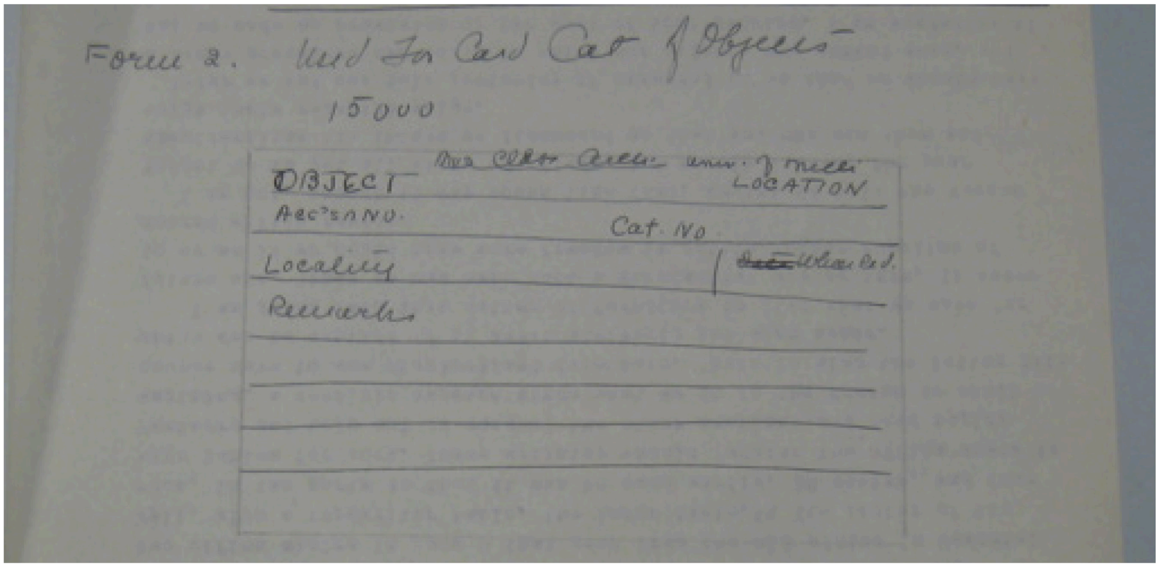
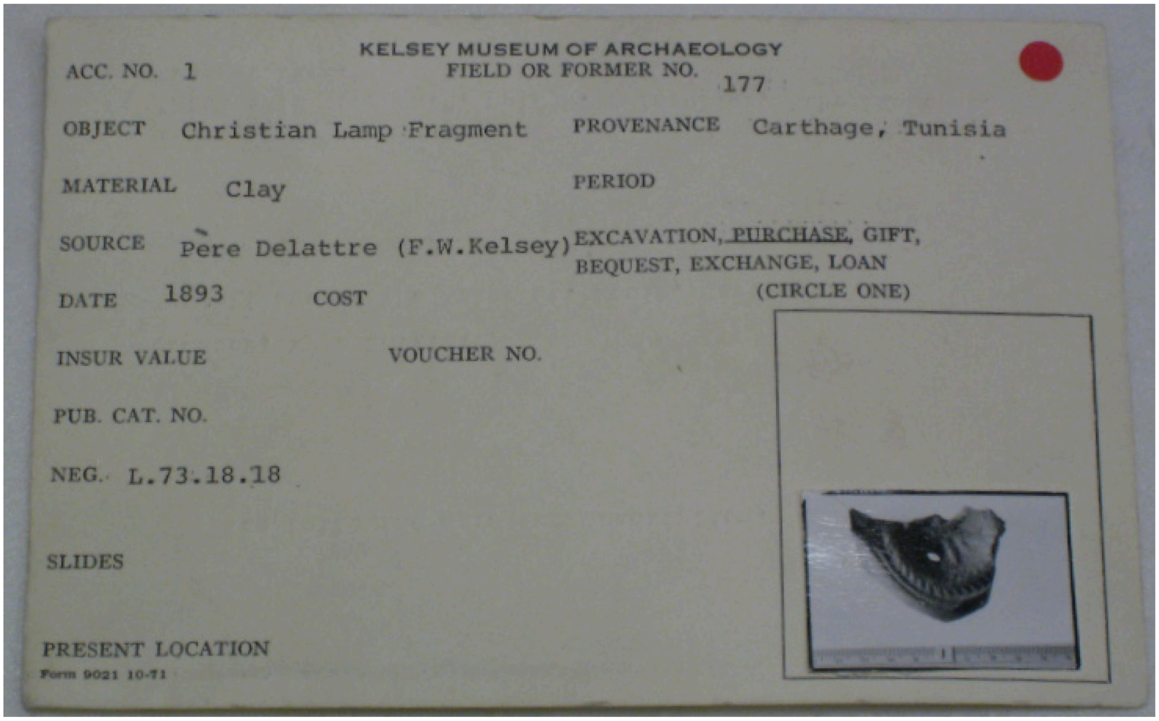


Figure 4.5 Form 2 Used For Card Cat of Objects drawn by Orma Butler, Accessions, folder 7, box 5, Orma Fitch Butler Papers, 1913-1938, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

4.2.4 Information Systems

With some modification, the card designed by Orma Butler as Form 2 is still in use at the Kelsey today. While similar in structure and content categories, the object card for accession number 1, shown in Figure 4.6, has a great deal more detail than Butler's sketch for form 2. While accession number, object, when received (now "date"), and remarks are still present on the later card, fields like provenance, date and style, history, and bibliography allow the museum to be more specific about the history of the object- both its source and its history of publication. The date and style field in Figure 4.6 references a typology of terracotta lamps from Corinth written by Oscar Broneer and published in 1930 (Broneer 1930). While his type 28 is identified with a question mark, indicating uncertainty, the inclusion of this category ties this object to broader epistemic practices in archaeology by fitting it into a type determined by another archaeologist. It references a publication with a series of plates of lamps organized by the typology Broneer developed. Furthermore, the image attached to the card allows the user to make a visual check that the card represents the object of interest.


KELSEY MUSEUM OF ARCHAEOLOGY

ACC. NO. 1 FIELD OR FORMER NO. 177

OBJECT Christian Lamp Fragment PROVENANCE Carthage, Tunisia

MATERIAL Clay PERIOD

SOURCE Père Delattre (F.W.Kelsey) EXCAVATION, PURCHASE, GIFT, BEQUEST, EXCHANGE, LOAN (CIRCLE ONE)

DATE 1893 COST

INSUR VALUE VOUCHER NO.

PUB. CAT. NO.

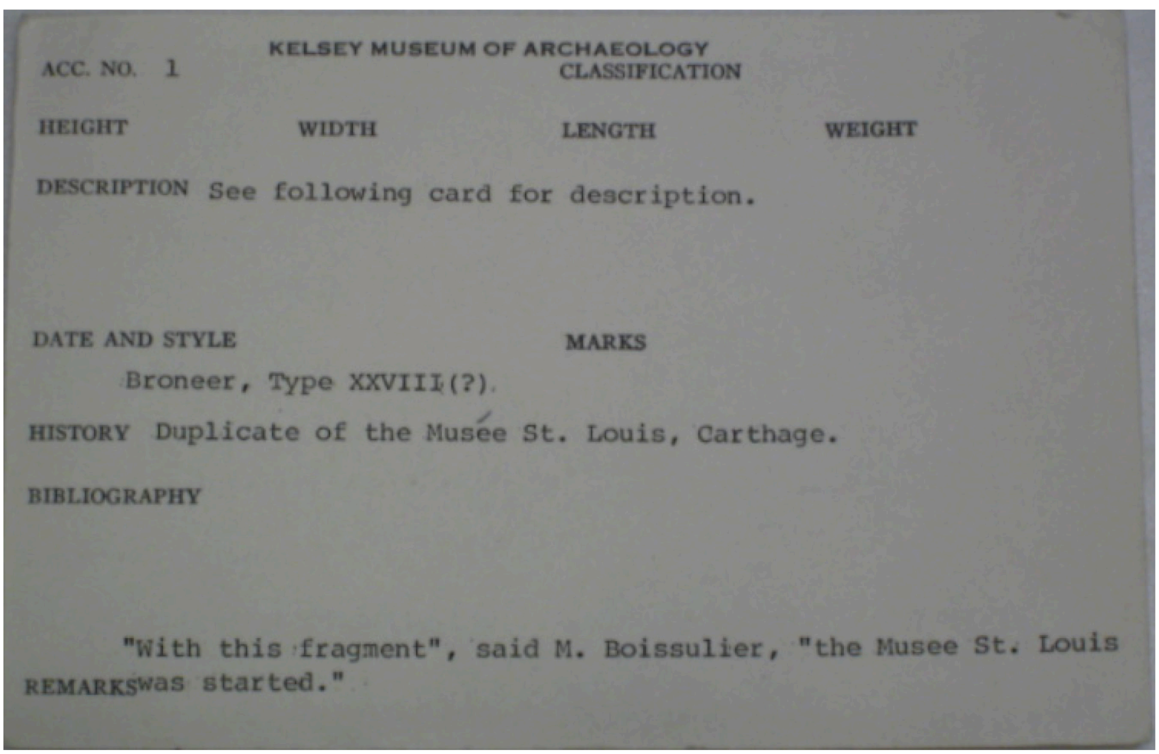
NEG. L.73.18.18

SLIDES

PRESENT LOCATION

Form 9021 10-71

Figure 4.6: Front of object card for accession number 1, Kelsey Museum


KELSEY MUSEUM OF ARCHAEOLOGY

ACC. NO. 1 CLASSIFICATION

HEIGHT WIDTH LENGTH WEIGHT

DESCRIPTION See following card for description.

DATE AND STYLE MARKS

Broneer, Type XXVIII(?)

HISTORY Duplicate of the Musée St. Louis, Carthage.

BIBLIOGRAPHY

"With this fragment", said M. Boissulier, "the Musee St. Louis

REMARKS was started."

Figure 4.7: Back of object card for accession number 1, Kelsey Museum

More recently, cards have been produced directly from the electronic catalog. Figure 4.8, showing the object card for Accession 2009.01.0001, was printed by a collection manager from the coin's catalog record. The fields here are essentially the same as those given for accession number 1, but they now include a place for the museum to record objects' use in exhibitions, indicating that a record of the museum's own use of the object has now become a priority. Another notable difference between the object cards for the first and more recent accessions is the numbering system, which the museum changed from a strictly serial number to one that begins with the accession year.

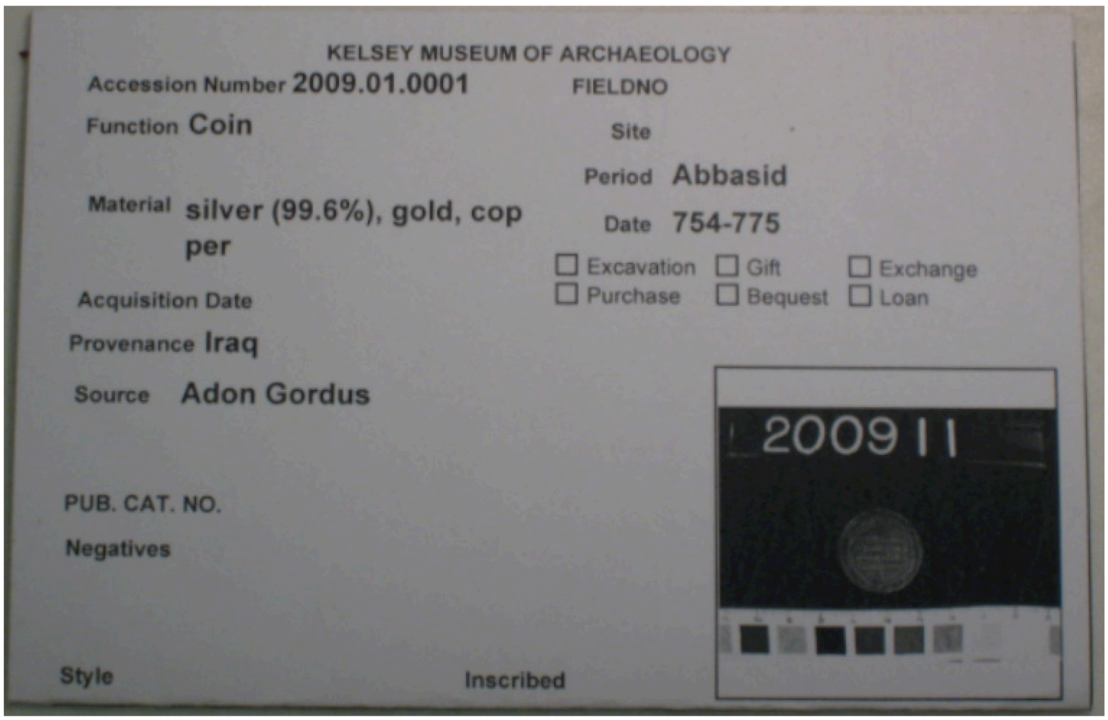


Figure 4.8: Front of object card for accession number 2009.09.0001, Kelsey Museum

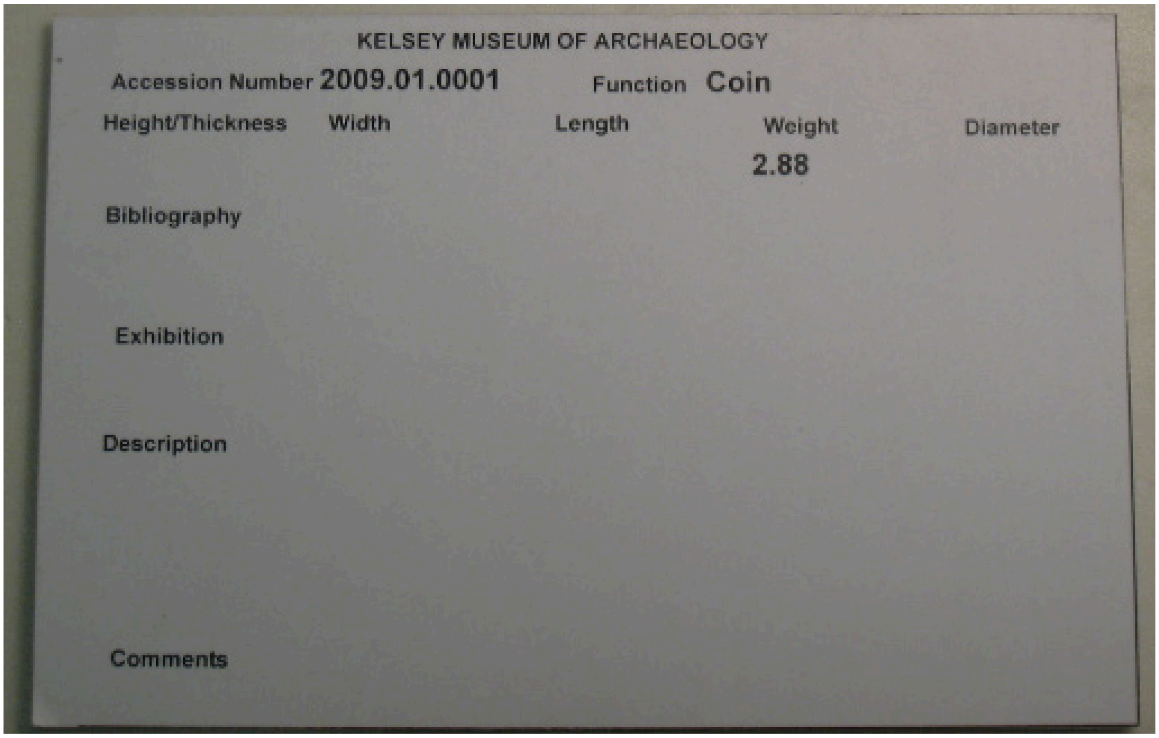


Figure 4.9: Back of object card for accession number 2009.09.0001, Kelsey Museum

While the object card system has been an important information management tool since the museum's founding, it is no longer the only source for object information. In the 1980s, the museum adopted an electronic catalog for objects. While the accessions book and object cards are still kept current, they are now derived from the electronic catalog. As collection manager AS1 explained,

> Nowadays it actually goes backwards. We start off creating records in a database along with the actual paper files, the deed of gifts and all that. So we get the deed of gifts and then once it's been accepted, and once it's been formally given over to us, somebody will create a database record for each object. Then from there, because we've had to type things in or write things into a ledger and then print that out, I'll type in brand-new accession cards. I've created a database for that. The accession ledger pages and the accession cards all print from the database. So we just enter everything here and then everything else prints off in that way.

In AS1's account, paper files ("the deed of gifts and all that") are the original source of information. Those files are used to created electronic object records and are stored in a series of filing cabinets. Each object has its own file containing these original documents along with copies of publications referencing the objects. The source of this original documentation, object collectors, was not always reliable, as the next section shows.

4.2.5 Gathering Information from Collectors

Butler viewed capturing information about the collection held in the memories of the individuals who had obtained them for the museum as another important task. In her correspondence with Winter, she often asked for artifact information from him or lamented the difficulty she faced in getting others to provide her with that information. Examples abound in Butler's papers, including the following, which she wrote in a July 18, 1929 letter to Winter, "Amundsen messed up some of the sherds so that I cannot tell from what house they came. Harden did the same with the glass by dividing fragments into two classes, one for a study of the technique and the other for storage. It made my work in accessioning three times as hard as it would have been if I could have had the stuff first." Butler lamented that, "Without co-operation between the people responsible for the different digs and me the whole business goes on the rocks."[19]

Between excavation and accessioning, physical management of the materials was an instrumental part of information management. The objects themselves needed to be in an intelligible order, grouped by origin, in order to identify them correctly and maintain their provenance. Butler's lament also provides an example of a researcher's organization scheme potentially impacting later secondary use. Because Harden had grouped the glass objects by intended use (for study or for storage) their provenance was no longer evident in the physical organization. If Butler remained unable to determine the house from which each fragment came, their value as data would decrease. Groupings such as Harden's, no doubt useful to his research, were harmful to the accessioning process and for preserving the meaning of the data for others.

Dig supervisors were responsible for submitting information along with the objects to detail their origin. Butler expressed a great deal of frustration with a faculty

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[19] Letter from Orma Fitch Butler to John G. Winter, July 19 1929, Correspondence with John G. Winter 1934-1935, folder 7, box 5, Orma Fitch Butler Papers, 1913-1938, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

member at the University on this score. Leroy Waterman directed the excavation of Seleucia on the Tigris near Baghdad in Iraq from 1927 to 1932 and appears to have provided insufficient information for cataloging finds from that work (Kelsey Museum 2011e). Butler wrote to Winter on October 11, 1933 to report on her progress in accessioning materials from Waterman's dig, "This afternoon, I was held up in starting, I accessioned some fifty pieces, and only about five had a dig number. I do not dare put my thoughts into words." Winter wrote in the margin of the letter, "Place the stuff on shelves, labeled, to get it out of way. It is up to Waterman to study it."[20] While the precise nature of the difference between labeling the materials and fully accessioning them is not known in this case, it begs the question, how often did circumstances necessitate accessioning objects with only partially complete identification? This vignette also points to the division of responsibility in the museum- the collector (Waterman, who was also a faculty member) was responsible for describing the objects, not the curator. This caused a delay in accessioning that Butler and Winter were unable to directly address—these materials could not be fully accessioned until Waterman had done his part in documenting the objects. The description and interpretation of these objects was not part of the curator role, in Winter's opinion.

Correspondence between Butler and Enoch Peterson, in charge of the University of Michigan excavations at Karanis and Dimé between 1926 and 1935, reflects the difficulty of understanding notations made at an archaeological site once objects returned to the museum. In response to Butler's question about the source of a number of objects sent to the museum, Peterson wrote,

> All of last year's shipment was from Karanis, except the papyri and ostraka. We followed a different system of recording at Dimé, which will always tell you whether an object is from Dimé or Karanis. To designate levels, since 1926 at Karanis, we have used the letters A, B, C before numerals, which serve as house

[20] Letter from Orma Fitch Butler to John G. Winter, October 11, 1933, Correspondence with John G. Winter 1934-1935, folder 8, box 5, Orma Fitch Butler Papers, 1913-1938, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

> numbers. At Dimé all the objects are entered by house number also, but every house number has either I, II, III, etc preceding it, designating levels.[21]

The changing systems for designation at the excavation sites had not been made transparent to the curator of the museum that would hold a great number of the objects, a sign of the lack of communication between excavators and the museum.

The museum's third curator, Louise A. Shier, routinely wrote to her predecessor, Enoch E. Peterson, for information about the collection. Both individuals served as curator and then museum director: Peterson was curator from 1938 to 1950 and director from 1950 to 1961. Shier was curator from 1950 to 1973 and also director for the final two years of that time, from 1971 to 1973. Given Peterson's experience as excavation director, it is not surprising that he was an important source of information about the collection. In the following example, Shier wrote to Peterson asking him to decide which date is correct for a lamp, "In going over the lamp records, I find that I have two dates for 33-C 404 L, Late 3rd and Late 2nd to early 3rd. I think that the late date was corrected to the earlier one, and that is what I would expect from the type of lamp."[22] Peterson replied, "Then in regard to the date of a lamp from 33-C404L, the earlier date is correct, as you thought, Late 2nd to early 3rd."[23] Peterson does not give his reasoning for this determination, but given the reference to a specific area and layer within a dig (33-C404L) it was likely derived from his experience as supervisor on the dig. This example of verification of expertise among curators at the museum shows a case in which one individual's expertise is taken at face value.

Another important source that curators used to positively identify an artifact was photographic records. Orma Butler wrote to John Winter,

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[21] Letter from Enoch Peterson to Orma Fitch Butler, February 11, 1933, Correspondence with Butler, Orma Fitch, 1929-1933, folder 16, box 1, Enoch Ernest Peterson papers, 1924-1962, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

[22] Letter from Louise A. Shier to Enoch Peterson, July 11, 1964, Correspondence, folder 2, box 5, Louise Adele Shier papers, 1923-1977, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

[23] Letter from Enoch Peterson to Louise A. Shier, July 13, 1964, Correspondence, folder 2, box 5, Louise Adele Shier papers, 1923-1977, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

> I have often wondered where the Karanis photographs are kept. We often have need of them in identifying objects when the dig numbers become dim. Can you give me any information about them and how to get at them? I'm inclined to think that the photographs of our Museum material should be kept with the objects. I may be wrong in this. I'm open to conviction.

Winter replied by writing on the letter, "The negatives and photos are, I believe, kept in the official file of the Excav. in Mr. Swain's room in the library. This was done to protect against loss by fire."[24] In this example we see the importance of photographs as a resource in managing objects, to verify dig numbers written directly on the objects. It also illustrates the museum's tactic of physically separating records related to a dig based on their provenance and preservation needs.

4.2.6 Early Research Use

Archaeological excavations sponsored by the museum were organized through the Committee on Near East Research, supplanted in 1931 by the Institute of Archaeological Research, a group comprised of many of the same faculty members at the University. In addition to its work overseeing the University's excavations in the Near East, the Institute of Archaeological Research received funds from the University to begin the Humanistic Series, published by the University Press, which released a series of reports of the Karanis excavations and studies of finds including papyri and ostraka discovered at the University's archaeological sites (Robbins 1958, p.1464). The Humanistic Series first appeared in 1907, co-edited by Francis Kelsey and Henry Sanders, Professor of Latin (Pedley 2012, p. 174). With the Institute of Archaeological Research and the Humanistic Series, the University built a key part of the infrastructure for reporting the results of its excavations.

In 1941 a group was established within the museum to both oversee the research use of Near East archaeological collections and to promote the accumulation of further collections.

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[24] Letter from Orma Fitch Butler to John G. Winter, January 26, 1934, Correspondence with John G. Winter 1934-1935, folder 9, box 5, Orma Fitch Butler Papers, 1913-1938, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

> After the University closed its excavations at Karanis and Seleucia, the general direction of these projects exercised by the Institute of Archaeological Research came to an end. It may be added that there were two chief reasons for establishing the Institute: 1) to assume responsibility for the general program of excavation and to assist Professor Kelsey while he was abroad; 2) to make it possible for the Rockefeller Board to allocate funds to a specific body for specific purposes. Most of the members of the Institute believed that with the stopping of field work and the expiration of Mr. Rackham's last grant, an important phase of their work had been finished. It was also thought that a smaller organization could more effectively handle the general matters of research and publication that remained.[25]

The smaller organization formed was known as the Committee on Research of the Museum of Art and Archaeology. The members of this group, appointed for indefinite terms, were charged with approving access to museum objects and photographic reproduction requests for research. In the group's mandate was a policy of granting access, particularly to internal users:

> It shall be the policy of the committee to permit access to all materials in the collections for purpose of study and of publication to such members of the University staff and student body, regardless of departmental affiliation, as are competent to make such use of them, subject only to such restrictions as are necessary for the safeguarding of valuable University property. The committee shall control the use of unpublished materials in the collections by persons not connected with the University.[26]

With this reorganization, the management of research access to collections was placed directly within the museum and made an explicit goal of the organization. Permission was generally granted for the reproduction of images, both in the Committee on Research of the Museum of Art and Archaeology and its earlier incarnation. A letter from the Executive Secretary of the Institute of Archaeological Research on August 18, 1938, references a request from Mrs. Nellie S. Johnson to use photographs from the museum's Egyptian textiles in a book "Simple Looms and Weaving Techniques." Permission was granted, with the statement that "We would prefer, however, whenever it is possible that the illustrations be of textiles already published. We have no objection,

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[25] Memorandum Concerning the Duties of the Secretary of the Committee on Research of the Museum of Art and Archaeology, undated, folder 6, box 1, Papers of John Garrett Winter, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.
[26] Memorandum to the Honorable Board of Regents for May 28, 1943 folder 2, box 1, Papers of John Garrett Winter, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

however, if unpublished specimens are especially desired to permit her to use them provided use is specifically approved by the Museum of Classical Archaeology."[27] Perhaps because her writing tended to showcase weaving from around the world from a craft technique rather than an archaeological perspective, the group preferred that she use objects that had already been published for her book (McKenna 1998).

Research use of the museum's materials was not without hazard. Correspondence between Orma Butler and John Winter refers to a Miss Wilson whose "arbitrary procedure in cutting some of the textiles" … "exceeded the authority given to her" by Winter. The museum director had instructed the researcher that "in cases where a cloth was manifestly a composite patchwork of several pieces she might separate the parts." He notes that "this is a scholarly method, adopted by all who work with composite papyri. More than this she had absolutely no right to do." While Butler wanted to reproach the researcher in a letter, Winter insisted that "the letter would make her sniff, but she would not reply, and that would leave us about where we are." Instead, he insisted that it would "be entirely proper to enter a note on the inventory cards and on the labels to the effect that such and such a piece had been cut by her while preparing her book."[28]

Orma Butler seems to have had a difficult time letting go of the matter. Several months after their previous correspondence on Miss Wilson's use of the textiles, she wrote to Winter, "While the girls were mounting the textiles last winter, we made frequent use of Miss Wilson's book. At that time we found several slips. Recently, after the textiles had been arranged and accessioned, I went through her book and checked all the Karanis material. I found so many errors that it seemed best to bring the matter to your attention." She found discrepancies in the measurements of the textiles of half an inch in many cases and specifically listed 19 objects for which she disagreed with Wilson's descriptions on the basis of their measurements, Wilson's incorrect record of the dig number at the excavation from which pieces were unearthed, and in some cases,

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[27] Letter from the Executive Secretary of the Institute of Archaeological Research, August 18, 1938, folder 6, box 1, Papers of John Garrett Winter, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.
[28] Letter from John G. Winter to Orma Fitch Butler, March 6, 1934, folder 9, box 5. Papers of Orma Fitch Butler, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

incorrect listing of the museum's number for objects. Butler also complains that "she did not keep some of the tags which she took off the pieces which she published in her plates. That means we have nothing but her word to fall back upon when we wish to know their provenance and for my part […] I don't think her word is of any great value."[29] Butler's letter illustrates an interesting relationship between the museum record and the published record in archaeology. Because some of the objects were lacking tags that connect them to their provenance in the museum records, Miss Wilson's book became the authoritative source on those objects. Until another publication corrected her errors, they would be taken as correct by any archaeologist who did not consult the museum itself. Some of the errors to enter Miss Wilson's work were carried over from an earlier publication describing the objects. Butler wrote that, "She cannot be blamed for errors made by Midgley [the earlier author], but, if she used the dig register, as she should, she would have found them herself."[30] In order to be a thorough archaeological researcher, then, Butler suggests that consulting records from the excavation that produced the objects is essential. Earlier publications describing those objects were necessary resources, but insufficient ones.

The importance of publication of objects in the museum is apparent from numerous parts of the Butler/Winter correspondence. As Butler wrote to Winter,

> I have been looking over coin records lately and have made up my mind that if you still wish me to undertake the cataloging of the ancient coins now in the collections I will undertake to get it done in the five year period. There are not so many of them unless the Karanis coins and Waterman's coins are included, and I understand that those are to be done in connection with an account of the excavations in those places.[31]

By focusing on coins in the museum's collection that were not slated for publication, Butler could assure that the museum's research efforts would not be duplicated in others' work. In turn, the museum's catalog could be augmented with those publications.

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[29] Letter from Orma Fitch Butler to John G. Winter, July 7, 1934, folder 9, box 5. Papers of Orma Fitch Butler, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.
[30] Ibid.
[31] Letter from Orma Fitch Butler to John G. Winter, July 27, 1929, folder 7, box 5. Papers of Orma Fitch Butler, Kelsey Museum Papers, Bentley Historical Library, University of Michigan.

Descriptions of collections were clearly an important intellectual output of the museum. Butler wrote to Winter on September 29, 1932, "I am asking Miss Shier to start the record of the lamps this year filling out the sheets as the blanks indicate. If she does this well, could she, in time, be allowed to publish this as part of our Catalog? I think it would add an incentive to her work if this could be done." Winter replied on October 6,

> It is highly desirable that all the various collections be catalogued as completely as possible in the immediate future. The assistants should, therefore, be assigned definite tasks, e.g. Miss Shier can take the lamps, and Miss Ogden the coins, woodwork, pottery, mosaics, or varia as you determine. The entries should be made on uniform cards of the sort approved some time ago. It is our aim to publish the collections, and the assistants can help in organizing the material.

In their discussion of assistants' role in the process, Winter insists that they should "help in organizing" rather than being "allowed to publish," as Butler requested. This conversation hints at the importance of these published descriptions of collections and at the division of labor inherent in museum employees' early roles. People in excavation roles, like Waterman in the case discussed above, were responsible for researching collections and publishing their findings while assistants should focus on cataloging, leaving publication to those with greater expertise. While Miss Shier was assigned the task of cataloging the lamps in 1932, her affiliation with the museum lasted through 1973, and she served as curator of the museum for the final 23 years of that relationship.

These role divisions, in respect to generating content at the museum, are still in place today. While curators are expected to create exhibition content and publish material based on the collection, non-curatorial staff working with collections may contribute research that adds to the museum's knowledge of the collection, but they are not expected to publish their findings.

4.2.7 The Kelsey Today

The next great era of change for the Kelsey Museum took place from the 1970s through 1990s. Curator AS5 described both a new fund raising initiative and an expansion in the staffing structure of the museum during this time.

> [We] hired quite a few new staff members and new curators. We expanded enormously, we got money to renovate the old building—not in the galleries areas so much as putting in a new floor that allowed us to contain our very fragile

> collections in a climate-controlled environment. We had no climate control before that. The hope was always that we would get a new building, but it was very unlikely because museums are not tuition-generating units at the university and they don't have much priority in the scheme of things. So our only hope of doing that was to find private funding and that finally came through. We established […] a friends group called the Associates of the Kelsey Museum.

Through the Associates group, the museum made contact with potential donors, including those who would eventually fund the William E. Upjohn Exhibit Wing, completed in 2009. Both the relationships with donors aided by the Associates group and the improvements they enabled to the building housing the collection were important infrastructural advances during this time.

The switch in staffing from one curator to several was another important change during this era. AS5 reports that the museum director was able to hire a full-time conservator for the museum and to expand to two curators, one of whom (AS5) was in charge of the collections while the other was in charge of producing publications from the museum's excavation history. Through her own growing knowledge of the collections, AS5 began to lobby for additional curatorial staff with expertise in parts of the museum's collections.

> I began […] to explore pockets of the collection and began more and more to realize how much there was, and how many different specialties it would require in order to do justice to this set of materials. And so, there was a retiring elderly curator […] who was a year away from retirement or so when I arrived. And when she retired, [the museum director] argued to keep that salary at the museum, and split it with one of the departments. And so we hired another collections person not in Roman, but in Ancient Near Eastern, and that's [another curator] who is still here on campus. […] And then, I can't remember exactly how this happened, but we had some leave money that we were able to split with Near Eastern studies, who were looking for an archaeologist. We needed an Egyptologist in the worst way because we just really have a lot of Egyptian material. […] And we ended up with two Egyptologists: one in Early Period and one in the Late Period. And they were not solid appointments at that point, they were kind of interim appointments, partly using money that was freed up when [another curator] became chair of this department. But it evolved and they became so central to our operations that over the years we were able to make them solid curatorial and faculty appointments—tenure track. And so that was another avenue and so we ended up instead of one collections curator, we had five collections curators.

This extended quotation illustrates the slow expansion of the museum's curatorial staff as museum leadership responded to funding opportunities throughout the University and worked with academic departments to meet both academic and curatorial needs while sharing the funding burden. In addition to finding funding for new curators, retaining funding for salaries when people left was an ongoing priority. As the curatorial staff expanded, curators were hired whose expertise matched strengths in the Kelsey's collections of artifacts. The curatorial component of the museum's infrastructure grew substantially during this time, bringing with it a shift towards curatorial specialization that remains in the museum today.

It was also during this era that the first electronic database of the Kelsey's collection was created. As AS1 explained, the database was derived from the accession cards describing objects in the collection. "The first database was created in the 1980s, mostly by students, from what I am told. […] As far as I understand, everything in the database derived from the accession cards almost verbatim." Because the new records were derived directly from the paper records preceding them—and created by students rather than museum professionals—terminology was not standardized. These records formed the basis of today's system, as AS1 described.

> Since then there have been some upgrades in software, but not in nomenclature or categories. Those have remained static, with no changes since I arrived. There have been record-by-record tweaks, but nothing on the whole. Categories for objects, locations were all left to the whim of the data entry person, which created many typos or different spellings of words. And dates...woooh, that field is all over the place.

While the content of specific records has been updated since the 1980s, no attempt has been made to apply controlled vocabularies or follow any archaeological or museum specific guidelines for structuring data. This has implications for database users who want to see all objects with a specific attribute, as that attribute may have different names in different records. The homegrown system now uses a FileMaker Pro database, but this should change within the next several years, as all museums within the University's College of Literature, Science, and the Arts (including both the Kelsey and the Herbarium) switch to a unified catalog using the collection management software KE

EMu (KE Software's Electronic Museum management system).[32] With the adoption of the new system, AS1 hopes to be able to incorporate controlled vocabularies like the Getty Research Institute's Art and Architecture Thesaurus[33] to describe objects using standards common to the museum community.

More recently, during AS1's tenure, the museum built two other research databases: an excavation database, holding information from the museum's excavation ledgers at Karanis and Seleucia, and a photographic database, cataloging the museum's collection of photographs (particularly those of George Swain, a photographer who traveled with Kelsey). The excavation database was created from the metadata in the ledgers themselves while the photograph database, like the collections database, is derived from a card catalog already created.

Because they are easily shared, the databases enable AS1 to send collection information to researchers in response to their inquiries, but when questions remain, he shares scans of the originals themselves, as he described below.

> The first step is, I had a grant a couple of years ago. Those excavation ledgers that [my student assistant] showed you, the colored ones up front, I had several people work on creating a database with nothing but that information. So all the excavation information is now in a database. So, the first step is just to share that with them. If they want more, I can share the excavation ledgers with the same information.

While the excavation database contains the same information as the ledgers themselves, the documentation as it was originally recorded still has a great deal of research value, and is often consulted as an authoritative data source. Figure 4.3, a page from the Karanis Record of Objects, bears an annotation history that uniquely conveys information about the disposition of artifacts from that excavation.

Throughout these changes to the building housing the collection, museum staffing, and the collection and supplementary databases, the Kelsey has continued to sponsor excavation projects. The Kelsey's website lists 19 past fieldwork expeditions, including the three mentioned above, along with seven ongoing fieldwork sites in the

[32] http://www.kesoftware.com/
[33] http://www.getty.edu/research/tools/vocabularies/aat/

Near East. The oldest of these current projects began in Abydos, Egypt in 1995 (Kelsey Museum 2011b, 2011d).

In contrast to Karanis and the Kelsey's other early excavations, many of the more recent excavations have not resulted in the addition of artifacts to the Kelsey Museum's collections. The 1970 UNESCO *Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property* changed the legal and ethical standards governing international archaeological excavation, largely stopping the export of archaeological materials from their country of origin. Requirements for stronger oversight of excavations, specific documentation for the international movement of archaeological objects, and requirements that member nations assist with the repatriation of stolen goods were some of the outcomes of the UNESCO convention that greatly impacted archaeological practice (UNESCO 1970). Because excavated materials now remain "in-country" to be studied onsite at a dig prior to their eventual deposit at a museum in that country, the data kept by archaeologists, including their notes, excavation records, and the images they create in the course of their work, are now the primary things archeologists working with the Kelsey bring back with them. Thus, these representations have more salience than for previous generations of archaeologists.

Objects entering the Kelsey's collections now are mainly donations of antiquities purchased by collectors prior to 1970, but they are not accessioned without clear and trustworthy documentation, due to the museum's concern about following UNESCO guidelines. As Collection Manager AS1 told me,

> We need strong provenance [...] If somebody says a lot about unclear provenance, that's a red flag for us, and that's kind of a no-no. Anything that might then look like it may have been done illicitly, we'll steer clear of, to the point that if somebody wants to have us identify anything, we follow the same thing. Because we don't want to tell somebody, 'Oh, that's really ancient, you have something really fabulous,' and then they go on and sell it, because we're trying to get away from that sort of thing.

The other way in which accessioning currently takes place at the Kelsey is when objects without accession records surface in the collection. The museum uses a great deal of caution dealing with these objects as well, as AS1 described.

> Although we're really good about knowing what we have, every museum, every once in a while, finds something in their collections that they don't have records for. After months of research, to make sure that it hasn't been previously accessioned and that we rightfully own it, we could accession things that have been here.

The Kelsey currently has a collection of 98,207 objects, each of which has a record in the museum's online, publicly available, artifacts database (Kelsey Museum 2012a). The museum describes their most notable collections on a dedicated page of their website, touting eleven groupings of materials, beginning with "The largest corpus of daily life objects from a Graeco-Roman Egyptian town (Karanis) outside of the Cairo Museum (ca. 45,000 items)," "One of the largest collections of Parthian pottery outside Iraq (ca. 8,500 items)," "The largest collection of Latin inscriptions in the West (ca. 375 items)," and "A distinguished assemblage of early Byzantine and Islamic textiles (ca. 5,900 items)." Other groupings include glass fragments and vessels, Near Eastern seals, Egyptian mummy masks, Roman brick stamps, ancient coins, and a photographic collection documenting late 19th and early 20th century Mediterranean archaeology (Kelsey Museum 2012b). These categories provide a glimpse into the makeup of the Kelsey's collection and its extent, while highlighting aspects of the collection that the museum deems most valuable.

4.3 Collection History: The Herbarium

In this section I describe the history of the University of Michigan Herbarium as a collecting institution, recounting the establishment of botanical collections at the University, the changing organizational structures of which the Herbarium has been part, and different methods used to represent the collection over time.

4.3.1 Building the Collection

The first plant specimen collections given to the University of Michigan originated from the Michigan Geological Survey in 1838. Only one year after achieving statehood in 1837, Act No.49, 1838 of the Michigan legislature mandated a geological survey of all of Michigan, mapping out the land and inventorying its natural resources. Michigan's first state geologist, Douglass Houghton (also one of the first members of the

University of Michigan faculty) is widely credited for his work in the establishment of the Michigan Geological Survey (Allen and Martin 1922; Bradish 1889). He lobbied the government to establish a geological survey, envisioned as an organization with four divisions: geology, botany, zoology and topography. The leaders of each of these areas would report to the state geologist, Houghton himself, as they explored the new state. He was appointed to direct the overall survey expedition, with the charge that it would be his duty, "to make an accurate and complete geological survey of this state, which shall be accompanied with proper maps and diagrams, and furnish a full and scientific description of its rocks, soils and minerals, and of its botanical and geological productions, together with specimens of the same" (Michigan Department of Conservation 1956).

Regarding the collection of botanical and other specimens during the course of the survey, the Act specified "Specimens shall be collected and preserved in the following manner, to wit: first, the state shall be supplied with single and good specimens; second, if more similar specimens than one can be found, sixteen more, if possible, shall be procured, to be distributed by the regents amongst the university and its branches" (Mains 1958). The Regents of the University of Michigan responded by resolving to "pledge themselves for the erection of such buildings as may be necessary and otherwise to provide for the preservation of such specimens as may be collected under said Act and at any time entrusted to their care" (Mains 1958). The Michigan Geological Survey and the legislation supporting it were therefore instrumental in forming the basis of both the University of Michigan Herbarium's collections and the infrastructure needed for their care.

The collections have grown a great deal since this time, primarily through the fieldwork of faculty and students working in botany. Another important source for the growth of the collection has been purchases, including the herbarium and botanical library of the Pfizer company in 1933 and the lichen library and herbarium of Professor Bruce Fink in 1929 (University of Michigan Herbarium 2011d). A final major source of collection growth is exchange with other herbaria. The Herbarium regularly engages in exchange with other organizations, sending specimens to other institutions to enhance their botanical collections and receiving their duplicate specimens in return.

These exchanges between institutions rely on knowledge of the collecting interests of other herbaria, so that each herbarium knows which specimens will be most useful to which other organizations. Much of this knowledge is informal, residing with curators and collection managers at Michigan and other herbaria, but it is also made explicit in an important botanical resource, the Index Herbariorum. This published directory of the world's herbaria began in 1935, running to eight editions prior to its current incarnation as an online database maintained by the New York Botanical Society (Index Herbariorum 2007). In addition to providing contact information for each herbarium, it provides a list of important collections (given by collector name), journals and other publications produced by the herbarium, number of specimens owned by the herbarium (Michigan is listed at 1.7 million), a staff directory, and the herbarium's "specialties," the plant families and geographic areas of greatest collecting interest to the herbarium. For the Michigan Herbarium, the specialties are listed as follows:

> Worldwide, especially temperate North America and the Great Lakes region. Specific strengths include marine algae of eastern North America, West Indies, Alaska, and Pacific Islands; bryophytes of tropical America; *Agaricaceae* and *Hymenogastraceae* of western North America; vascular plants of Mexico, Iran, Himalayas, southwestern Pacific Region, and southeastern Asia; *Cyperaceae*, *Malpighiaceae*, and *Myrtaceae* of the New World. (Index Herbariorum 2009).

These listings are generated by the participating herbaria, which send updates to their listings to the Index Herbariorum as needed. The Great Lakes focus of Michigan's Herbarium can be traced to its founding in specimens derived from the Michigan Geological Survey. Michigan plants continue to be a focus for the Herbarium, which publishes and is widely known for its *Michigan Flora*, a guide to the plants of the state. The Herbarium has published three volumes of *Michigan Flora* since 1972 and now offers an online database to supplement and update the printed work.

Beyond the boundaries of Michigan, the Great Lakes focus also represents a broader interest in the botany of the entire region. While these collections grow through the ongoing work of Herbarium staff, students, and researchers, the other specialties listed reflect the particular research interests of a given researcher at a given time. The Herbarium may have a strong collection in a given area, but not be currently conducting active research in that taxonomic family or part of the world. This largely depends on the research interests of curators and other botanical researchers depositing specimens at Michigan. Herbarium exchanges strengthen collections in areas not actively being researched in addition to collections in active research areas.

Importantly, the Index Herbariorum also codifies the four to eight letter alphabetic code associated with each herbarium. The University of Michigan's code is MICH, and botanists use these codes frequently – particularly when citing a specimen they used in research. Throughout the botanical community, "MICH" and the University of Michigan Herbarium are synonymous. While this is a seemingly minor area of standardization, the letter codes provided by Index Herbariorum allow for a shared referent throughout the botanical community, specifying the ways in which herbaria and their collections are cited. This piece of standardization is a simple example of the norms within social worlds influencing both museum and researcher representational practices. Herbarium codes found in Index Herbariorum and other botanical information systems influence the practices of their direct and indirect users by specifying the format of references to herbaria and their specimens: botanists who may not frequently consult the Index Herbariorum still employ the codes in their publications.

Plant specimens at the Herbarium currently number nearly 1,700,000. The Herbarium describes them by plant group, listing 96,000 algae specimens, 163,000 bryophytes (liverworts, mosses, and hornworts), 280,000 fungi specimens, 57,000 lichens (composite organisms consisting of a fungus and an algae), and 1,100,000 vascular plants (land-based plants with a vascular system distributing water and nutrients throughout the plant). In descriptions of the strengths of each of these collections, the Herbarium emphasizes their geographic foci, the major collectors who have contributed specimens to them, and the genera that are best represented in each group (University of Michigan Herbarium, Collections 2011). Given the large number of specimens held by the Herbarium, it is not surprising that the majority of them have not been cataloged. A brief history of the representational systems in use at the Herbarium is discussed in the upcoming section on the museum's representations and information systems over time.

4.3.2 Formalizing and Institutionalizing the Museum

The first faculty appointment in botany at the University of Michigan was made in 1838, with Asa Gray, Professor of Botany and Zoology. In 1841, the collections were consolidated in Mason Hall under the care of the botany department and in 1881 they were moved to the University's new Museum of Natural History, but in 1915 the phanerogamic (seed bearing plant) collections were moved to the Natural Sciences Building, reflecting a shifting home for the collections, between museums and academic departments (University of Michigan Herbarium 2011d). The Herbarium was not formalized as such until 1921, when "the various botanical collections, the phanerogamic and cryptogamic [plants that reproduce by spore] herbaria in the Department of Botany, and the herbarium in the Museum of Zoology were united in the Herbarium of the University of Michigan, which was given a separate budget" (Mains 1958). In 1928 the collections were moved to the Ruthven Museums building and in 1960 they were again moved to the renovated North University building (University of Michigan Herbarium 2011d).

These changes in physical location reflect a convoluted history of departmental affiliation. Natural science and anthropological collections at the University were housed and managed together, in a Cabinet of Natural History, throughout the 19th Century, with curatorial responsibility shifting between faculty members in zoology. An early 20th Century revival of faculty interest in the collections, spearheaded largely by zoologist and curators Charles C. Adams (who curated the collections from 1903-1906) and Alexander Ruthven, led to collections growth and an interest in establishing a museum building. In 1925, in advance of the museum building's opening, Ruthven was named director of the Museum of Zoology and director of the Museums Building, reflecting a new organization which placed four independent units, the Museums of Zoology, Anthropology, and Paleontology, and the Herbarium, within the Museums Building (a fifth unit). While Ruthven was appointed President of the University in 1929, he remained director of the Museums Building (but no longer directed the Museum of Zoology) until 1936, when that position was taken by Carl E. Guthe, director of the Museum of Anthropology. When Guthe retired in 1944, the directors of the four subject-based museums formed an operating committee to oversee the Museums Building. This arrangement changed again in 1956, when the Exhibit Museum was created, emerging again as a fifth, equal unit, in charge of public exhibitions (Bentley Historical Library, n.d.). The 1960 movement of Herbarium collections out of the Exhibit Museum and into the North University building was a symbolic movement closer to research and further from public exhibition. In 2002, the Herbarium moved to its current location on Varsity Drive in Ann Arbor, a dedicated facility with a vast temperature and humidity controlled specimen storage area, research lab, library, dedicated specimen data entry, scanning, and mounting spaces, and offices for personnel.

4.3.3 Early Herbarium Representations

Given the early curation of botanical collections by zoologists, it is perhaps not surprising that the earliest writing I was able to find about botanical collection care at the University of Michigan was from a ledger at the University of Michigan Museum of Zoology. In 2000, a collection manager from that museum's ornithology division sent the Herbarium photocopied pages from a ledger with the attached post-it note "These are the first few pages in the Ornithology 1 catalog- UMMZ catalog 4." The pages, which summarize the early work of the Herbarium, are unsigned (but presumably the writing of the curator of zoological collections), and given the title "1879 Record of Work in Herbarium and of additions to Botanical collections, etc." The Record begins:

> From 1876 when Professor M.W. Harrington gave up the charge of this work until the present school year 1879-80, comparatively little work has been done in the herbarium owing to the absence of Miss Allmendinger who was formerly employed here and the large amount of work of the Instructor in Botany. Some volunteer work has been done from time to time by students and others and I have been able to devote a small portion of my time to the review of specimens already mounted […] The present year more has been accomplished and the record of the year as far as it can now be stated is as follows. (University of Michigan Museum of Zoology 1880, p.9)

This four page account of work with the Herbarium collection shows that it received spotty attention in its early years. Faculty primarily worked with the collections in the summers, when they had more time to devote to this work. An October 1879 record states "At the October meeting of the board of Regents Miss E.C. Allmendinger was formally appointed to take charge of the herbarium and has been engaged most of the time in determining and mounting the plants of the Jewett Collection." She had recently recovered from an illness and was able to give more consistent support to the collection (University of Michigan Museum of Zoology Ledger 1880, p.11).

In the ledger featured in Figure 4.10, an unknown staff member recorded and tracked new acquisitions and the disposition of specimens. Figure 4.10 shows that on June 21, 1879, the author wrote, "Dr. J.B. Steere presented to the University as a portion of the Beal-Steere Collection the following plants obtained in South America in the Summer of 1879" followed by a list of specimens.

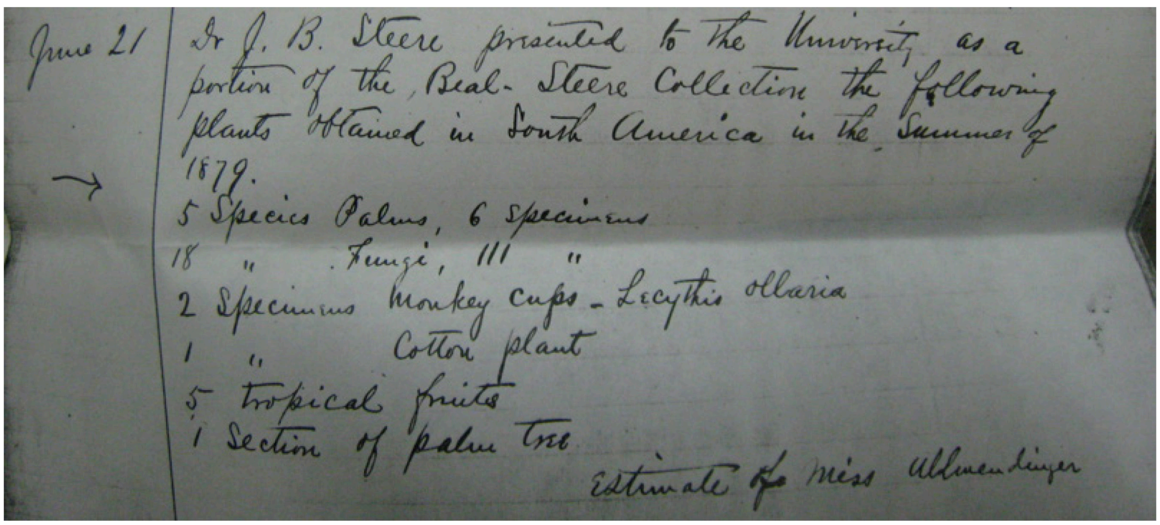

June 21 Dr J. B. Steere presented to the University as a portion of the Beal-Steere Collection the following plants obtained in South America in the Summer of 1879.
5 Species Palms, 6 specimens
18 " Fungi, 111 "
2 Specimens Monkey cups - Lecythis ollaria
1 " Cotton plant
5 tropical fruits
1 Section of palm tree
Estimate of Miss Allmendinger

Figure 4.10 University of Michigan Museum of Zoology Ledger, 1880, p.12

Far from a collection catalog, these listings seem intended simply to track new acquisitions. Entries vary in specificity in their descriptions, from the more detailed list shown above to the much less detailed "October [1879] Thirty species of Iowa plants. Dr. S.B. Parsons" and "March 9 [1880] Finished mounting Dr. Steere's collection of ferns. See Prof. Harrington's list in Proceedings of Linnean Scy." The primary function of this record seems to be accounting for gifts and exchanges. Rather than recording what each specimen was determined to be along with a collector number and location, as we would find in a collection catalog, these records are concerned with attributing credit for additions to the collection. To meet that goal, the record keeper simply provided the collector and number of specimens, sometimes listing them by plant species. In the final example, however, the number of specimens in the collection is not given, referring the reader to the publication record instead for a description of the accession. In this case, the publication record supplants the museum's own record.

The earliest record keeping system from the Herbarium as its own organization dates from 1921—the year the Herbarium was established as an independent unit. This loose-leaf ledger is captioned "Book 1 Begun 1921. Mrs. J.H. Ehlers entering. Dr. Kaufman's first year as Director of the Herbarium. Flowering Plant Entry." A later Herbarium staff member wrapped this ledger in paper and stored it in a filing cabinet in a room at the Herbarium where I happened upon it with collection manager HS3 while looking for early records from the museum.

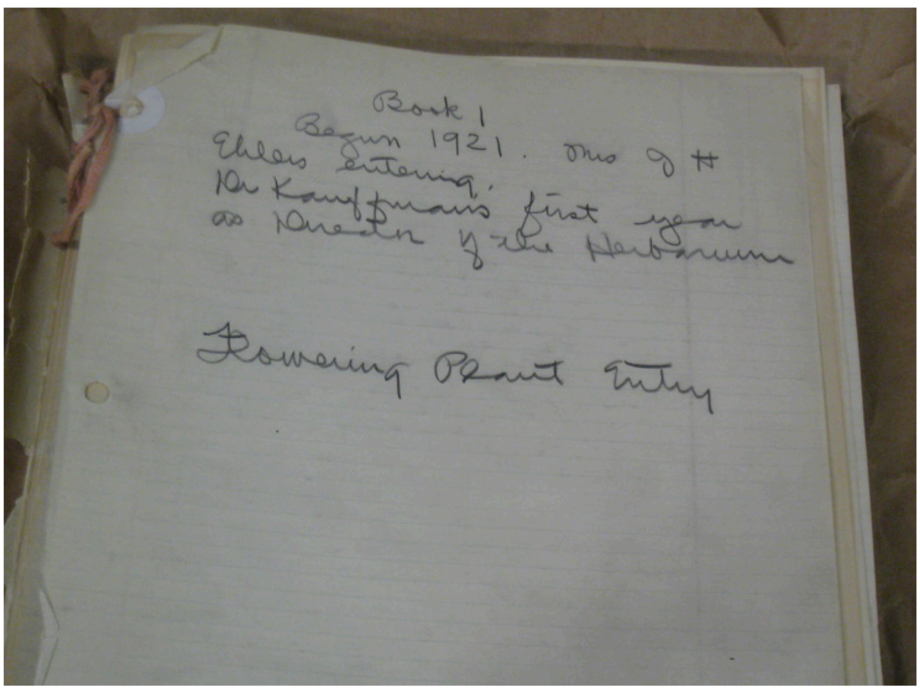


Figure 4.11 Accessions Book 1 Flowering Plant Entry. University of Michigan Herbarium 1921-1928

The contents of Book 1 are remarkably detailed, giving lists of acquisitions at the specimen level. HS3 was surprised to see this level of detail in a Herbarium ledger, saying:

This is the sort of thing that they often did in the Museum of Zoology, where they had these ledger books and when there was an addition made, they would list all the specimens out. I didn't think we did that. But now I find that we did and […] there's the collection: the name, where it was from, and the date. So it's essentially a very simplified listing of specimens that came in.

The following image is typical of the pages of this ledger, listing the original owner of the collection and its geographic range at the top of the page and providing species, the town in which the specimen was collected, and the date of each collection on each row. In some entries, a collector name is also given for the specimens.

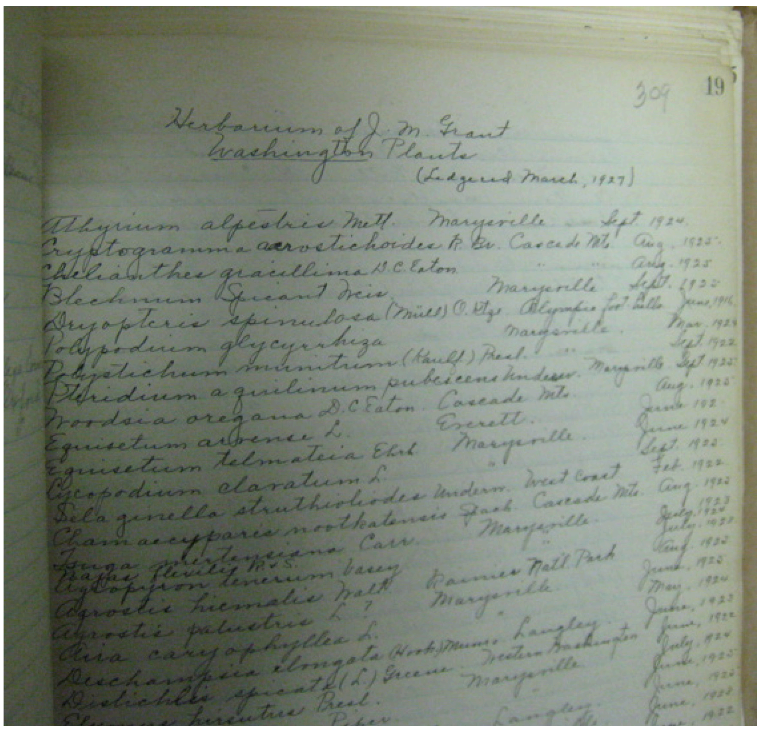
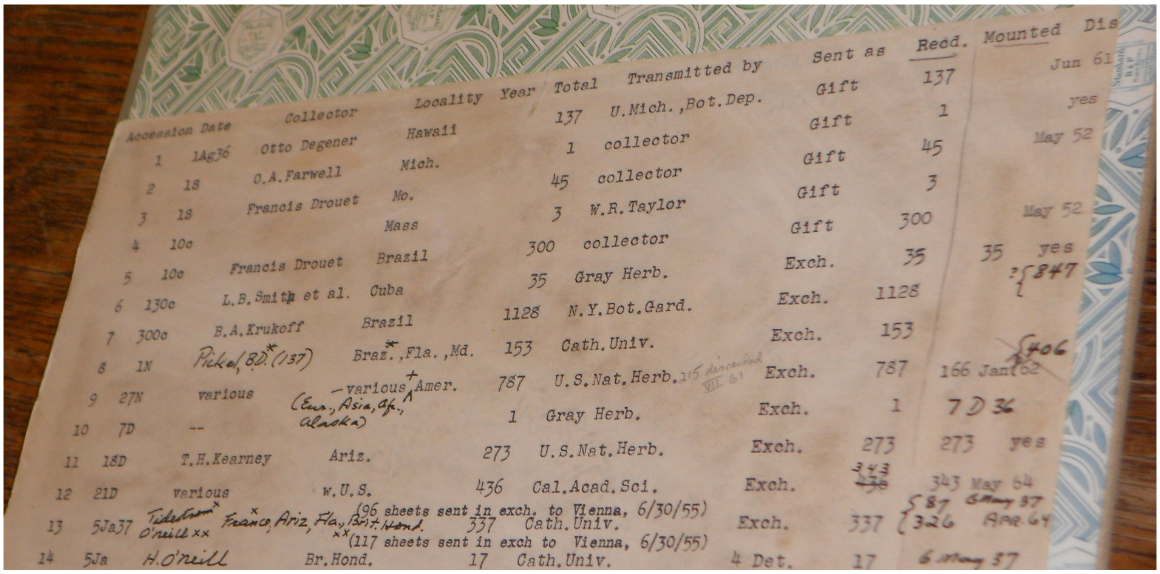


Figure 4.12 Accessions Book 1 Flowering Plant Entry. University of Michigan Herbarium 1921-1928, p. 309

Book 1 from the Herbarium shows that at the time it was founded as an independent unit, staff were interested in accessioning each specimen separately, giving each one an individual ledger entry. The entries here track new acquisitions rather than describing them fully, using more detail than today's accessions database by itemizing the specimens, but not recording the complete information supplied with specimens (for instance, the collector number for each specimen was not recorded here). HS3's observation that "This is the sort of thing that they often did in the Museum of Zoology" raises the possibility that the format of this ledger was influenced by accessioning practices at that museum, from which the Herbarium had recently become an independent unit when the ledger began.

Prior to finding the 1921 ledger, Herbarium collection managers believed that the 1936 ledger depicted in Figure 4.13 was the oldest record of accessions.



Accession	Date	Collector	Locality	Year	Total	Transmitted by	Sent as	Recd.	Mounted
1	1Ag36	Otto Degener	Hawaii		137	U.Mich.,Bot.Dep.	Gift	137	Jun 61
2	18	O.A.Farwell	Mich.		1	collector	Gift	1	yes
3	18	Francis Drouet	Mo.		45	collector	Gift	45	May 52
4	10c		Mass		3	W.R.Taylor	Gift	3	
5	10c	Francis Drouet	Brazil		300	collector	Gift	300	May 52
6	13Oc	L.B.Smith et al.	Cuba		35	Gray Herb.	Exch.	35	35 yes
7	30Oc	B.A.Krukoff	Brazil		1128	N.Y.Bot.Gard.	Exch.	1128	?{847
8	1N	Pickel (BD)* (137)	Braz.*, Fla., Md.		153	Cath.Univ.	Exch.	153	{406
9	27N	various	— various Amer. (Eur., Asia, Af., Alaska)		787	U.S.Nat.Herb.	Exch.	787	166 Jan 62
10	7D	--			1	Gray Herb.	Exch.	1	7 D 36
11	18D	T.H.Kearney	Ariz.		273	U.S.Nat.Herb.	Exch.	273	273 yes
12	21D	various	W.U.S.		436	Cal.Acad.Sci.	Exch.	343 ~~436~~	343 May 64
13	5Ja37	Tidestrom* O'neill xx	France, Ariz, Fla, Brit. Hond.		337	Cath.Univ. (*96 sheets sent in exch. to Vienna, 6/30/55) (xx117 sheets sent in exch to Vienna, 6/30/55)	Exch.	337	{87 6 May 37 {326 Apr 64
14	5Ja	H.O'neill	Br.Hond.		17	Cath.Univ.	4 Det.	17	6 May 37

Figure 4.13 Accession book, University of Michigan Herbarium 1936

Comparing the two accession ledgers, we see that they became both less and more specific over time. In the fifteen years between the two record keepings systems, staff had begun to list accessions in groups by collector name. Accessions three through five in the 1936 ledger show two collections from Francis Drouet and a third with an unlisted collector (who may have also been Drouet). They are split into separate listings according to locality and a total number of specimens for each accession is given. While this book lacks the detail provided in Figure 4.12 for each specimen, it provides more information at the accession level, including the field "Transmitted By," which tracked institutional specimen exchanges as well as those with collectors. I compare the 1936 accessions book with the current database in an upcoming section.

4.3.4 Information Systems

Accession ledgers remained the primary information system for most of the Herbarium's history. A full catalog of the collection, describing each specimen separately, has never been attempted. However, many collectors described individual specimens in their own record keeping systems, primarily field notebooks and index cards, and the Herbarium took ownership of many of these representations along with the specimens they described.

The first major attempt at specimen-level description for a portion of the collection, providing more detail than the 1921 ledger, came with the introduction of computerized databases. The Herbarium's first database of plant records stemmed from a 1972 curatorial grant from the National Science Foundation (NSF) awarded to curator Rogers McVaugh (Estabrook 1979). George Estabrook, a mathematician and botanist who applied mathematical concepts to biological collections, developed the underlying system, TAXIR, while at the University of Colorado. After presenting a paper on his work at the University of Michigan in 1970, he was offered a position at the Herbarium (Schwartz 2011). With the NSF grant and Estabrook's system, the Herbarium was able to create database records for its entire collection of type specimens.

Estabrook described the system by saying, "The basic information in the data bank is of three kinds: What *is* the name and its taxonomic placement; who *made* the name and where was the description published; and who *collected* the specimen and where was it collected" (Estabrook 1979, p. 197, emphasis in the original). In his paper describing the system, Estabrook listed the 36 fields present in the database of types, in several cases also giving the sources used to standardize these fields. The plant family names used, for instance, are "As recognized by Engler & Prantl, but slightly modified to reflect widely accepted modern concepts" (ibid.). Estabrook continued with the Authority field, which uses, "Abbreviations as suggested by the 'Author Index' of Kew, else last name followed by all initials each followed by a period. Multiple authors are connected with '&'. Instances of 'in' and 'ex' are also included as part of the authority" (ibid.). For Place of Publication field, he noted "Abbreviations for periodicals as suggested by Botanico-Periodicum-Huntianum 1968" (Estabrook 1979, p. 198).

Adherence to the published authorities included in this list help herbaria like Michigan's use community-wide standards to manage their data. Engler and Prantl, for instance, were two German botanists who published a comprehensive 23 volume classification system of plants in 1887-1915. Either their classification system, or that of two English botanists, George Bentham and Sir J.D. Hooker (published in 1862-3), is in use at most of the world's herbaria. As one plant systematics textbook author stated,

> Although the systems of Bentham and Hooker as also of Engler and Prantl are now obsolete in light of current phylogenetic views, they continue to be the most dominant systems followed in Floras and Herbaria, on the strength of their thorough treatment, enabling one to identify and assign any genus to its family. Unfortunately no subsequent publication on classification of flowering plants has been that thorough, and although we may have very sound systems of classification, our Floras and Herbaria will continue to follow one of these two systems for years to come. (Singh 1999, p. 24)

The other authorities referenced by Estabrook in 1979, the Botanico-Periodicum-Huntianum 1968 and the Kew author index, are still available and in use by botanists working as researchers and herbarium staff. The 1991 supplement to the Botanico-Periodicum-Huntianum increased the number of botanical journals listed to 25,000 from 12,000 in the 1968 edition. The Kew author index was produced by that herbarium until 1998, at which point it was used to create the International Plant Names Index, an online resource that allows users to search plant, publication, or author names to learn about the publication history of a species or the correct citation for a given author. With the ability to search by publication name, the International Plant Names Index may also supplant the Botanico-Periodicum-Huntianum for researchers.

Incorporating these standards, Estabrook developed the original type database, which still forms the basis for the databases in use at the Herbarium today, as collection manager HS3 told me,

> [T]he standards that we're still using in terms of naming our field structures were derived from that database. […] his basic field structure is exactly what we're still using […] And there's only so many ways you can really describe the data, but there are differences in how much detail you want to atomize it into, and that's where some of the differences really come into play. And now that we've got geo-referencing in place, we also have differences of... Well, we've got a whole different field structure, it's not just latitude and longitude, there's also, well, was that GPS reading taken from the field, or was it interpreted off a map? Some

> indication of the term that I've heard now used is veracity of the data, in terms of, well, who identified it, was it a student or was it a professional? Where was that GPS reading? How was that derived? What status do the coordinates really have?

Built on Estabrook's system, but with additions to reflect changes to botanical practice (such as the adoption of GPS for location data), staff designed the Herbarium's subsequent specimen databases to have flexibility and allow for new data fields with additional data standards. HS3's statement about the level of detail of systems is also reflected in the 1979 Estabrook article describing TAXIR. He wrote,

> Many ways to improve the design of a Type data bank such as this have already become apparent. Information concerning Volume, page, and figure number should all be placed in one descriptor. Detailed locality data probably should not be included, but left to reside on the label only. All the collectors' names should be put in one descriptor, just as they would appear in exsiccatae citations. Ideally, only collectors in whose number series occurs the collection number should be included. Remarks should be held to a minimum, and these in one descriptor only. (Estabrook 1979, p. 203)

While these closing comments do not receive any discussion in the 1979 paper, they denote several questions about level of detail that have remained with the Herbarium. The best way to represent multiple collectors for a single specimen, for instance, is an issue still being discussed by the botanical community and Herbarium collection managers, as discussed later in this chapter.

As the Herbarium's first collections database, Estabrook's TAXIR established the basic field structure for today's collections database. HS3 explains that the selection of fields in TAXIR was based on suggestions from the database designer:

> The person who was putting it together, George Estabrook, made a presentation about the fields and then sent this to the faculty, and they discussed it among the Herbarium faculty […] So it was essentially decided by one person making the suggestion and having a consensus after that.

This process has remained a part of the Herbarium's workflow when they make changes to their databases, as HS3 told me. When Herbarium staff decided to revise the database, they reviewed the TAXIR database in comparison with databases in use at other herbaria, finding that TAXIR was following many best practices in use at the time.

> And that's basically how we went through in revising it, was to look at it versus the other standards that had been developed, that were out there, and finding out that our was pretty darn close to what people were doing. So ours was a

predecessor, in a way, of a lot of what's been going on. And some of the fields we have are exactly what we had then, and they're still serving the same purpose.

TAXIR has since been replaced by a Microsoft Access system with six data entry tabs. The screenshot in Figure 4.14 depicts the Minimal Data Set for specimens, requiring entries in the fields highlighted in green. Other tabs allow staff members to enter details about the collecting locality, species publication history, additional collectors, data specific to type specimens, and entries linking the specimen to its GenBank entry and other external resources, where appropriate.

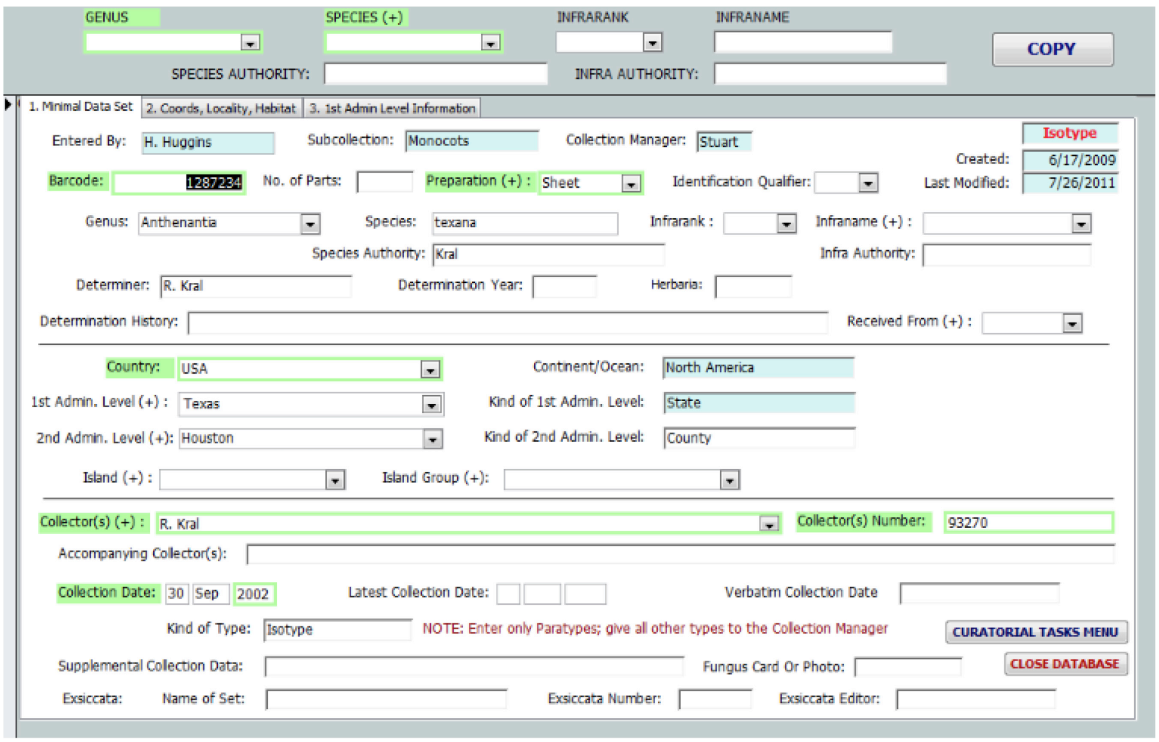


Figure 4.14 Michigan Herbarium Collection Database: Minimal Data Set

Herbarium staff have considered data standards an important part of their databasing work since TAXIR. Collection manager HS3 told me about his experiences recommending Darwin Core for the Herbarium's data, when that standard was first developed.

> When we were thinking about changing databases, and when the Darwin Core transfer format was beginning to be developed and was out there, I thought "well, if we want to be able to communicate our data with others in the world, it's going to behoove us to have our data in a form so that when somebody else gets it, they don't have to mess with it significantly." To put it in a form that's actually useful

> by others. […] One of the things that we really still think about is the economy of, is it easier to type the data in or, if we've got it in electronic form, can we manipulate it as minimally as possible? […] If you get a dataset that you have to split fields and do a lot of manipulation, is it really a time saver? And the answer is, no, it isn't.

This statement illustrates the centrality of data reuse concerns as collection managers design the Herbarium's data representations. They consider standards like Darwin Core as one means of making their data more easily reused. This concern for reuse is well aligned with the history of specimen sharing in botany. In a discipline where specimen loans and exchanges are an integral part of research practice, it is not surprising that data standards have been so whole-heartedly embraced by many herbaria.

Like the Kelsey, the Herbarium is also part of the College of Literature, Science and the Arts, and as such it will also be part of the College-wide switch to the new collections management system, KE EMu. The benefits and drawbacks of switching to this new system remain to be seen, as is the effect that this change will have on the Herbarium's work practices.

4.3.5 Gathering Information from Collectors

At the Herbarium, staff members have gathered specimen information primarily from collector-provided labels, which plant mounters attach to a specimen sheet at the end of the accessioning process. Curators and collection managers viewed that information as an essential part of a specimen, integral to its value. Without a specimen label, they would consider a specimen to be incomplete and inadequate. Responsibility for a specimen label rests entirely with the collector, as the guide provided on the *Michigan Flora* website states,

> Only the collector knows fully the circumstances of collection, and thus bears responsibility for sharing (on the label) what he or she knows about the locality, habitat, appearance, and attributes of the plant—whatever cannot, years later, be determined from the pressed, dry carcass. (Voss 1999, p. 57)

A collector may provide supplementary material as well, but the completeness of a specimen label is of primary importance when considering the value of a specimen. The importance of a specimen label to herbarium practice reveals a norm in this epistemic culture for the value of data: without the metadata provided in a specimen label, the specimen lacks value as a data source.

Throughout its history, Herbarium collection managers have also accepted supplementary materials from collectors, including field notebooks, notecards, drawings and photographs of specimens, along with specimens. Individuals associated with the University of Michigan as botany faculty or Herbarium staff have been the source of most of these supplementary materials, although some have also come to the Herbarium with purchased or donated collections. While the Herbarium retains these materials, it does not catalog them in any way, relying instead on staff members' memory to be aware of their existence and to associate them with specimens collected or donated by those individuals. Collection managers stored the supplementary materials in various locations throughout the Herbarium building to facilitate retrieval by staff working with the related collections: i.e., the drawings of fungi are kept in one location near the office space for the collection manager in charge of mycological collections. The Herbarium has a collection of field notebooks related to the vascular plant collection located near the loan records for those materials.

These supplementary materials are not consulted during accessioning. Instead, they function as back-up materials in case questions about the collections arise. Staff members use the collector's label affixed to a specimen as the definitive source of information about a specimen. In the upcoming section "Botanical documentation and context," I discuss the variation in specimen labels, while in the section "Sharing information with researchers," I address the ways in which Herbarium staff members provide access to these supplementary materials.

4.3.6 Early Research Use

Unlike the Kelsey, where my archival research revealed discussions about how research should be conducted early on in the museum's history, my work with the Herbarium's archives did not reveal similar conversations. Instead, I was able to find a copious supply of loan records held at the Herbarium itself, documenting relationships between herbaria and referencing the individuals on whose behalf loans were requested.

Onsite research use was not similarly recorded, although traces of that activity can be found on annotation slips affixed to specimens, through the Herbarium's visitor log, and in citations to specimens in the botanical literature. In this section, I review the Herbarium's loan recordkeeping systems, noting the kinds of information captured in these systems over time.

Figure 4.15 shows a 1937 loan record, typed onto an index card. While the card provides the loan date, borrowing institution, and the name of the researcher who requested the loan, staff used it to describe the specimens with only summary detail, giving the number of specimens and plant family. Like the other cards in this series, it is not annotated with a loan return date, showing that this system documented loans made but not loans returned.

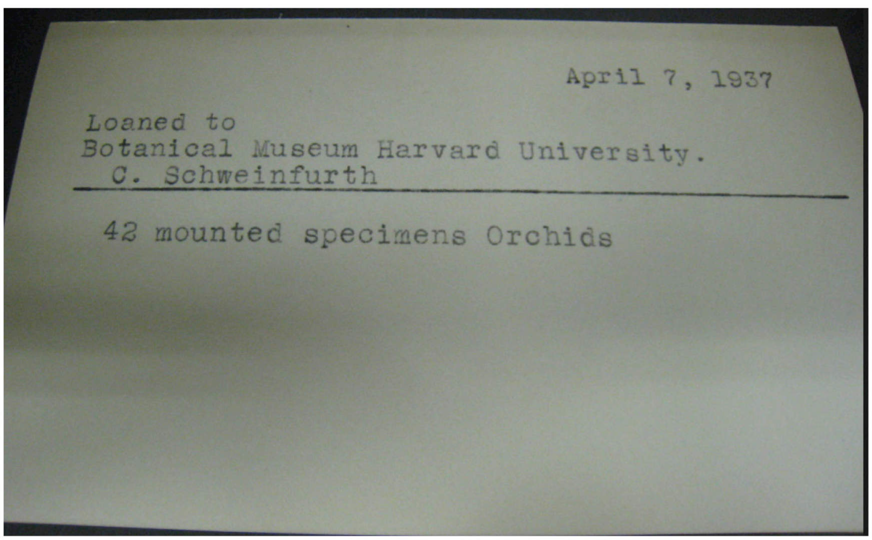
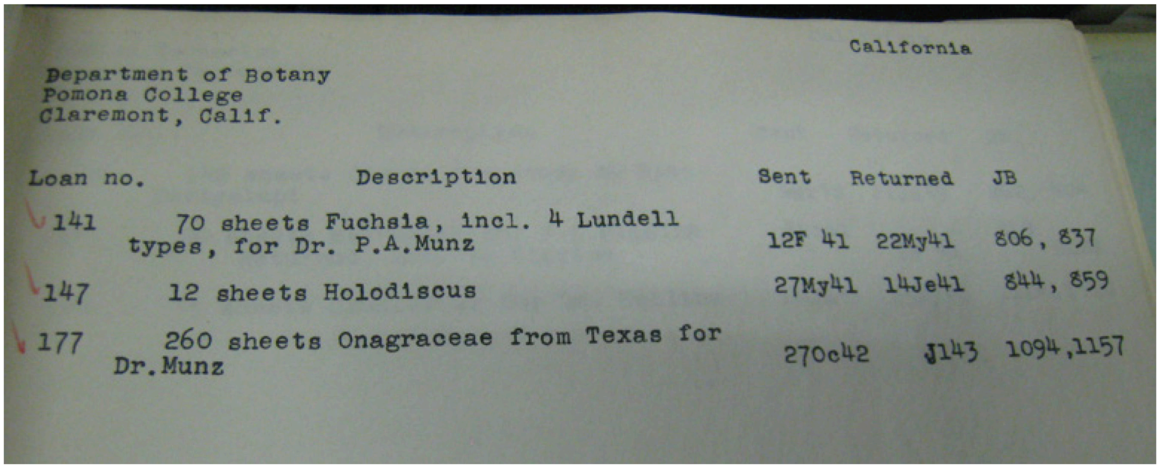


Figure 4.15 Michigan Herbarium Loan Records, 1937

The slightly later system depicted in Figure 4.16 included a mechanism for documenting loan returns. Staff organized loans, again, by borrowing institution (arranged geographically). By using loose-leaf notebooks, collection managers could remove individual sheets and use a typewriter to update records with their return date once received back at Michigan.



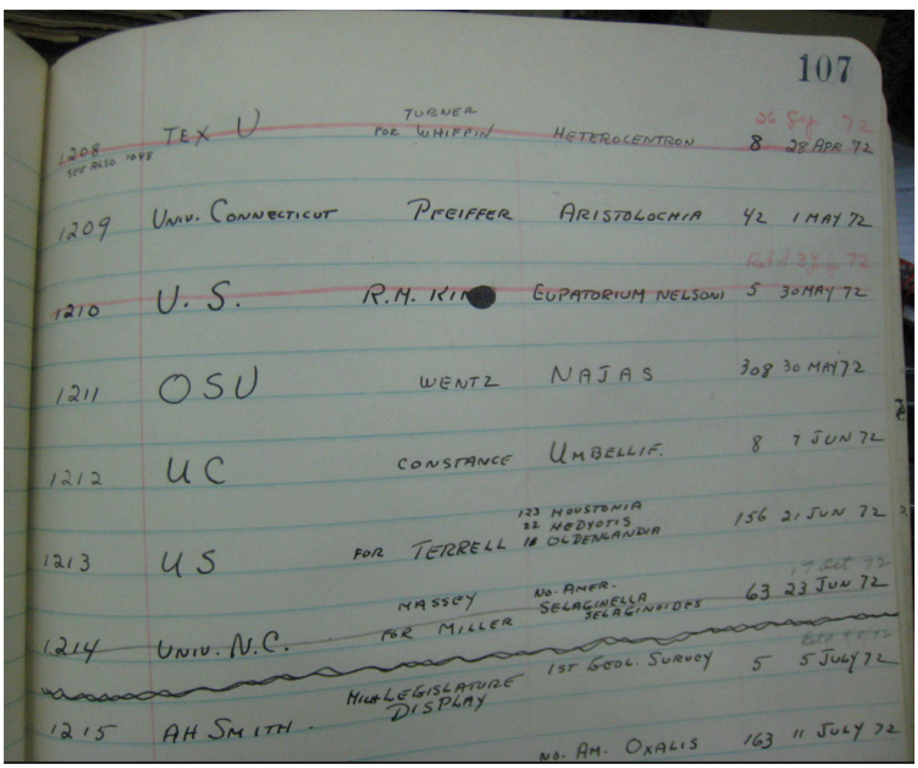
California

Department of Botany
Pomona College
Claremont, Calif.

Loan no.	Description	Sent	Returned	JB
141	70 sheets Fuchsia, incl. 4 Lundell types, for Dr. P.A.Munz	12F 41	22My41	806, 837
147	12 sheets Holodiscus	27My41	14Je41	844, 859
177	260 sheets Onagraceae from Texas for Dr.Munz	27Oc42	J143	1094,1157

Figure 4.16 Michigan Herbarium Loan Records, 1941-1942

In the 1960s and early 70s (Figure 4.17), collection managers recorded loans in a notebook with loan number, borrowing institution and researcher, a brief description of the specimens, number of specimen sheets, and loan date. In this system, loans were listed chronologically and collection managers indicated the return date of a loan in pencil and red ink.

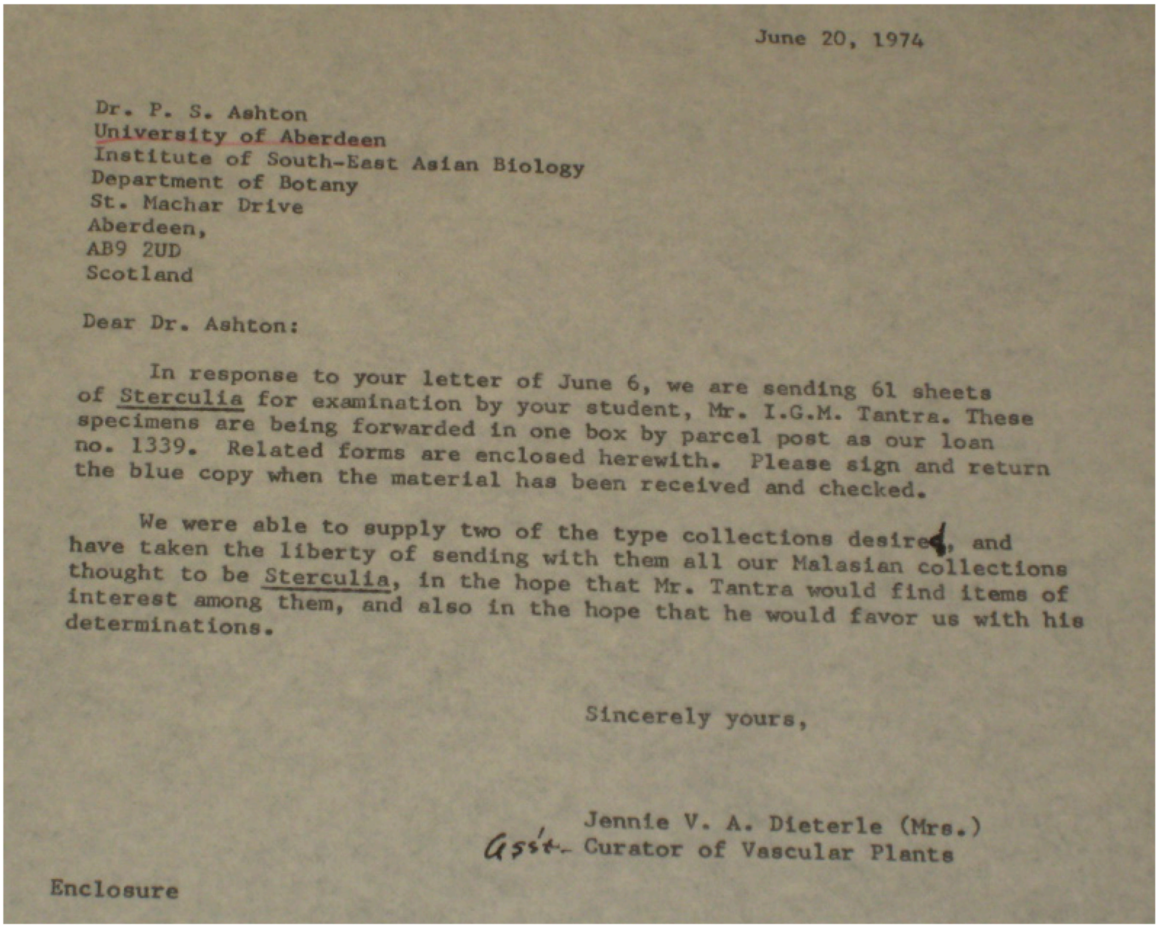


107

1208 SEE ALSO 1048	TEX U	TURNER FOR WHIPPIN	HETEROCENTRON	8	28 APR 72
1209	UNIV. CONNECTICUT	PFEIFFER	ARISTOLOCHIA	42	1 MAY 72
1210	U. S.	R.M. KI	EUPATORIUM NELSONI	5	30 MAY 72
1211	OSU	WENTZ	NAJAS	308	30 MAY 72
1212	UC	CONSTANCE	UMBELLIF.	8	7 JUN 72
1213	US	FOR TERRELL	123 HOUSTONIA 22 HEDYOTIS 11 OLDENLANDIA	156	21 JUN 72
1214	UNIV. N.C.	MASSEY FOR MILLER	NO. AMER. SELAGINELLA SELAGINOIDES	63	23 JUN 72
		MICH LEGISLATURE DISPLAY	1ST GEOL. SURVEY	5	5 JULY 72
1215	AH SMITH.		NO. AM. OXALIS	163	11 JULY 72

Figure 4.17 Michigan Herbarium Loan Records, 1972

While these record-keeping systems summarized loans (and were mirrored by separate records of loans made *to* the Herbarium) they were not the Herbarium's sole record of these important intra-institutional exchanges. Collection managers have consistently maintained filing cabinets of correspondence documenting loans as well. They organized these files by institution, in folders containing copies of the paperwork that accompanied loans, including loan request letters, forms sent with the loaned specimens, and letters that accompanied the loans when sent out from Michigan and returned by the borrowing institution. Figure 4.18 is a typical letter accompanying a Herbarium loan. In addition to briefly describing the loan: the number and type of specimens, researcher who will be using them, and loan number, the Assistant Curator also notes that extra specimens were sent which were not part of the request. These loans for determination are one way in which the Herbarium adds value to its collections through the loan process. This letter also largely reiterates the information included in loan forms. One major difference, however, is that loan forms also include the collector numbers assigned to specimens, so that the Herbarium can track them on an individual basis. If a loan is only partially returned, the collection manager can determine which specimens were not sent back, and follow up with the collection manager at the borrowing institution.



June 20, 1974

Dr. P. S. Ashton
University of Aberdeen
Institute of South-East Asian Biology
Department of Botany
St. Machar Drive
Aberdeen,
AB9 2UD
Scotland

Dear Dr. Ashton:

In response to your letter of June 6, we are sending 61 sheets of Sterculia for examination by your student, Mr. I.G.M. Tantra. These specimens are being forwarded in one box by parcel post as our loan no. 1339. Related forms are enclosed herewith. Please sign and return the blue copy when the material has been received and checked.

We were able to supply two of the type collections desired, and have taken the liberty of sending with them all our Malasian collections thought to be Sterculia, in the hope that Mr. Tantra would find items of interest among them, and also in the hope that he would favor us with his determinations.

Sincerely yours,

Jennie V. A. Dieterle (Mrs.)
Asst. Curator of Vascular Plants

Enclosure

Figure 4.18 Loan Letter from Jennie Dieterlie to P.S. Ashton. June 20, 1974. University of Michigan Herbarium loan records.

Collection managers now document specimen loans in a curatorial database, and they continue to retain and annotate the paperwork accompanying loans in vertical files organized by borrowing institution. Email has supplanted letters as the format for the majority of loan requests, but collection managers print out requests, and print-based documentation always accompanies the loaned specimens. While loans are not the only type of research use of the Herbarium, they are the best documented and the most prevalent mode of specimen reuse. In this section, I have reviewed loan recordkeeping as a system that documents and supports organizational priorities: relationships between herbaria and the preservation of collections.

4.4 Collection Histories Compared

When viewed together, the collection histories of the Kelsey museum and the Herbarium have a number of differences as well as some striking similarities. The differences stem largely from the disciplinary communities served by the collections: the data collected by each museum is very different. Whereas botanical specimens function as samples of plant life, directly comparable regardless of collection date or location, archaeological artifacts are reliant on their context to be interpreted as data, and artifacts from separate contexts are viewed as incommensurable. In addition, the collecting status of the museum is tied to the practices of its disciplinary community. As an archaeology museum specializing in the Near East, the Kelsey can no longer build its artifact collections through excavation due to UNESCO regulations. Collection growth is slow, and is not a priority for the museum, leaving staff time for researching the current collections, facilitating their use in research, and creating exhibitions. Botanical collection and deposit at the Herbarium, however, is ongoing.

The public focus of the Kelsey and the research focus of the Herbarium is another major difference between the two museums. The Kelsey expends a great deal of time and resources on exhibitions, while the Herbarium has no such mandate. Curators in both museums, however, split their time between academic faculty appointments and conducting research using the collections.

Similarities between the museums' collecting histories include a strong tie to faculty research, which served as the original source of data—and as an important continuing source of collection growth for the Herbarium. For both museums, faculty research interests have helped shape collecting endeavors, building the collections' strengths over time. Their holdings document the research activities of faculty in their role as data collectors. In this way, the two museums serve as data repositories for local research communities. While the Herbarium adds to collections through the fieldwork of affiliated researchers and exchanges with researchers and other herbaria, collection growth is not a priority at the Kelsey, in light of the 1970 UNESCO regulations.

Both museums have seen an increase in staffing complexity, from a single curator overseeing the entire collection to multi-curator staffing, with the addition of collection managers. This change has allowed curators to focus on particular subject areas within the collection, and to take responsibility for the growth and research activities involving that area.

Finally, the museums' relationships to external infrastructure are different, reflecting the resources available to the research social worlds the museums serve. The Herbarium is listed in the resource Index Herbariorum, guiding researchers and the staff of other herbaria to its collections. The Kelsey is not similarly included in an index of archaeological museums, rather, it relies on publications of the museum's collections, by Kelsey-affiliated researchers and others, to distribute knowledge of the collection among researchers. While the Index Herbariorum presents collection information for all participating herbaria throughout the world, no similar centralized resource exists for Near East archaeology. Through common practices like loans and exchanges, and shared resources like Index Herbariorum, herbaria have formed a worldwide network supporting botanical practice that is unmatched in archaeology. This and other distinctions between the botany and archaeology social worlds have a great impact on the ways that museum staff members ingest data and make them accessible, the topic to which I now turn.

4.5 Accessioning at the Herbarium

At the Herbarium, collection managers accession specimens quite frequently. In this section, I discuss the accessioning process at the Herbarium as a collection manager of vascular plants (HS2) taught it to a new student worker. I was not able to observe a similar process at the Kelsey due to the infrequency of accessioning there. Because accessioning is often done by HS2 on her own, this was an opportunity to learn about an important aspect of museum practice as she made the tacit norms and practices behind accessioning more explicit for the benefit of a student. This training session functioned as an act of legitimate peripheral participation for the student worker, introducing her to the procedures and values of herbarium work through supervised practice, as they worked together to accession new specimens (Lave and Wenger 1991). The student's work was legitimately important to the accessioning activity, helping HS2 review a large stack of specimens, yet peripheral, in that her participation included reviewing specimens but not completing the process by entering them into the database.

Accessioning involved reviewing the specimens for quality and completeness, prioritizing their processing for mounting (a later step in which plant mounting staff attach the plants and their labels to archival quality paper for long term storage), and recording the accession in an in-house database describing the materials. I will examine the process from the perspective of prioritization, uncovering what the collection manager articulated as most important in the process as she made decisions about what and how to accession. Through training in accessioning practices, HS2 communicated a "mode of practice, how to code a relevant perceptual field in terms of categories that are consequential for […] work" (Goodwin 1994, p. 614). Legitimate peripheral participation provides novices with ways of seeing as well as acting as a member of a community of practice.

Although botanists affiliated with the University of Michigan are consistently adding to the collection through their fieldwork, one collection manager, HS3, explained to me that this is not currently the primary source of new materials. Instead, they come to the Herbarium as a result of exchange with other institutions or as gifts for determination from other researchers, where one specimen collected is sent to an expert in that species and in return they provide their opinion of its identity to the collector.

> Nowadays, I think we get the bulk of our materials actually coming in from either other institutions that are sending things on exchange or they're coming in as material that is being sent to Michigan, to one of our specialists, as a gift for determination. I'm gonna say most of our material is probably is in one of those two categories. We do have a lot of it that is generated by our people on staff but there's a lot more that comes in the door because they know our specialists are here and they're sending it to either be essentially added to our collection, to supplement it, or they know that a specialist is here that can probably identify it and essentially as a gift for their services, we get to keep the specimen as long as we tell them what the identity is.

Because the bulk of the Herbarium's new materials come through exchange and gifts for determination, the organization and its members' reputations in the field of botany is a central factor: botanists send gifts for determination because someone on the Herbarium's staff—primarily curators—has expertise in that plant family. This links the acquisition of new materials back to resources for awareness of the institution and to informal knowledge within the community about who holds which forms of expertise.

While the ostensible purpose of accessioning is adding new materials to the collection, the maintenance of relationships with other herbaria is another important goal fulfilled in the process. Following the call from Graham and Thrift (2007) to examine repair and maintenance in studies of infrastructure, I examine this process as one of maintenance: both of the Herbarium's collection of specimens and of its relationship with other institutions. By verifying and recording gifts from other herbaria, and communicating those records back to the other organization, in the process of accessioning HS2 not only worked to maintain the Herbarium's collection, but also fortified its relationship with the herbarium that sent Michigan specimens for exchange. Through her attention to the exchange balance with the other herbarium (particularly at the end of the accessioning process), the collection manager demonstrated the norm of equality matching within the social world of herbaria: "equality matching (EM) relationships are based on the model of even balance and one-for-one correspondence […] People are primarily concerned about whether an EM relationship is balanced, and keep track of how far out of balance it is" (Fiske 1992, p. 691). Assuring reciprocity between the two herbaria was important for HS2.

Accessioning takes place in a dedicated room within the Herbarium, located off "The Range," an enormous shelving area where specimens are stored. A long wooden worktable is the centerpiece of the room, the walls of which are lined with several shelved cabinets for specimen sorting and storage and side tables holding materials to be processed, loaded with bundles of newspaper sheets. Each of these folded sheets of newspaper contained a dried plant specimen and each was labeled with the collector's number.

The collector number (or collection number, botanists used the terms interchangeably) is one of many standards I observed in use during this process. In botany, collector numbers generally consist of the collector's last name or initials followed by a multi-digit number. In a paper provided on the *Michigan Flora* website, former curator Edward Voss specified the format collector numbers should take for deposit into the Michigan Herbarium. The format described below was followed on all of the specimens I saw handled during the accessioning process.

> At the bottom of the label belong the collector and number. These do belong *together*, the number *immediately following the name*, not somewhere else on the label. The easiest and least ambiguous numbering system is to start with simple number 1 and keep going the rest of your life. Trying to incorporate part of the date and/or locality, renumbering from 1 every year or in different regions or for different groups of plants, adding prefixes, or other schemes can lead to confusion in the future. (Voss 1999, p. 63, emphasis in the original)

By using the standard numbering system suggested by Voss, botanists are able to associate a single collector number with a single specimen, forming a link between the botanist's professional biography and the herbarium, through the specimen itself. Standardization of collector numbering echoes the emphasis in the data reuse literature on reliable provenance information, as well as the propensity of reusers to consider the reputation of the data producer as a proxy for data quality (e.g. Fear and Donaldson 2012; Van House 2002a; Zimmerman 2003). By promoting standards for conveying this information on its website, the Herbarium reinforces the importance of data producer metadata as an element of the epistemic culture of botany and helps ensure that data selection criteria are provided with each specimen they receive.

Prior to accessioning, collection manager HS3 had unpacked and organized the specimens, bundling the folded newspaper sheets containing specimens into groups in manila folders tied with string. He had attached notes to the manila folders specifying their disposition, leaving them for HS2 to accession when the opportunity arose (Figure 4.19). In the bottom bundle of specimens, an exchange from a Mexican herbarium, the notes say "Ready for MICH" and "2nd series MICH," indicating that the specimens in those folders were ready to be accessioned into the collection. Notes on the top bundle, a gift from a researcher who had worked at the Herbarium in the past, read "Inigo Granzow de la Cerda @ 2003, Guyana- Gift 39 bundle 2 of 3 9/15/09" and "Inigo Gift could be set aside for now…" Through these notes, HS3 had indicated his decisions about the prioritization of accessioning directly on the specimen bundles. The note stating that the "Inigo Gift could be set aside for now…" influenced accessioning: the gift was not accessioned until two years later, when my observation took place in November 2011. (In contrast, the packing slip from the Mexican herbarium was dated October 2011, indicating a much faster turnaround in accessioning.) The simple routine of attaching notes to bundles of specimens allowed Herbarium collection managers to communicate easily about the prioritization and disposition of groups of specimens. They prioritized the bundles of specimens based on their origin: an exchange from another herbarium received higher priority (seen in its quicker accessioning) than a gift from a former researcher at their own institution.

Figure 4.19 Herbarium specimens prior to accessioning

The student worked with the "Inigo Gift," with the collection manager guiding her through the process. At the same time, HS2 was accessioning the exchange from the herbarium in Mexico. The allocation of specimen bundles between the two processors reflected the priority given these two groups of specimens, with the less experienced student processing the accession that had waited longer in storage. This allocation is commensurate with the student's learning through legitimate peripheral participation—she was assigned the lower stakes material to work with (Lave and Wenger 1991). The two batches of material to be accessioned looked similar. Both sets were in leaves of newspaper bearing handwritten notes giving the collector number and sometimes the plant family name or number. Inside each newspaper fold was a specimen and a label providing the collection information for the specimen. The labels from the Mexican herbarium bore that herbarium's name and the legend "Plantas Mexicanas" while the donation from the former researcher at Michigan were labeled as belonging to the University of Michigan Herbarium series "Plants of Guyana."

As the collection manager and student reviewed the materials in their bundles, HS2 explained that the presence of a label written by the plant's collector was a necessary precondition to accessioning. Without an identification of where and when the plant was collected, by whom, and a determination at least at the family level, the plant could not be added to the Herbarium. If a specimen arrives without a label, however, it is not automatically rejected. Instead, this becomes an opportunity to repair the situation, and the collection manager contacts the collector or herbarium that sent it for more information.

> Sometimes, things come to us lacking a label. So we'll just set that aside and contact whoever sent it to us and see. Oftentimes, they'll just send the label. Things don't get thrown out easily. I mean, that's a lot of work to collect plants and, you know, people had risked their lives to do it, quite literally. And so, things are treated as of high value. (HS2)

With this statement, HS2 reveals the importance of a specimen label in the evidential norms of botany as well as the value placed on fieldwork. While the lack of a label makes a specimen lose evidential value and risk being thrown away, collection managers do not take that step lightly, attempting to restore a specimen's evidential value before deciding to discard it.

Along with the prioritization of bundles for accessioning, specimens within the bundles also received different priorities during accessioning. As they reviewed the specimens, the collection manager and student set aside higher priority plants for faster processing and addition to the collection. The highest priority categories of specimens ("Priority 1" on the collection manager's list) were plant families that hold a strong research interest for Herbarium researchers -- these would be routed directly to the curators working with those families for their assessment of the specimen's value and determination of its species. The collection manager provided the student with a list of these families: *Cyperaceae, Malpighia, Euphorbia, Caryophyllaceae*, and *Onagraceae* (with interest in only one genus of this final family). Staff also considered type specimens as Priority 1: the specimens that act as name bearers for species. "A nomenclatural type (typus) is that element to which the name of a taxon is permanently attached" (International Association for Plant Taxonomy 2012, article 7.2). This attachment is established through publication, and the specimen is preserved at a herbarium for future access to botanists, usually stored (as is the case at Michigan) in a separate section of the herbarium, where these high-value specimens can be easily retrieved. Next in the category "Priority 1" is plants from Michigan, where the Herbarium places a great deal of collecting emphasis, in part because of the *Michigan Flora* guide produced by Herbarium staff. In the Priority 2 category, HS2 placed Great Lakes plants. She explained,

> The Great Lakes has a lower priority. It's not being actively researched, but we anticipate as our herbarium gets involved in more consortia that there will be a focus on Great Lakes collections. So, we're just kind of anticipating that we should accession those and put a little higher priority on them over things from the rest of the world, and then prioritize, basically everything that doesn't fall in these categories.

Accordingly, the Priority 3 category on the list said simply, "everything else." Specimens were prioritized, then, by their immediate interest to current research staff before all else. While the special value of type specimens in botany also made those important, as did the Michigan-specific value of specimens from certain geographies, the prioritization for processing specimens was, first and foremost, tied to the ongoing research activities of Herbarium curators.

The collection manager and student proceeded to flip through their bundles, looking for specimens that fit into these categories while they filled out the fields stamped on a strip of manila paper under the title "University of Michigan Herbarium" and attached to each accession: Accession number, Number of specimens, Number of bundles, Collector, and Locality. This information would be added to the accessions database (and an accession number assigned) at the end of the process.

Specimen quality was another concern during the accessioning process, although it only arose in the case of two duplicate specimens, as HS2 decided which specimen to keep and which to designate as a specimen for exchange with some other herbarium.

> See here, we have a situation here. These two are next to each other. They look very similar and indeed they are the same collection number. So, we don't really want both of these. This is the better collection that's a little more ample. […] So I'll pull this [less ample specimen] and I want to keep track of where we got it from. It's a duplicate, sent as exchange. So I'm pulling it as a duplicate sent as exchange from [the Mexican herbarium] because we will exchange this with someone else, but we don't wanna send it back to [them]. […]
>
> Interviewer: Can you tell me what indicated ampleness?
>
> HS2: […] It was just a fuller specimen. If it has a root, that's a plus. If it has got flowering or fruiting material, that's a plus. Yeah, those are the big things. The reproductive parts are most significant, usually.

In this case, having two specimens with the same collector number, she was able to choose one of them for the Michigan collection and put the other aside for exchange to a third herbarium in the future. The collection data provided by the Mexican herbarium would be kept with both specimens, although they would ultimately reside at separate institutions. The collection manager's selection for the Herbarium reflects another aspect of the data quality standards of this epistemic culture. HS2 selected the more ample specimen for Michigan because it had visible more of the physical characteristics that botanists look for in a herbarium specimen, making it more valuable for research use, and more valuable as data. In this case the quality of the object itself determined its value as data in the accessioning process. While specimen quality helped HS2 decide between the two duplicate specimens, it was not something she mentioned during the rest of the accessioning process, indicating that the quality of the other specimens was adequate.

As she reviewed the specimens, HS2 kept notes on the packing slip provided by the Mexican herbarium tracking how the specimens would be processed.

> I'll write down this paperwork and I'll say, 'Ten *Euphorbiaceae* to [the Herbarium curator working with this family]. One duplicate for exchange. One type...' This line is type accessions. And hopefully, all of those numbers are going to equal 251 or close to it. Now, they might have made a mistake counting at their end, too. So at least it should be within a couple. If it's not close or fairly close, if it was off by 10, I would recount everything. If it goes off by two, nah, maybe not. (HS2)

The packing slip functioned as a boundary object between the two herbaria, documenting the Mexican herbarium's understanding of the contents of the exchange which HS2 used to check against her own count of the specimens (Star and Griesemer

1989). As she categorized the specimens by the disposition they would receive at Michigan, she matched them with the description given by the Mexican herbarium to be sure that the packing slip and shipment matched. The packing slip functioned as a record of institutional relationships and a means to manage the accessioning process.

At the same time that HS2 identified the specimens using the Mexican herbarium's description, she was also re-categorizing the specimens to make them amenable to the accessions database for internal record keeping purposes. Her categorizations were based on collector name, plant family, and the geography in which the plant was collected.

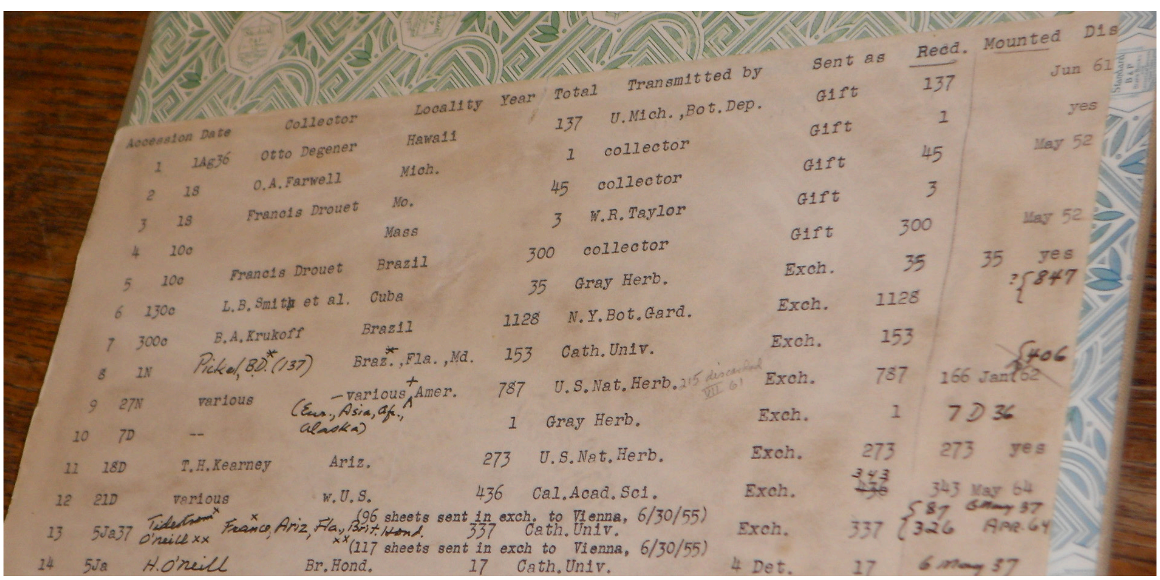
> So, as I go through and attack a bundle of accessioning, I'm going to watch for if I can break out collectors. If I can't, if it's just a mismatch of a whole bunch then it just gets entered as "various." Sometimes, it works out that you can separate things by geography and it's more practical than worrying about the collector. But if there's, oh, at least 10 or 12 that are by the same collector, generally, they'll get accessioned together. (HS2)

Depending on the size of these groupings, then, HS2 would attribute the specimens to a particular collector, family, or locality or as "various," and accession them together by group. Because the Herbarium does not accession each specimen individually, the collection manager's accessions may be the only database representation for an entire group of specimens, recorded as numbers of items within collector, plant family, or locality groupings. Grouping accessions by collector is the ideal method collection managers have spelled out in the Herbarium's Handbook for Vascular Plant Curation, authored in 1986 with revisions in 2000 and 2004.

> Any collector who has at least ten individual specimens can be entered separately in the accession records; there may occasionally be reasons to override this number and create smaller batches. There is no maximum limit to the number of specimens that can be put into a single accession. For collectors who have fewer than 10 specimens, combine their specimens by locality of collection until you have at least 10. If it makes sense to put all the Venezuelan specimens together and there are 30 of them, that's fine. (Freidlander 1986)

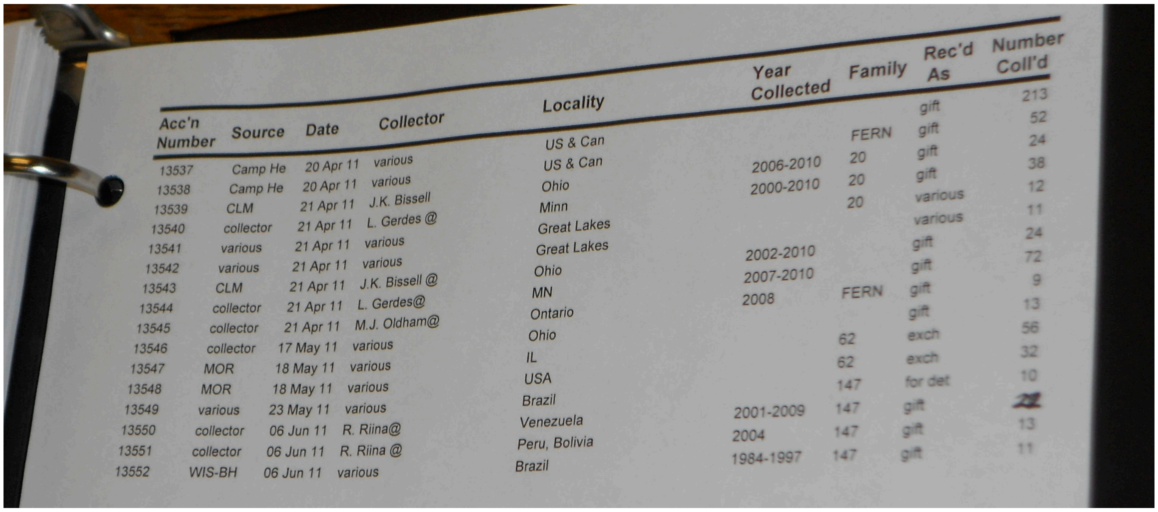
While accessioning specimens by collector is the ideal, then, the number of specimens in a given accession record is a consideration that may override this concern. The guidelines themselves allow for a collection manager to use his or her own discretion when following the accessioning procedures.

After she had sorted through the bundles, the collection manager input the material from the Mexican herbarium into the accessions database, using a desktop computer located in the Range, the vast room where specimens are stored. She chose to divide the materials into six separate accession records. Three of them were grouped by collector and described in the accession records by collector name, locality (Mexico), and the date range during which the collections were made. Two of the accession records were attributed to various collectors, but included single families of plants from Mexico (141 and 147, *Malpighiaceae* and *Euphorbiaceae*- two of the families of interest to the Herbarium). The record for the *Euphorbiaceae* accession also included a note that it contained a type specimen. Each of the records was attributed to the Mexican herbarium's code, recorded with that day's date, and assigned a consecutive accession number by the database. A list of accessions would be printed from the database and added to a three-ring binder, which was part of a series of notebooks recording accessions, dating back to 1936. While the 1921 book shown in Figure 4.12 actually predates the 1936 book, the 1936 accessions book shown in Figure 4.20 was the first to include accession numbers and to use a larger number of data fields to describe an accession. In Figures 4.20 and 4.21, I contrast the first page of accessions from 1936 and the most recent, at the time of my visit in November 2011, showing that the information recorded about accessions at the Herbarium remained fairly stable over this time period.



Accession	Date	Collector	Locality	Year	Total	Transmitted by	Sent as	Recd.	Mounted	Dis
1	1Ag36	Otto Degener	Hawaii		137	U.Mich.,Bot.Dep.	Gift	137		Jun 61
2	1S	O.A.Farwell	Mich.		1	collector	Gift	1		yes
3	1S	Francis Drouet	Mo.		45	collector	Gift	45		May 52
4	10c		Mass		3	W.R.Taylor	Gift	3		
5	10c	Francis Drouet	Brazil		300	collector	Gift	300		May 52
6	130c	L.B.Smith et al.	Cuba		35	Gray Herb.	Exch.	35	35	yes
7	300c	B.A.Krukoff	Brazil		1128	N.Y.Bot.Gard.	Exch.	1128		? 847
8	1N	Pickel, B.D.* (137)	Braz.*,Fla.,Md.		153	Cath.Univ.	Exch.	153		406
9	27N	various	various Amer. (Eur., Asia, Af., Alaska)		787	U.S.Nat.Herb. 215 discarded VII 61	Exch.	787	166 Jan 62	
10	7D	--			1	Gray Herb.	Exch.	1	7 D 36	
11	18D	T.H.Kearney	Ariz.		273	U.S.Nat.Herb.	Exch.	273	273	yes
12	21D	various	W.U.S.		436	Cal.Acad.Sci.	Exch.	~~436~~ 343	343 May 64	
13	5Ja37	Tidestrom× O'neill××	Franco, Ariz, Fla., Brit.Hond. (96 sheets sent in exch. to Vienna, 6/30/55) (117 sheets sent in exch to Vienna, 6/30/55)		337	Cath.Univ.	Exch.	337	87 6 May 37; 326 Apr.64	
14	5Ja	H.O'neill	Br.Hond.		17	Cath.Univ.	4 Det.	17	6 May 37	

Figure 4.20 Accession book, 1936



Acc'n Number	Source	Date	Collector	Locality	Year Collected	Family	Rec'd As	Number Coll'd
13537	Camp He	20 Apr 11	various	US & Can			gift	213
13538	Camp He	20 Apr 11	various	US & Can		FERN	gift	52
13539	CLM	21 Apr 11	J.K. Bissell	Ohio	2006-2010	20	gift	24
13540	collector	21 Apr 11	L. Gerdes @	Minn	2000-2010	20	gift	38
13541	various	21 Apr 11	various	Great Lakes		20	various	12
13542	various	21 Apr 11	various	Great Lakes			various	11
13543	CLM	21 Apr 11	J.K. Bissell @	Ohio	2002-2010		gift	24
13544	collector	21 Apr 11	L. Gerdes@	MN	2007-2010		gift	72
13545	collector	21 Apr 11	M.J. Oldham@	Ontario	2008	FERN	gift	9
13546	collector	17 May 11	various	Ohio			gift	13
13547	MOR	18 May 11	various	IL		62	exch	56
13548	MOR	18 May 11	various	USA		62	exch	32
13549	various	23 May 11	various	Brazil		147	for det	10
13550	collector	06 Jun 11	R. Riina@	Venezuela	2001-2009	147	gift	22
13551	collector	06 Jun 11	R. Riina @	Peru, Bolivia	2004	147	gift	13
13552	WIS-BH	06 Jun 11	various	Brazil	1984-1997	147	gift	11

Figure 4.21 Accession book, 2011

Accession number, source ("transmitted by," in the 1936 book), date, collector, locality, year collected, received as, and number collected ("rec'd" in 1936) have all been retained as important categories of information. Over time, collection managers have changed the metadata captured about accessions by including the family category, which uses family number or name, and removing the "mounted" and "dis" categories from the 1936 book. When I asked about these categories the collection manager told me, "I think that's keeping track of when they were mounted. […] Whereas now, we keep track of our mounting records separately. They're not in with our accession records" (HS2). These changes reflect a shift in the documentation of workflow over time (where plant mounting is documented) and an addition to the specificity of the Herbarium's recordkeeping. Where accession 9 in 1936 recorded the addition of 787 specimens from 5 geographic areas, we can imagine that these specimens would now be recorded as several accessions, grouped by geography, collector, and plant family in cases where substantial numbers of specimens in a group warranted accessioning together. Today, the accessions book is printed directly from the database. Figures 4.22 and 4.23 show the data entry screen (mirroring the categories printed in the recent accession book) and the records summarizing the accessions made from the Mexican herbarium.

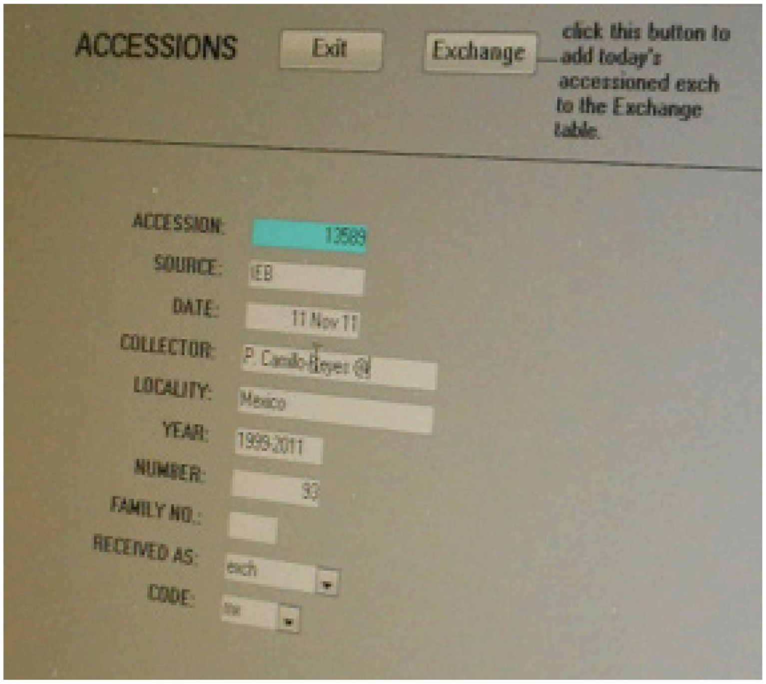


Figure 4.22 Accessions data entry screen

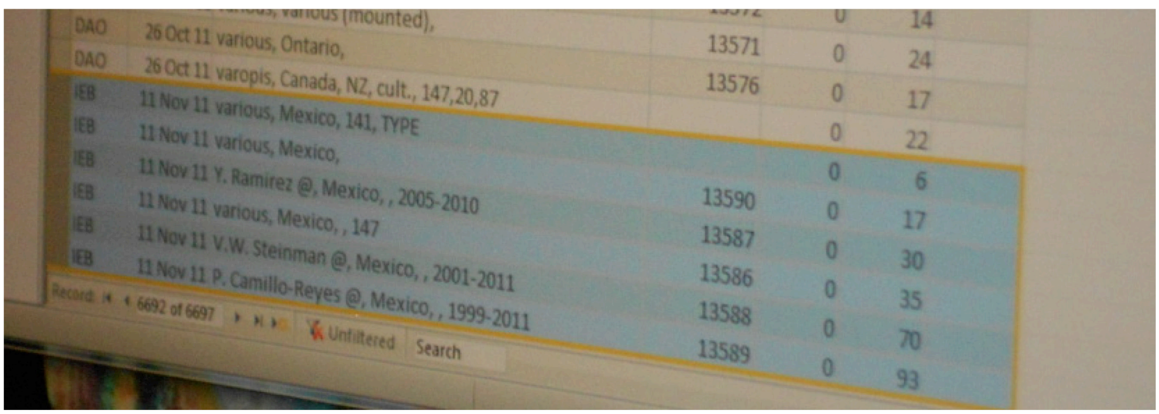


Figure 4.23 Summary screenshot of the group of accessioned materials

The accession database is part of a larger curatorial database that also tracks plant mounting assignments, exchanges, gifts from Michigan to other herbaria, and loans to and from other institutions. Collection managers record workflow and maintain relationships with other herbaria and collectors throughout the world using these two databases. After she accessioned the materials from Mexico, the collection manager ran a report in the database to see the exchange balance with that herbarium. At the bottom of a list of all exchanges with this herbarium, the total read "-1917" using the minus symbol to indicate that the Mexican herbarium had sent Michigan 1917 more specimens than Michigan had sent it. Her decision to finish the accession from Mexico before the materials from a former researcher at Michigan, and her decision to run a report on the exchange balance with that institution indicate that this accession was important, in part, because of the relationship between the Michigan and Mexican herbaria. She wanted to update that information right away so it could be communicated back to the other organization, maintaining a shared record of materials exchanged between the two institutions and the balance of exchanges between them. In these actions, the function of accessioning in maintaining relationships between herbaria is clear.

A second takeaway concerns the relationship between specimens and recordkeeping in the accessioning process. While the packing list enabled HS2 to compare the Mexican herbarium's records with her own, notes attached to the bundles of specimens themselves served a similar function within the Michigan Herbarium. They enabled curators and collection managers to communicate data management decisions about the fate of incoming specimens, setting priorities for the institution regarding which specimens would be processed first. The packing list functioned as a boundary object between the herbaria, helping both institutions coordinate their work as sender and recipient of specimens.

Finally, it is notable that the prioritization criteria HS2 used while accessioning specimens maps closely to criteria found in the data reuse literature. The relevance of specimens to curators' current research was the primary prioritization concern, while quality was an important factor for HS2 in deciding between two comparable specimens. Zimmerman (2003) notes the centrality of research questions and goals in selection decisions made by secondary data users, while Van House et al. (1998) illustrate the role of data quality judgments in the data reuse process. The work done by HS2 and her student during the accessioning process revealed the importance of accessioning high-quality specimens to maintain the collection's research value and the importance of processing materials that were directly relevant to curators' research goals. Individual curators' research goals have been institutionalized as priorities in the accessioning process, with collection managers filtering data for curators by forwarding specimens directly to them for determination. Their species determinations, in turn, add value to the collection.

Once specimens are accessioned, identified to the species level (in cases where there is curatorial expertise on that family), and mounted, they go into the Range (the Herbarium's vast specimen storage room) organized by taxonomy, and subdivided by geography, to be retrieved as needed for research. Once shelved, their taxonomic placement (rather than their source, as in the accessioning process) becomes the key to retrieval.

The accessioning process turns botanical specimens into herbarium specimens, making them a permanent part of the institution. Having an institutional home, and meeting the minimum standards for accessioning (adequate label metadata), specimens become a new kind of data once they are accessioned into the Herbarium. They become vouchers, and can only be cited and used as evidence in botanical publications once they receive that status. The accessioning process is therefore a crucial element of botanical research. The validating function of herbaria in botanical practice extends the importance of this activity beyond the walls of the Herbarium itself, to impact a larger research social world.

4.6 Collection Source and Representation

Both the Kelsey and the Herbarium are limited in terms of what they can say about the objects they hold and the detail with which they can describe them. This limitation has several sources: it is social in the sense that neither museum can provide information about an object that the collector does not provide (as in the explanation given by HS2 of how she handles missing specimen labels). The collector's ability to document and share information about the object's source to the museum is paramount in the museum's ability to convey information about the object. Some limitations are technical: they may stem from the tools in use at the time of collection. In this section, I explore the limitations facing collection managers at the two museums in their descriptions of objects as well as the strategies they use to mitigate these issues. Staff members' work with collection representations mapped onto their subworld memberships: curator and collection manager roles as well as areas of specialization. In addition, staff members' systems-based and content-based expertise defined their approach to collection representation issues. While curators' content-based expertise enabled them to definitively identify many museum objects, collection managers used their systems-based expertise to incorporate identifications and other updates into the museums' information systems.

4.6.1 Archaeological Documentation and Context

There are several types of sources for the objects in the Kelsey's collection. A large portion of the museum's holdings came from archaeological excavations in the Near East sponsored by the University and the Kelsey Museum from 1924 to 1970. The remainder of the objects were donated or sold to the museum at some point in its history. Kelsey staff and researchers used these two categories, excavated and purchased objects, to discuss the value of the museum's objects for research, as I will address in the next chapter, but these categories also have a great influence on the descriptions that the museum has given to its objects, the issue I discuss here.

Depending on an archaeological object's source, collection managers accessioned it with a greater or lesser amount of information. Objects that were excavated have detailed information (although the amount of detail varies) about the location where the object was found. This information is held in different forms of documentation dispersed throughout the museum. For example, collection managers placed excavation notebooks and object files in the registrar's office, where they work, while other excavation documentation, including photographs and site plans, resided in the museum archives in a large room upstairs. Purchased objects, on the other hand, have details about the circumstances of the purchase – from whom they were bought, when, and for what price, along with the seller's identification of the objects. This information is held primarily in the object files in the collection managers' office.

Although the records available for excavated materials are generally more abundant than those for purchased and donated objects, that information may be more difficult to access and understand. As this quote from collection manager AS1 illustrates, knowledge of each excavation's numbering scheme is key to figuring out where to find the appropriate documentation for each object:

> The only thing we need is an accession number, and that accession number will then relate back to our records, so we can see all its metadata, so we know where it comes from, we know how it got here […] Some pieces, because they come from an excavation, have these numbers on them, so the 31DX refers to the excavation number, 1931, DX, that must have been a Terenouthis piece. Pieces from Karanis have other numbering schemes on them.
> Interviewer: So, DX would probably have something to do with the room and the level it was found at...
> AS1: Yeah, I've got to take a look at that one.
> Interviewer: Okay. But that number is from the excavation?
> AS1: Yeah, 1931. Well, with a number like this, 29SG, that's not very helpful. SG stands for Summer Guard. So when the excavators weren't there, that's what people who were guarding the site were just finding. Numbers from Seleucia are a little bit more tricky in that they are just four or five-digit numbers, sometimes they're supposed to have a prefix to them, like the season they were excavated so A, B, C, D, E or F. But it's not always there, it's just a manner of recognizing it.

The numbers on excavated objects are an important key to the excavation records, since these are the numbers that the excavators used to label them and to record their own information about them. Understanding their numbering systems helps the collection managers pinpoint the relevant excavation records, but the systems would take a great deal of time and experience for a new user to understand. AS1 highlights the uneven use of numbering schemes at the digs themselves when he says, "sometimes they're supposed to have a prefix to them, like the season they were excavated so A, B, C, D, E or F. But it's not always there." His knowledge of these numbering schemes allows him to quickly identify the source of an object and locate additional information about it. His knowledge of these coding systems is not entirely complete, (e.g., "I've got to take a look at that one") but it is extensive.

The importance of maintaining this context in order to enable data reuse would be hard to overstate. Excavation numbers not only link artifacts to various representations documenting their provenience, they also link together artifacts from a given excavation, revealing their geographic and temporal relationships by showing which objects were found together at the same stratigraphic layer. Each artifact's context is centrally important to its function as data, following Hodder's assertion that "Archaeological data can be defined as a set of dynamic, dialectical, unstable relations between objects, contexts, and interpretations" (Hodder 1999, p. 84). In the epistemic culture of archaeology, context is an essential part of the evidential value of data. Because he understands the numbering schemes used by various Michigan excavations, AS1 has a vital role as mediator between the artifacts and their context.

AS1's understanding of the numbering systems used at Michigan's excavations is an example of the systems-based expertise needed in collection managers' work. I use the phrase *systems-based expertise* to refer to collection managers' understanding of the museums' own systems for working with collections, and also those of collectors, who often used their own systems to track collections. In this case, AS1 uses his knowledge of a system devised and used by excavators to specify the context in which they found the objects now in the Kelsey's collection.

Another issue in using older archaeological records is the level of granularity captured in the records. AS1 explains that older archaeological records are often considered insufficiently detailed by the standards of today's archaeologists.

> While the Karanis excavations are pretty detailed, they are not on the level of what people do now. So, they didn't have GPS then, they didn't use coordinates or anything like that. They had really good maps. When something was excavated from a house, did it come from the structure? Whether they came from that wall over there or somewhere over there, they didn't note that, unless there was something very special like underneath in the stairs or "under the window" or something like that. That information was kept but not exactly where it came from. So, those numbers that I showed you like the 30B28 or whatever that number was, that will tell you which structure it came from but where in the structure? […] There's generic stratigraphy, 'cause A, B, C, D, I think it went to E, but that's general layer […] I don't think that modern archeologists would really take those as legitimate layers, but it's the layers that were used. […] In modern archeology, layers can be 10 centimeters because you keep track of each layer. But with a meter, it's hard to tell where something went.

As methods and technologies for recording archaeological context have changed, members of the archaeological community of practice have also changed their expectations for how context will be measured and conveyed. The level of specificity used in older records from the Karanis excavation would not be considered acceptable by today's standards, but modern-day users must make do with the information available.

Through their understanding of past data collection methods and recordkeeping practices, collection managers act as a repository of organizational memory that users need to access in order to understand excavation records and preserve context. Argote (1999) acknowledges that although organizational memory embedded in individuals has several drawbacks including susceptibility to decay, variable willingness to share knowledge, and potential turnover among employees, this may be mitigated by embedding that knowledge in routines, organizational structure, and technology. At the Kelsey, several of these alternate locations of embedded knowledge are in use. For example, AS4 told me,

> I'm at the Kelsey now, but I may not be there always, and I have a lot of information about the collection that I've just kind of thought about as I'm looking at the objects but it's really a good idea to get it in writing somewhere. Our old registrar used to have a notebook that was labeled, "In Case I'm Hit by a Bus."

Knowledge of the collection is also embedded in the museum's practices, or routines in Argote's parlance. When curators pass on an information request to collection managers, they do so with the knowledge that the collection managers have some knowledge that they do not and can better facilitate a researcher's use of the collection. Wegner terms this transactive memory, where "one person has access to information in another's memory by virtue of knowing that the other person is a location for an item with a certain label" (Wegner 1986, p.189). Within groups, an effective transactive memory system drives performance (Argote 1999). At the Kelsey, staff members use transactive memory to refer questions to others with the necessary content-based or systems-based expertise so those with the relevant expertise can act as mediators to understanding artifacts.

Objects that arrive at the museum through donation or purchase tend to arrive with much less information. The amount and type of information available depend on the documentation maintained by the object's donor. AS1 illustrated this lack of consistency between donors in his story of a donor who provided very detailed records of the objects he was giving to the museum.

> There are some people who are collectors, and they are collectors because they collect those kind of objects, and those kind of people usually have their own lists

> and their own descriptions, either that they created or they had somebody create. […] People who collect coins are a very particular kind of people. They're very meticulous and they'll collect records and there's a lot of literature out there to describe coins. So there are coins that come with premade lists, premade descriptions. The most recent coin donation was actually given by a professor who collected them because he was a chemist, who was testing their content down to 0.001 percent copper. […] Because he's a chemistry PhD, he took meticulous notes, [not] just about how much content was in the coins, [but] the history of the coin. That it was a Roman coin, but a Roman third century coin from North Africa. So he kept those kinds of meticulous notes.
>
> […] Other donations that may not have strong information on them, as long as we know that they're legitimate and we accept that, we'll accept them and be able to give them general records. Then over time, what we have, students or I have volunteers, or people who are interested in materials, they will just research them and fill out the other information on them. And the reason we have lists is because we don't want to accept anything unless we know exactly what's coming in. So there's at least a general list of a couple of boxes, a couple of pots, here and there.

While the Kelsey required some documentation in order to know that the donated artifacts were acquired legitimately, the amount of information that accompanied a donation varied. Although some did not have "strong information," other artifacts were received with lists compiled by the donors stating the age, geographic origin, and description of the object. "Strong information" was preferred, but less strong information was acceptable, to be fleshed out later through research. The presence of documentation was a baseline requirement for accessioning artifacts, but they could become a part of the collection and given "general records" without the extensive metadata some collectors provide. Metadata quality impacted the treatment of artifacts in terms of the extent of database records that collection managers could create as well as the need for continuing research to fill in gaps in the Kelsey's representations of its collections.

For both excavated and purchased or donated collections, the contextual information received by the Kelsey, created by collectors during the course of their use of the artifacts, had a great influence on what the museum knows and is able to communicate about the objects. In AS1's example above, the chemist donated a collection of coins that he had used in his own research to analyze their metallic content. His analyses, which formed his own research data, are now held as documentation by the museum. While the chemist's meticulous note taking about the coins' origins can inform the museum's basic descriptions of the objects, his research about their metallic content might be omitted from those database representations. This omission may have implications for later research use, as archaeologists interested in the chemical composition of these coins would not be aware of the chemist's data without assistance from the collection manager. In this case, organizational memory embedded in the collection managers and the object files they oversee would be the only access points to this information. Collection managers' systems-based expertise, their knowledge of the chemist's recordkeeping systems and the museum's, helps them access this information.

4.6.2 Botanical Documentation and Context

At the Herbarium, collection managers accessioned specimens with a label made by the collector, including where and when it was collected, and (sometimes) notes on its growing conditions. As was also the case at the Kelsey, the quality of metadata the museum received at the time of deposit varied a great deal. While some collectors gave precise locality information, others only named the specimen's country of origin. Where some collectors described the growing conditions in which a plant was found, others omitted that information entirely.

One important factor contributing to the quality of collector provided metadata was the date of collection and the technologies available to botanists during that era. Data capture technologies have changed in botany, leading, in general, to more specific descriptive metadata in more recent records. For instance, botanists now routinely record the GPS coordinates at which they found a specimen, while in the past they were reliant on paper mapping systems, providing the township, range, and section on their labels. Of course, best practices were not always followed then or now, so even with today's technological capabilities, metadata are only as good as the record creator's attention to detail. Because some specimens in the collection date back to 1838 and the first Geological Survey of Michigan, there is a great deal of variety in the specificity of labels as specimens were collected over time. Collection managers and curators referred to specimens acquired through the survey, as well as other, older specimens, as "historical collections." In our conversations, collection managers expressed lower expectations for the documentation of historical collections than they did for more recent specimens. The specificity of metadata, particularly locality metadata, was an indicator of data quality from their perspective, but lack of specificity did not prohibit collection managers from accessioning a specimen. I address the specificity of locality metadata as selection criteria from the perspective of data reuse in the next chapter.

Regardless of the technologies used by collectors to record metadata, collection managers were markedly dependent on collectors' representations of specimens as they processed materials and created new representations of them for the Herbarium. The accessions database that I discussed earlier is the only record the Herbarium makes of *all* specimens to enter the collection, and, as noted, these records describe plants at the group level rather than the item level. Some specimens were described at the item level, however, and for these objects I wanted to learn how staff members assess the descriptions made by collectors and how they translate them into the Herbarium's systems. HS2, the staff member who works most directly with the *Michigan Flora* database, noted that disagreements with specimen labels are dealt with through annotation, rather than outright change.

> Interviewer: [...] Do things get entered sort of verbatim from what the collector said when they did the collecting?
> HS2: That policy has changed. That used to be true for the *Michigan Flora* project that everything was very much done verbatim. That's not always the best way to handle data. Sometimes, it's better if you parse it out so that we have a locality field, a habitat field, specimen notes field, and different information goes in that. That means that the data entry person might have to rearrange things from how it is entered on the label but the content will be the same.
> Interviewer: Are there ever any questions about the veracity of the content?
> HS2: […] What will generally happen is that somebody who questions it will write a little note on the specimen, "This has been collected in July because this plant doesn't fruit until September," or something like that; they'll state the reason why they doubt some information that's on the label. […] And then that gets added in the database but bracketed. So the brackets will indicate that that's additional information beyond what was on the actual label.

Updating made to specimens in the *Michigan Flora* database then, was captured first on the specimen itself and second in the database, in a bracketed field. Brackets showed that a researcher or staff member disagreed with the label, recording the basis for that disagreement and allowing for multiple opinions while still favoring the original documentation on the label itself. The Herbarium maintains an ongoing, updatable record of the specimen on the specimen sheet itself and, in some cases, in a database as well.

Figure 4.24 shows several determination labels for a specimen in the Herbarium's collection. This plant from the family *Tinantia* was collected in 1957 by three people. The first listed, Rogers McVaugh, assigned it his collector number 16444. The original collectors identified the specimen only to the family level—the label suggests that they were collecting numerous specimens from the Nayarit region of Mexico. In 1978, Robert Faden of the Field Museum consulted the specimen and added his own species determination, *Tinantia macrophylla*, first published by Sereno Watson (Watson 1886). D.R. Hunt confirmed this determination in 1993. Through these determination labels, the specimen itself bears a part of the Herbarium's organizational memory, documenting the researchers that came into contact with this specimen and added their opinion of its identification. A botanist using this specimen would also be engaging with the researchers who came before him or her, relying on their expertise in the *Tinantia* genus to trust those determinations, or disagreeing with those earlier researchers to come to a new conclusion about its determination. Through the act of reviewing and annotating specimens, members of a botanical community of practice, in this case a community with the shared identity of *Tinantia* researchers, debate the meaning of data with each other, bringing new interpretations of data to the community's understanding of the genus (Lave and Wenger 1991).

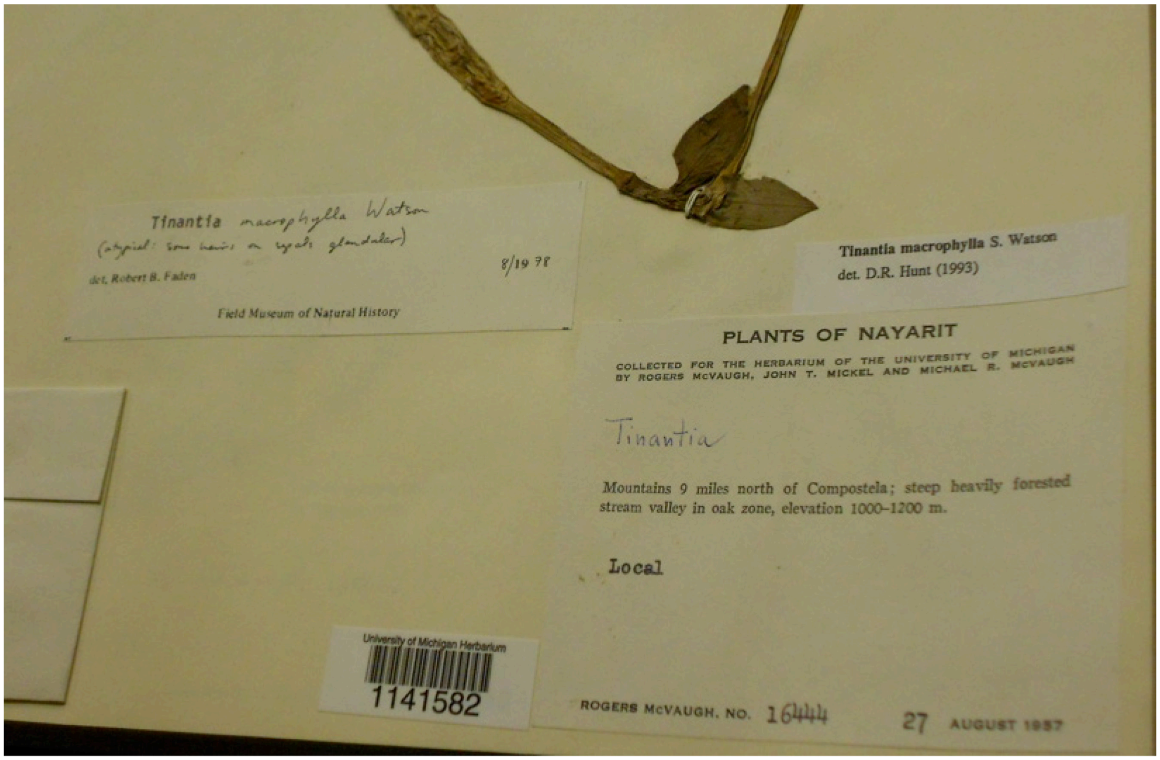


Figure 4.24 Detail of McVaugh 16444, *Tinantia macrophylla* at MICH

At both the Herbarium and the Kelsey, collection managers relied on the information provided by the objects' collectors to know the original context of the objects. While norms and standards for recording data have long existed in both archaeology and botany, these standards have changed over time along with technologies and priorities of the two research social worlds. In both botany and archaeology, recordkeeping has become more specific with the aid of new tools for measurement. While data documentation is, in general, becoming more fine-grained in botany and archaeology, this creates a gap in specificity between newer and older representations at the museums. Today's researchers use, and are conversant in, today's systems for describing context and may need the assistance of museum staff to make sense of context recorded by their predecessors.

4.7 Changes to Data

While both Kelsey and Herbarium staff relied heavily on the information provided along with objects by their donors, there are many ways in which they changed representations of the data they hold. Through these changes they made data more amenable to analysis and also more authoritative, providing a level of institutional validation that increased their evidential value. Using the typology developed in Daniels et al. (2012) I will explore some of these changes, showing the management of museum data as an active, variable process.

Collection managers *added value* to data by formatting and standardizing metadata. In both the Kelsey and the Herbarium, these changes included reformatting information when adding it to a database to make it more amenable to analysis. As previously quoted by HS2, "Sometimes, it's better if you parse it out so that we have a locality field, a habitat field, specimen notes field, and different information goes in that. That means that the data entry person might have to rearrange things from how it is entered on the label but the content will be the same." By breaking metadata into various fields, it became amenable to more structured analysis. Collection managers routinely reformatted location metadata using georeferencing tools for those specimens with their own database records. In addition to making mapping specimen distribution easier, this also served as a metadata validation technique, since clearly inaccurate localities such as land plants found in the ocean would denote faulty location information.

Other kinds of data validation, including the identification of a specimen, could not always be done at the Herbarium. As HS1 explained,

> With some exceptions, any data is sent out strictly on a buyer beware basis. […] For areas that we specialize in we can have much higher levels of data accuracy and standardization. So, we can... For Michigan stuff, we actually vouch for the determinations. We fix them and we can usually vouch for the geography too, because old stuff that was often labeled with just a town or a lake, no county, we filled a lot of that in because we know and collections where it just had a two year century, we filled it in whether it's 1879 or 1979. Someone looking at the electronic data would never know. If you give them the specimen it's obvious.

The ability to validate data at the Herbarium, in the sense of providing an authoritative determination for a specimen, depended on curator expertise in a given area, highlighting the need for *content-based expertise* among staff members in order to provide data of the highest quality. As HS3 described, specialist expertise in a given plant family allows the Herbarium to provide quality control in the determination of new specimens added to the collection.

> The process we're dealing with, with sedges and grasses, we have an advantage here because all the sedges were most likely determined by one person because he's the specialist in the group, and everything goes through him before it goes onward. And that really is going to be a tremendous advantage for our collection.

Content-based expertise, the term I use to refer to curator familiarity with the specimens or artifacts in the museums' collections and their deep knowledge of a related research area, enabled the Herbarium to add in-house determinations to specimens in some plant groups, giving those specimens higher research value because they have been authoritatively identified. With the exception of HS3, who is a plant systematist as well as a collection manager, content-based expertise at the Herbarium was a characteristic of curators rather than collection managers and other staff, reflecting the expectations associated with staff roles within the organization. Plant families in which a curator was expert were a source of subworld membership for individuals, who strongly identified with the plant families they studied, and organizational identity for the Herbarium itself.

Staff engaged in data validation at the Kelsey in a very similar way. Curators worked with collections to provide authoritative determinations of the artifacts within their geographic and temporal area of expertise. They often relied on student labor for this work, but verified their work before it was used to update the collection database.

> We do have the curators, one at a time, work with the collections and identify them, particularly for publications or for exhibitions. Then their students, also for these publications, for exhibitions, but also students who are doing more class work […] will pick an object, or pick a group of objects, and then they'll research that. Then if a curator finds that their information, that their research is sound and helpful, they'll turn that research over to us and we fill out the rest of it into the database.

External researchers were also an important source of expertise in identifying artifacts at the Kelsey. As AS1 told me, "We have researchers from around the world who come visit us all the time, so they are the experts," contributing identifications of the objects they use.

The process of *error correction* was similar at the two museums, where staff or external researchers using the collection discovered errors needing to be fixed. Among external researchers, both archaeologists and botanists alerted museum staff when they felt an object had been incorrectly identified. At the Herbarium, however, researchers simply left an annotation slip with the specimen when they were done using it, which collection managers would later affix to the specimen sheet itself. At the Kelsey, collection managers verified changes to an identification with the appropriate curator before applying them to the database. Because the Kelsey's collections were not loaned for research purposes, the museum was reliant on onsite visits to take advantage of external expertise, but the Herbarium was able to harness external expertise with frequent specimen loans, as researchers annotated the materials they used.

Changing interpretations of objects at the Kelsey and Herbarium, and subsequently *changing representations of data to reflect new knowledge* are relatively commonplace occurrences. As they were used for research, both curators and external researchers came to new conclusions about what an object was and how it should be described. I asked staff members about this process to learn how they validated and incorporated these new interpretations into existing representations. At the Kelsey, curators verified these new assessments and then collection managers updated the museum's database. As AS1 told me, changes to the way an artifact is identified,

> usually have to go to the overseeing curator. It's their collection, so they have to approve it. So, if we have a student who says, "It's this," they'd have to approve it. But if it's a researcher that is an established researcher, established scholar, then that would very likely be accepted, especially if they publish it.

Although the curator with the relevant content-based expertise had final say, the researcher's background and professional credibility came into play in those decisions, as well as whether or not the researcher published work on that object: the *source* of this new information was of central importance. At the Herbarium, the identification of a specimen as belonging to a different species might stem from a systematist's new assessment of the characteristics defining a species, to become "new knowledge" upon publication. While the systematist disagreed with his or her predecessors, this does not necessarily denote a past error, simply a change in perspective.

Both museums *created consistency* among their collections through several practices overseen or performed by collection managers. At the Herbarium, they mounted and labeled plants consistently, attaching vascular plants to herbarium sheets and boxing fungi. For specimens given a database record, the use of Darwin Core, authorities for taxonomic terms, and the use of geographic coordinates for locality data assured that specimens were described consistently from record to record. At the Kelsey, consistency was created through the application of an accession number and use of a database to describe the objects. Because the museum did not follow an archaeological data standard, though, the museum's metadata were not compatible with other systems. Rather than seeking to make their metadata compatible with other archaeological datasets, collection managers sought a baseline of internal consistency among artifacts in the collection.

Collection managers were *responding to their designated communities* by recording and making data available to researchers in new ways. At the Kelsey, creating excavation and photographic databases enabled the museum to respond to the need for quick and easy access to contextual information surrounding the collection. At the Herbarium, linking specimen information to GenBank deposits acknowledged the centrality of genetic analysis to modern botanical research. By keeping up with the needs of their users, these museums maintained their relevance as data resources.

The final category of change identified in Daniels et al. (2012), *evolving practices around collecting*, refers to changes in the kinds of data collected by repositories as the practices of their research communities change. The Kelsey's collecting has dwindled as a result of changing research practices in archaeology, where UNESCO regulations have halted the export of archaeological finds from the Near East. While the Kelsey still sponsors excavations in that region, it does not have a role in preserving or providing access to excavation records from these ongoing projects—they are managed by the dig's project director instead. The Herbarium continues to accession specimens collected by botanists, linking specimen representations to GenBank deposits where applicable, but it may eventually decide to further alter its practices to meet the changing needs of the botanical community. As herbarium specimens are increasingly used for DNA analysis, for example, some herbaria have begun preserving extracted material. A group of mycologists argued in 1990:

> For curators, extensive use of herbarium specimens for molecular genetic investigations may soon make it desirable to develop guidelines for sampling of type collections and methods for storage and retrieval of extracted DNAs,

> particularly since one DNA sample can be used for many different PCR [polymerase chain reaction] experiments. (Bruns et al. 1990, p. 183)

While several herbaria, like the Missouri Botanical Garden, maintain DNA banks from a portion of their specimens, preservation of DNA samples has yet to become a widespread activity in most herbaria, including Michigan's (Missouri Botanical Garden 2013).

Some Herbarium staff members have changed their specimen collecting practices in response to the growing prominence of DNA analysis in botany. Curator HS1 explained

> More recently, especially now that techniques have become so sophisticated that very little is needed, we are perfectly fine with having people destructively sample small amounts of the specimens to get at the DNA. In fact, when I'm collecting I usually will get a little wad extra just in case they might be useful for that. So there is a fair bit of that going on now. (HS1)

Because DNA analysis is minimally destructive to specimens, the Herbarium tends to approve requests to remove samples from specimens for that work, and HS1 has responded preemptively to these requests by collecting extra plant material for that purpose during his fieldwork.

As collection managers worked with the objects in their care, they made routine changes to object metadata and occasional changes to their work practices. Through formatting, standardization, and error correction, they created consistency and added value to their collections. By changing their collecting practices and making representations available in different ways they responded to the changing practices within their designated communities of users. Staff members' roles in the process of change to metadata corresponded largely with the kinds of expertise they were expected to use in their positions—whether object or systems based. While curators' expertise informs the identification and description of objects, collection managers are responsible for updating systems to reflect these changes. Through this work, museum staff assured that the data they manage met the evidential standards of the research community they support and would be relevant to that community, as users and contributors to museum data collections.

4.8 Information Dissemination

At the Herbarium and the Kelsey, information about the collections resided in several different systems, some of which, (including accession files and databases), were internal documents and others that were publicly accessible. In this section, I discuss the latter category: information resources available to the public that could be accessed by researchers without prior communication with the museum. I also address systems that existed for internal use where the contents were often shared with researchers once an interaction between researchers and staff had begun. This section deals the role of staff members, both curators and collection managers, as mediators in the research process, acting as access points to information.

4.8.1 The Herbarium: Electronic Access to a Fraction of the Collection

Throughout its history, the Herbarium has produced auxiliary representations of its collections in ledgers, moving later to databases. The majority of these systems were designed for internal use by Herbarium staff, including the accessions ledgers and database discussed earlier. These limited representations helped collection managers track exchange relationships with other herbaria and record new specimens that entered the collection. Over time, these have been supplemented by databases developed in the course of Herbarium research projects, several of which are publicly available online and may be accessed directly, while other requests require negotiation with staff members. Some Herbarium staff viewed the online databases as identity markers for themselves and the Herbarium within the botanical research world. Collection manager HS2, for instance, described her involvement with the *Michigan Flora* database as a major part of her work. She took pride in the accuracy of the database and its usefulness to Michigan botanists and ecologists. Online databases were one tool staff members used to stake a claim to expertise in botanical subworlds on the Herbarium's behalf.

Databases hosted on the Herbarium website include the *Michigan Flora* database, several databases of the Herbarium's type collections organized by plant group, as well as an all-inclusive database of type specimens, and three databases produced as a result of specific research projects: "Seed Plants and Bryophytes of Mexico, Central America, and the West Indies [Mex@MICH project],” “Vascular Plants of Mount Kinabalu,” and “*Malpighiaceae* — Taxonomy and Nomenclature” (University of Michigan Herbarium 2011c). The final database, a “Gazetteer of Obscure Michigan Place Names,” is also the result of research. It is derived from research into specimens at the Herbarium performed by former curator Ed Voss as he was working on the *Michigan Flora* project. Voss wrote,

> For 50 years I have been gathering this information, as the necessity was presented periodically to determine the localities (especially counties) where herbarium specimens—mostly older ones—with very scant data had been gathered. Others have often asked for help with fragmentary localities in (or thought to be in) Michigan, and it would appear useful to make this eclectic catalog more widely available despite the varying and inconsistent level of detail (and of citation) as items accumulated over the years without any intention of eventual publication. (Voss 2005, p. 189)

He originally published the Gazetteer in the periodical *Contributions from the University of Michigan Herbarium* in 2005 – it has since been adapted as an online database by curator Christiane Anderson. The database provides several options for search and sorting data, which are presented in a table with county name, place name, and Voss’ text disambiguating the location, often including township, range, and section information for the locality. It is a resource valued by collection managers, who explained that they refer it when they need to figure out a collecting locality in Michigan.

Like the other databases on this site that emerged from research projects, the Gazetteer provides Herbarium staff the opportunity to share research findings with other researchers and interested members of the public in a way that allows users to explore item by item and make sense of the data. While the *Malpighiaceae* database has an emphasis on “nomenclature and generic relationships” within this plant group (University of Michigan Herbarium 2009), the Mount Kinabalu database catalogs all plant collections from that mountain over time, offering search by family, genus, and species; text-based lists of individual collections, including the herbaria throughout the world that hold them; and type, synonym, and reference search capabilities (University of Michigan Herbarium 2004). Similarly, the Mex@MICH project lists specimens in the Michigan Herbarium that were collected in Mexico, Central America, and the West Indies. It provides the catalog number at Michigan, the taxon, and georeference, locality, and collection information (collector number and date). While the taxon column links to the species name on the website Tropicos (hosted by the Missouri Botanical Garden), many of the links to species on Tropicos are unfortunately dead, suggesting that the Mex@MICH database is in need of updating. The Michigan database does not provide specimen images, but some of them are available in Tropicos, making those links potentially useful to researchers. Despite the wealth of information available in each of these databases, many are clearly not being continuously being updated. The Mex@MICH database, for example, was last updated in 2009.[34]

In contrast, the *Michigan Flora* database, which is prominently placed on the Herbarium's website, features its frequent updating as a selling point in comparison with the printed volumes of *Michigan Flora*. The site's introduction reads, in part:

> Few things in science are more certain than the fact that floristic works become outdated almost as soon as they are printed, and this is certainly true of *Michigan Flora*. The web is, however, ideally suited for presenting such dynamic information. We hope that distributing information through this website will allow us to regularly update our knowledge. (Reznicek et al. 2011b)

The site is regularly updated with occurrence records derived from specimens that have been deposited at herbaria throughout Michigan. Although the database is populated with data from herbarium specimens, it does not provide the records themselves –instead, they are used to produce points on a map of Michigan displaying the plants' localities. Figure 4.25 shows the mapping function available in *Michigan Flora* for the species *Alnus glutinosa.* The system uses specimens to derive occurrence data, but does not provide detailed information for the specimens themselves. The page for this species also provides its common name, several measures related to its habitat and scarcity, a description, and numerous photographs of the living plant.

By putting *Michigan Flora* online, its authors (Herbarium curators and collection managers) have been able to expand the scope of the work, including types of plants not included in the printed edition, interactive maps, and downloadable data about the species

[34] On a return visit to the Herbarium's online databases in November 2013, "Seed Plants and Bryophytes of Mexico, Central America, and the West Indies [Mex@MICH project]" and "Vascular Plants of Mount Kinabalu," were no longer posted.

and their localities within the state (Reznicek et al. 2011b). Public contributions to the flora are welcome, but in order to be included, a herbarium specimen documenting the data point must be made and deposited. The brief instructions for making herbarium specimens given on the website, as well as the Voss article about labeling herbarium specimens, are instructive for learning about the Herbarium's requirements for specimens. While the instructions may be geared more towards an amateur collector audience, rather than a professional one, they clearly describe what the Herbarium looks for in a high-quality specimen (Reznicek et al. 2011a, Voss 1999).

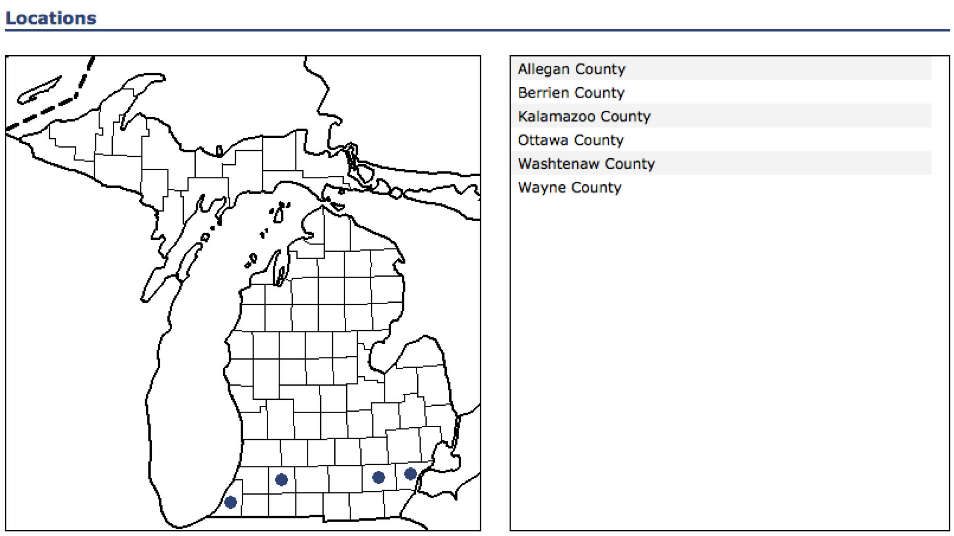


Figure 4.25 Location data for *Alnus glutinosa* from *MICHIGAN FLORA ONLINE*. A. A. Reznicek, E. G. Voss, & B. S. Walters. February 2011. University of Michigan.

Each of these databases delivers representations of herbarium specimens, but only the type database provides images of the specimens themselves. The latter database, hosted by the University of Michigan library, provides users with high quality digital scans of the specimens with the capacity to zoom in to see detail on each plant. The type specimen digitization project is an ongoing, multi-institutional endeavor. For this consortium project, the Michigan Herbarium is one of a few herbaria that have high quality scanners set up to image type specimens from their own herbarium and several others in the region. Staff member HS5, in charge of production for the project, and the students working with her are imaging the specimens and either entering metadata from the specimen sheets into a database or checking the metadata already entered by comparing it with the specimen label. Specimen images and data are sent back to each institution for their own web hosting while also being sent to the Global Plants database hosted by JSTOR.

In the JSTOR product, all type specimens digitized under the international Global Plants Initiative collaboration can be searched and viewed at extremely high resolution by members of subscribing institutions. The JSTOR product also includes a precise measurement tool so that users can perform morphological analyses directly from the images themselves (Patmore 2010). In addition to collaborative scanning and data entry, the Andrew W. Mellon Foundation funded project includes a website for collaborators with tools that support the digitization project including indices of localities and botanists. The latter index supplies biographical information and a handwriting sample for collectors, to help disambiguate between collectors when deciphering specimen labels (Royal Botanic Gardens Kew 2013).

Another major project in which the Herbarium is involved is called Integrated Digitized Biocollections, or iDigBio. Under the National Science Foundation program Advancing Digitization of Biodiversity Collections, iDigBio provides the infrastructure and advises on workflows and standards for participating organizations to use as they digitize and share specimen data. It also provides tools for access and research use of "digitized information about existing, vouchered natural history collections" throughout the United States (Integrated Digitized Biocollections 2013b). Collection managers affiliated with numerous natural history collections add materials to iDigBio through Thematic Collections Networks (TCNs), each of which is "a network of institutions with a strategy for digitizing information that addresses a particular research theme, such as impacts of climate change or biota of a region. Once digitized, data are easily accessed and available for other research and educational use" (Integrated Digitized Biocollections 2013c). Through TCNs and similar grant programs, natural history institutions like the Herbarium have the resources to develop their own local information infrastructure and make substantial progress in digitizing their collections while contributing to the larger research infrastructure for biology. As trends in large-scale data analysis impact funding options for the broader biology community, the participation of herbaria in these projects also benefits botanists.

TCNs are funded by National Science Foundation grants, including the four in which the University of Michigan Herbarium currently participates: 1) "The Macroalgal Herbarium Consortium: Accessing 150 Years of Specimen Data to Understand Changes in the Marine/Aquatic Environment," 2) "The Macrofungi Collection Consortium," 3) "Plants, Herbivores, and Parasitoids: A Model System for the Study of Tri-trophic Associations," and 4) "North American Lichens and Bryophytes - Sensitive Indicators of Environmental Quality and Change" (Integrated Digitized Biocollections 2013c). As an example of the research focus behind these digitization projects, the North American Lichens and Bryophytes TCN states:

> This project will image about 2.3 million North American lichen and bryophyte specimens from more than 60 collections to address questions of how species distributions change after major environmental events, both in the past and projected into the future. Large-scale distribution mapping will help identify regions where such changes are likely, fostering programs designed to protect these organisms. (Integrated Digitized Biocollections 2013a)

As a multi-institution project, iDigBio provides a number of benefits to participating organizations. First, it provides standards for data ingest and description, helping participants to develop and conform their own practices to sector-wide norms. Using the TCN structure, iDigBio funds natural science collections to digitize their materials using thematic guidelines, drawing staff attention to particular parts of the collection. It also allows network participants to assign digitization tasks to various institutions, allocating resources and expertise where they will be most useful. Within the Plants, Herbivores and Parasitoids Thematic Collections Network, staff of the New York Botanical Gardens have installed digitization equipment at other participating herbaria, including Michigan, where the imaging work takes place (Tulig and Watson 2012).

One common theme in this overview of the digital resources available through the Michigan Herbarium is the role of grant funding in digitizing its massive collections. The Herbarium leverages research funding to catalog and/or digitize specimens that help answer a particular research question, whether it involves understanding the flora of Mount Kinabalu in Borneo or the taxonomic relationships between members of the family *Malpighiaceae*. Curators take on leadership of the project, as Principal

Investigators or Collaborating Award PIs, defining the research questions and methods the project will use, while collection managers survey their collections to determine the scope of the digitization project and manage the process, developing digitization guidelines. Projects are consortium based, bringing together specimen data from a number of herbaria that are linked in theme, whether by plant type, geographic region of origin, or type status of the specimen. The projects often stem from ongoing research relationships between specialists in the same plant family or geographic region, leveraging existing relationships between curators and other faculty and extending them to collection managers and project staff. The extent to which that research is continuously ongoing, as is the case with *Michigan Flora* and the type digitization project, is an important factor in whether or not the database will continue to be updated and expanded.

The digitization projects in which the Herbarium has participated are not without their own problems. The development of standards for data interoperability, the difficulties of updating materials over time, and sustainability and ongoing maintenance of resources all come in to play. These issues highlight the central importance of staff members' work practice in the development and maintenance of infrastructure.

Although the development of standards for the representation of botanical collections is a valuable benefit of participation in a data consortium, there are a number of ongoing discussions about the form those standards should take. Collection manager HS3 discussed one simple problem with database representation of botanical specimens: how to treat specimens collected by more than one person in database that only has a "collector" field. He said,

> […]let's say if you have three people that have collected and one number, well, which one of those three people does the number go with? Is it all three of them? Or is it any one of them but not the other two? Because sometimes you'll have a situation where it actually will say on the label like, [collector 1] with, let's say, [collector 2] and [collector 3]. Well, the number is associated strictly with [collector 1]. The other two people are what we call associated collectors. They're there, but they're not associated directly with that number. Now, the question is how do you represent that in a database? When you usually have a collector's field and you may not have any other field to put collectors in, then you're automatically representing the data incorrectly. And I've pointed this out to a couple people and say, "Well, all I've got is a collector and a number field, what

> do I do?" Well, you do it wrong, in that case, because that's not what the label really says. […] Ideally, there'd be an associated collector's field in some way so you could actually put the data on those, what we call other collectors, in there, and that way, you'd clearly identify where the number went.

Attribution is clearly important in this community of practice, so developing a standard for representing multiple collectors in databases is a significant challenge. As this example of multiple collectors suggests, there are still some unanswered questions about the best way to represent botanical collections in databases—questions that must be decided by participants in database consortia.

Indicating the reliability of a determination is another issue HS3 raised in online representation. In this case, the issue is one of conveying an element of botanical expertise: the ability to evaluate the reliability of another person's determination using one's own knowledge of the researchers who have worked with a given plant group. In Van House's study of CalFlora, a botanical digital library, she found "three factors determining an observer's credibility: the skill of the observer, the observer's relationship to that which is observed (e.g., expertise in a particular taxon or geographical area), and his or her certainty in making this particular identification" (Van House 2002b, p. 236). Many of the botanists I interviewed characterized knowing about the expertise of others in their field as part of the disciplinary knowledge that comes with membership in that community. As HS3 argues:

> And you often can look at a specimen, you know whether the guy was a specialist, a well-known collector, or a student, you can just sort of figure it out. But to somebody else looking at our data from the outside, they're not going to know who Joe Blow was, nor will they know how authoritative that determination really is. And that's what... I'd not really thought about that concept until I was at the steering committee meeting for our TCN project. Somebody said, "One of the things we would like to do is figure out a way to tell people how reliable that identification really is." And I thought, "Oh boy, how are you going to figure that one out?"

Because the audience for a TCN extends beyond botanists, a user's ability to recognize other botanists and judge the credibility of their work cannot be assumed. Conveying botanical expertise to non-botanists is a great challenge. Interpretations that botanists might easily make can be opaque to non-botanists, particularly those interpretations that depend on knowledge of individual botanists and their work. HS6 provided a concrete example of how this general knowledge of botanists and herbaria works in his use of herbarium specimens.

> You'll generally know sort of some of the major authorities of families. But sometimes there'll be a person on staff whose job it is to just routinely identify plants, and you might not know who that person is or how reliable those determinations are. So you try to find out and again, assess that. I know I used to work at the Missouri Botanical Garden, which is a larger herbarium, and they have a person there whose job it is to do general determinations. And so, it's a specialist versus a generalist. He's very knowledgeable and he's very good getting things at, say the family level, the genus level. But when it gets down to a species, it's much less reliable because he's just dealing with a lot of volume and he's trying to do the best he can. So when you see that person's name, you always take that with a big grain of salt because you know that it's really good to get it down to genus […] but really narrowing it down, you have to be careful.

The data reuse literature has shown that a data producer's reputed expertise in his or her community of practice is an important factor in the decision to use a data set created by someone else (Zimmerman 2003, 2008; Knorr Cetina 1999; Van House 2002a, 2002b). These quotations concerning the reliability of botanical determinations confirm the findings in that literature, but they paint a more complex picture of reputation. In judging the usability of a specimen, the expertise of the researchers making determinations is in question, not necessarily the expertise of the original specimen collector. A botanist may need to know the reputation of more than one other researcher, depending on the number and variation between determinations attached to a specimen. The TCN "Plants, Herbivores, and Parasitoids" is likely to encounter an even greater challenge of representing researcher credibility because it collects representations of specimens used by botanists, entomologists, and parasitologists. For any of these researchers to successfully use the botanical data, they must have some idea of the reliability of the specimen determinations, but for entomologist and parasitologist users, the name of the person who made the determination is not enough to gauge reliability.

Curator HS6 explained that skepticism in regard to specimen identifications is part of botanical practice:

> Interviewer: Have you, in your use of herbarium specimens, have you questioned their identification?
> HS6: Yes, all the time. I mean, you're trained basically to question it de facto, right? I mean if it's a type specimen and you're confident that it agrees with what

> was published, you take that as the specimen that accompanies the name. And so that's sort of the starting point. But anything else that's been determined, I mean you always have to be skeptical, and re-check, and verify. Because often times these people will have misidentifications. And so one thing we do is that, it depends at what group you're working on, but usually if you're sort of considered an authority on a group or you study that specifically, you'll sort of make an annotation. You'll add your name on a slip, either with the same name or a new name, and then people will tend to believe you or trust you more than say if you put a name on a plant that you don't really know and just pulled a name off the Internet.

Social world norms in botany, as described by HS6 and many of my other interviewees, dictate that annotations to specimens are made by botanists with expertise in that group. Botanists view determinations with a grain of salt, reviewing them to come to their own conclusions about their veracity. While they use the annotator's reputation as a proxy for data quality, reviewing the specimens themselves provides a level of certainty that metadata alone cannot provide.

Representing changes to determinations of a specimen over time is also complicated as herbaria digitize their collections. Once a digital image of a specimen is produced, that static image is frozen in time. Although annotations showing different determinations may be made later, the high cost of imaging specimens and the large volume of specimens herbaria work with make it doubtful that the specimen will be re-imaged to show those new annotations. In fact, simply keeping databases up to date with new determinations can be difficult, as HS3 describes,

> Interviewer: Do you update the database to reflect those changes?
> HS3: Irregularly is probably the best way to say it. For our specimens, we try to. I know that some have slipped through before but the intent is to at least update it to the correct identification. One of the issues that is under discussion in various databasing projects is the idea of determination history and how much of it do you record. And this has been a problem because a lot of times we'll record the most current determination and who did it but not necessarily all of the previous determinations. On some sheets, I could point to some in the back if I had a chance to look for them, they may have five different annotations on them where different specialists have disagreed with each other over what the specimen really is. […] So in theory if you were going for complete data entry you would have four entries under determination history. Some people would say, "Well, why don't you just put down the most recent one and be done with it? And then later if you had time you could go back and capture the rest of the data." Well, in the grand scope of things with the amount of collections that are out there, are we really going to have time to go back to get this stuff? That's somewhat unlikely. If

> you took an image of the sheet or an image of the label area, then you'd have that information if you wanted to go back and catch it. That brings up another point that some people say, "Well, you've imaged the specimens, somebody's now annotated it. The specimen image is now outdated because it doesn't have the most current annotation. Should you go back and re-image that specimen?" Well, if you had a lot of time to deal with these issues the answer could be yes. In most situations the answer is probably going to be no. Which is in a way the problem we've got is we're curating yet another collection within a collection because we've got the physical specimens, now we've got the database and if we have a collection of images, we have another collection. So how can you keep all of them up to date has become a major problem.

The gulf between this vision of complete metadata to be captured and presented to researchers and that which is affordable, given limited staff time, is a large one. Simply updating old records can often fall by the wayside in herbaria, where specimen collections grow to a massive scale, and community norms about updating specimen descriptions and images in shared databases have yet to emerge.

The work involved in updating specimen descriptions is an example of one final issue I would like to raise in relation to databasing projects: sustainability and the maintenance work that must take place to keep digital resources current. Two of the resources linked from the Herbarium's website mentioned above, "Seed Plants and Bryophytes of Mexico, Central America, and the West Indies [Mex@MICH project]" and "Vascular Plants of Mount Kinabalu," are no longer available on the Databases page of the Herbarium's website, as of early November 2013. I learned from collection manager HS3 that a server crash had disabled the databases, and when he and other staff realized that the databases used a version of FileMaker that was no longer being supported, they decided to take them down rather than prioritize migrating the materials. The outdated links and long ago publication dates mentioned above (2009 for the Mex@MICH project) are evidence of overdue maintenance for these databases. This is a widespread problem found in museums, libraries, and archives: "while a specific digitisation grant will certainly include someone in a project management role, once the project is finished, management of the digital resource is not always clear" and management may lapse over time (Maron et al. 2013, p. 44). As Graham and Thrift (2007) argue, the invisibility of maintenance work can render it an overlooked, but still essential, part of infrastructure.

As institutional priorities and resources change, the maintenance of resources generated from specific research projects may fall by the wayside.

4.8.1.1 Sharing Information with Researchers

Because the majority of specimens were not included in any public database, a great deal of information exchange between Herbarium staff and researchers external to the Herbarium took place on an as-requested basis. In these cases, external researchers contacted curators and collection managers and requested certain specimens and related materials. While curators fielded some of these requests, they were generally handed off to collection managers to fulfill. Some requests were rather general, as in this example from collection manager HS3, "If somebody gives us a request, 'Do you have any material from such-and-such a state?' We go out back and find out" by searching through the Range for the species and geographical area in question. Others asked for specimens from a certain collector. In the example below, collection manager HS7 recounted the story of a prominent mycologist associated with the Herbarium whose specimens and associated records, including drawings of the fresh specimens, were frequently requested for study. Most of these requests, she explained, were prompted by researchers' literature search, a common method for both locating and interpreting data, as other studies have shown (Zimmerman 2007; Fear and Donaldson 2012).

> Interviewer: Do those researchers suspect that this auxiliary information might exist because they know that Smith was related to the collection?
> HS7: They know the literature for their group. If Dr. Smith was a... We'll just use him as an example. There were other mycologists, but he is the one that is a source of, I would say, most of the inquiries. They'll ask for particular collections cited by him often or identified by him, and then they ask for any supporting material because things like existence of cards would not appear in the literature. And then I go looking for supporting material.
> Interviewer: Okay. But they generally know to ask for [supporting material]?
> HS7: […] Yes, they would know if they were interested. […Often] they want to borrow [supporting material] in connection with borrowing the specimens, almost a one-on-one. Usually, they want the specimen also.

For these mycologists, drawings and photographs of specimens were useful along with, but did not supplant, the specimens themselves. These auxiliary information sources were generally not cited in the literature, but mycologists knew to ask for them, because they were records commonly kept by members of their scientific community. Norms within this research sub-world influenced the scope of its members' requests to the Herbarium. When requested, HS7 digitized the cards and photographs pertaining to requested specimens and emailed them to the requestor, usually while also preparing a loan of the specimens themselves.

The mycological images discussed by HS7 were an example of records generated in the course of a collector's research that existed in a gray area. Along with field notebooks, spreadsheets and databases, and other written and computer generated records, they may be central to the work of an individual researcher without ever becoming part of a herbarium's collection. When herbaria do take custody of these records, they usually do so quietly, without attaching fanfare to their ownership of the records or adding them to a collection catalog. A researcher must know to ask for these things, as mycologists often will, but people studying vascular plants rarely do. My discussion with HR10, curator at another herbarium, drove this point home.

> Interviewer: Do researchers ever ask to look at field notebooks from collectors?
>
> HR10: Sometimes. Not so often, usually, if it's vascular plant material. But the ones who ask about for those things more are people who are doing mycological studies, so fungi. People who study fungi.

This example points to one of the effects of subworld membership I observed in my data: specialization within a field influences expectations for the availability and use of representations. Mycologists expect that specimen collectors will have made images of the fresh specimen, spore prints, and detailed descriptions, and that herbaria may have these records in their possession. In contrast, botanists studying vascular plants expect that collectors will have included all pertinent information on the specimen label, and while that information was also recorded in a field notebook, the latter documentation is seen as a redundant source rather than a source that might shed new light on a specimen. I discuss researcher expectations for contextual information and representations as a function of the epistemic culture to which they belong in greater detail in the next chapter.

4.8.2 The Kelsey: Electronic Access to the Collection

At the Kelsey, although the entire collection is represented in a public database, the extent of those representations varies. Each record includes an accession number and standard fields like description, site, function, material, source, provenance, bibliographic references, and physical dimensions that are populated with varying levels of detail. As discussed earlier, the database developed internally from legacy paper-based records without reference to any data standard or direct use of the artifacts described in the records. It is updated as needed by collection managers and their assistants, to make changes to the content of individual records. One common gap in record detail stems from small objects accessioned in large groups that were frequently given a single accession number and received a single database entry. As collection manager AS1 explained,

> [W]hen some materials were first excavated, they were just found in groups of stuff. So, there is this one accession number, 5431, which is for this group of glass. Just looking at it, you can tell there's more than one backlog here. We have […] various print fragments, very different colors […] you can just see, the fabric of it is completely different. And there's tons of it. There's a whole bunch of them. What a student did in 1997, she started separating them out and each individual piece started getting its own number.

Making these descriptions more complete was part of the ongoing work of the Kelsey's collection managers. As the above quotation shows, while each object was described in a record, it may not have had its own record, per se.

There was also a great deal of variation in the completeness of records in the object database, which AS1 explained to me was a product of the data entry process.

> It handles a lot of information, the only problem is most of the information is from the accession cards, so a lot of the information is missing. So descriptions [and] sometimes measurements are not there. Still, I think we're trying to get it in there, but it's a lot of data entry. The information exists. It's not all in the database.

From AS1's perspective, database limitations stemmed from the information source, relying on accession cards, rather than directly using the artifacts they represent. Augmenting the information derived from the accession cards was a lengthy process, generally done in a piecemeal fashion, as in his example of a student working with a group of glass fragments. The process to make database records more complete depends on the labor of students and volunteers working directly with artifacts, with collection managers overseeing, rather than directly participating in this process.

The object database was not the sole database related to artifacts at the Kelsey. While the Kelsey Museum Artifacts Database was publicly accessible on the Kelsey's website, two other databases, Michigan Excavation Records (for all records of Karanis and Seleucia excavations) and the Photo Captions database (for captions to photographs in the Kelsey Photographic Archive, excluding fine arts photographs) were mentioned on the site but not linked. For access to these databases, researchers were instructed to contact the collection manager (Kelsey Museum 2011f). AS1 discussed the role of the excavations database in the research process, saying that it is one of the first resources he makes available to external researchers seeking information on excavations.

> I had a grant a couple of years ago. Those excavation ledgers that [you saw earlier], I had several people work on creating a database with nothing but that information. So all the excavation information is now in a database. So, the first step is just to share that with them. If they want more, I can share the excavation ledgers with the same information.

While the content of the Artifacts database duplicated the excavation ledgers, AS1 acknowledged that some researchers might still wish to see the original source, and made that available as needed. Since the electronic resource duplicates the paper-based resource, one might ask why researchers would need access to the original. In the next chapter I address this question through an example of researchers' need for handwritten records at the Kelsey, although database records of the same information were available to them. This will reveal more about how evidence is collected, weighed, and valued in this community of practice.

The Photo Captions resource was similarly derived from a paper-based resource that was transcribed into a database. As AS1 explained,

> I think in general, they came from Swain's photographs. He had journals where he kept this information and those may have been transferred to this and then from this. Whether they came from this cabinet or another cabinet, I don't know but from his notes to these cards, and from the cards to the database.

In other words, the system was based on photographer George Swain's recordkeeping system of notes and cards that described each of his photographs. The photographs primarily documented expeditions and excavations in the Near East with Francis Kelsey and other University of Michigan faculty.

Each of the Kelsey's databases, then, is derived in large part from an extant analog recordkeeping system that came before it: object cards supplied the material for the Artifacts database; the Michigan Excavations Records database came from the ledgers used during the excavations; and the Photo Captions database content came from the indexes created by photographer George Swain. The electronic format makes search, sorting, and information retrieval easy, but it does not remove the occasional need to consult the original record keeping systems from which the databases were derived. AS1's statement, "The information exists. It's not all in the database" highlights the limitations to the databases. They are not necessarily complete in their representations of artifacts and contextual material and their completion is an ongoing project of the museum and its volunteers. The quotation also emphasizes the need for collection managers like AS1 to use their systems-based expertise to guide researchers to various representations in the numerous record keeping systems where they can be found. Because "It's not all in the database," collection managers are an important mediator between the researcher and the contextual information they require. With their systems-based expertise, collection managers "capture the tacit knowledge, the subtlety, and the understanding behind the technology" of the Kelsey's databases, making the organizational knowledge they contain more accessible to users (Argote 1999, p. 90).

4.9 Staff and Social Worlds Revisited

The division of labor used in both museums for the description of objects reflects both functional role assignments and expertise. At both museums, collection managers were responsible for creating and updating database records, developing and using their systems-based expertise. Responsibility for affirming the content of those descriptions belonged with curators, considered the content experts in their areas.

This is not to say that the collection managers at the two museums were outsiders to the research communities they supported. On the contrary, the collection managers had their own expertise within those communities of practice: at the Kelsey, both collection managers were themselves archaeologists, although neither specialized in Near East archaeology. At the Herbarium, one of the collection managers was a plant systematist, specializing in a particular family, while another actively collected specimens for *Michigan Flora*. Only one of the three collection managers (HS7) was not a botanist – she had a background in library science.

Although curators and collection managers had some overlapping areas of expertise, their responsibilities concerning the representation of the collections were clearly divided between creating and maintaining information systems (the work of the collection managers), and generating content about the objects themselves (the responsibility of the curators). HS3 straddled this line, as a collection manager with botanical knowledge and experience that made him an expert in his plant family, a role that I imagine AS1 would also have, if the Kelsey collected objects from the geographic region in which he had conducted research.

HS3 spoke about his work at several points as "curating details," saying, "We sometimes think of 'curating details' around here. As a matter of fact, we think of being overwhelmed with details." However, different sorts of details were managed by collection managers and curators. While collection managers recorded and processed information about the source of the objects in their care, curators provided them with a definitive identification. Collection managers maintained the physical organization of the objects in their care while curators used them to create new knowledge in their field, by producing papers, museum exhibits, and monographs using the museums' collections.

This chapter has addressed the complementary roles and forms of expertise belonging to collection managers and curators in the production of information systems, however, this complementarity extends to other aspects of the museums' work as well. In the process of selecting objects for an exhibit, for instance, AS3, exhibition designer at the Kelsey, said,

> Well, the curators themselves know the collection perfectly. And they know exactly the objects they're looking to use. So, they walk in and just start pulling objects and then we see: do these objects work together? I've got 10 of the same vase or whatever it may be, which one works best for this exhibit? Here are all of them from that time period. Which one works best? Then having conservationists take a look and say, "well, you can't use that one because it's falling apart" or whatever it may be. So, kind of, it's a give and take between all the departments here and me saying, that is the coolest one, that's the one that's gonna capture people's attention.

The systems-based and content-based forms of expertise belonging to collection managers and curators correspond with their roles and professional identities within the two museums. The Kelsey's collection managers had expertise in collection management and archaeology (but not Near East archaeology). The Herbarium's collection managers had botanical expertise that enabled them to make some taxonomic determinations (HS3) and contribute specimens to *Michigan Flora* (HS2), but they were responsible, above all, for maintenance of the specimens and the information systems supporting the collection. The one collection manager I interviewed who claimed not to have content area expertise (HS7) described her job succinctly, in a way that clearly delineates her realm of responsibility,

> [M]y position, I would say for most of the time I've been here, is to know about the collections, to keep in mind issues related to the care of the collections. To know how to operate the database and accession things, but also […] it's my job to worry about the things that the curator should not have to worry about. And there are many things the curator should not have to worry about such as boxes, and that kind of thing.

As a former librarian who began at the Herbarium as a museum technician, ("over some years, HR reviewed the position and all the ways in which my duties had changed, and I was promoted to collections manager"), HS7 saw change on the horizon for the position of collection manager. She said,

> I think the job is changing. I think that someone with my background would not be hired for this job now. I think that now […] there is more and more pressure to combine the support with one more place for someone who is a content specialist. Institutions can't afford to divide these things.

If HS7 is correct, then the subworld memberships of museum staff may become more similar as time progresses, with collection managers needing more research training in the content areas represented in their collections. This may become a source of identity friction for collection managers like HS7 who lack substantial content expertise. However, as the gap in content knowledge decreases between collection managers and curators, the need for expertise in information systems is likely to continue, with expertise in information management as the defining boundary between the two roles.

AS1 also sensed a dichotomy between archeologists and other museum professionals at the Kelsey. He said, "Because this museum has been run by archaeologists, they are interested in the archeology and the museum side of it was left to professionals, which have all been hired recently. We're trying to catch up, to the point that we're trying to make the museum more standard." For AS1, the legacy of archaeologists, rather than museum professionals, in charge of collection management has resulted in a lack of standardization of systems, and it will take a while to catch up. AS1 emphasizes subworld membership as a factor in changing museum practices towards standardization.

At the level of curation, changing subworlds in botany are also influencing the stewardship of collections in herbaria. As HS3 described,

> [A] number of the people that are getting assigned to curate a herbarium may not have had much formal training in it. For example, I know of a couple of colleagues I have where their chief research aspect is molecular, and yet, they're also the curator of the herbarium, and so they don't have a lot of the familiarity with either methodologies or protocols.

While this chapter has argued that curators primarily use content-based expertise in their interactions with objects, HS3 maintains that familiarity with herbarium methods and protocols is also essential for this position. As greater numbers of molecular researchers attain curator positions in herbaria, their lack of training in herbarium methods may create identity frictions for staff members as the practices of different subworlds gain prominence.

Returning to the research question motivating this chapter *What factors influence the practices of staff members as they describe and manage museum data?* the findings I presented here have revealed several major concerns influencing this work. While collection managers in both museums expressed interest in following best practices for representing collections, they were largely reliant on past descriptive forms used at their museum, which showed little variation over time and were frequently copied directly from one information system to the next. Descriptive forms at the Herbarium, however, have long been standards-based, beginning with curators' use of the taxonomic system, which is itself a standardizing tool that has been incorporated into all Herbarium practice from the institution's beginning. The plant family names provided by Engler and Prantl are another standard that has long organized Herbarium practice. While standards-based elements of botanical practice have influenced the Herbarium from its beginning, early record keeping at the Kelsey did not benefit from standards for archaeological data description, as archaeological data standards have been primarily ad hoc, developed for a single excavation or artifact typology, for most of the museum's history.

Staff at both museums depended on collectors to provide adequate metadata about the objects—inadequate metadata lessened the value of collections for research. At both museums, facilitating research using the collections was a goal underlying collection management. In my observation with HS2, data reuse concerns influenced priorities in the accessioning process. At the Kelsey, the construction of separate databases for access to collection documentation indicated the importance of data reuse. Descriptive metadata linked to objects and documentation at the two museums helped make them findable for research use, while continued research use helped the museums develop and change the representations of their objects. Collection managers relied on internal researchers (curators) and external researchers to contribute content-based expertise to the ever-evolving understanding of the museums' collections. They weighed evidence based on the reputation and expertise of researchers, giving more credence to descriptions provided by known experts. At the Herbarium, the annotation system provided a mechanism for multiple interpretations to coexist, while at the Kelsey, the final word on whether or not to accept the interpretation of an artifact rested with the curator.

Within both museums, description is not entirely comprehensive. The Herbarium only has database records for specimens that have been catalogued for a given project. While the type collection database includes imaging of specimens, most of the larger collection lacks database representations entirely. Specimens sit along a continuum ranging from no database representation to full database records that include a high-quality digital scan of the specimen sheet. At the Kelsey, where the catalog is more comprehensive, objects still emerge that do not have their own individual record or were originally misidentified. In many cases, systems-based expertise held by collection managers is essential for learning about objects, in part because of inadequate or incorrect descriptions. For documentation related to museum objects, too, collection managers act as essential intermediaries because supplementary materials are often incorrectly or incompletely identified in databases or inaccessible without staff permission.

Collection description and data management practices impact research by delimiting what researchers are able to understand about museum holdings without direct conferral with staff. While this chapter has explored collection management and representation from the perspective of museum staff members, the following chapter explores the research practices of people using the collections. In this sense, the real research impact of museum practices is seen in the next chapter.

Chapter 5

Research Use of Museum Data

In this chapter, I discuss researchers' use of museum collections, from finding resources to gaining access to them, from selecting specific resources to interpreting them. Each of these steps, I argue, is determined by the researcher's assessment of his or her information need, often expressed as a research question, and often shaped by their position and perceptions within the structure of their professional social world. In this chapter I address my research question *What is the relationship between museum objects, their representations, and research use?* by examining the interactions of researchers with museum data as they seek to fulfill their own goals.

5.1 Researcher Goals

The researchers I spoke with at the two museums had a wide range of research goals and methods. At the Kelsey, researchers would examine an artifact's composition and features to determine its origins and use, compare artifacts created by individuals at various sites to better understand a geographic region (comparanda), and look at excavation documentation to reconstruct the archaeological history of a site. At the Herbarium, research goals included plant systematics, which involved identifying the range of variation in the characteristics of a species and (in some cases) extracting material for genetic analysis, compiling location data to map the distribution of a species, and training the researcher to recognize a species in the field. These varying research goals suggest a range of evidence needed to reach them. Among my study participants, I observed that researchers at both museums used type-based and provenance-based research to explore the collections, a distinction I will first define and then explore in this section.

5.2 Type-based Analysis

I identify one strain of research in both institutions as “type-based.” The word type has specific meanings in both botanical and archaeological communities of practice. In botany, a type is the individual specimen upon which a botanical name has been published and a botanical species has been identified (International Association for Plant Taxonomy 2012, Article 7). Type specimens are routinely deposited in herbaria as a condition of their designation as the type so that future botanists can not only read the description of a species, but can also see the physical evidence of that species, comparing its written description to the physical traits of the type specimen. In archaeology, typologies are classifications of objects that help make artifacts more manageable for analysis. “Typology makes it possible for the archaeologist to order objects into meaningful or developmental series” (Schnapp 2008, p. 403). As Bruce Trigger wrote,

> Archaeologists have […] succeeded in creating a large and growing corpus of data and low-level generalizations about the past that over the years has withstood careful scrutiny. Basic to these generalizations are typologies that have been devised for the classification of archaeological finds. It is generally accepted that these typologies are creations of archaeologists rather than reconstructions of categories that were necessarily significant to the makers or users of the material being studied, although claims for such equivalence are sometimes made. These classifications reflect the interests of individual archaeologists in dating, determining the function, and studying the style of archaeological material. (Trigger 1989 p. 382-3)

A type series is often established for a given excavation, either borrowed or adapted from type series designated by previous authors or determined anew based on materials found at the site.

While the type serves as a standardizing object in both fields, it has a different kind of power in archaeology and botany. In botany, type specimens have a permanent role acknowledged by botanists around the world, connecting specimens to a well-established, widely shared taxonomic structure that organizes relationships between the entire plant kingdom. In archaeology a type series is context specific, serving, for example, as a physical guide to ceramic vessels found at a particular excavation site or within a geographic region. These typologies are flexible, permitting adaptation and evolution as new evidence and interpretations emerge.

When I use the term "type-based" to refer to research using museum objects as data or evidence, I am referring to a comparison of materials in botany and archaeology that categorization makes possible. Comparative analysis is a major part of the evidential cultures of the researchers I interviewed. Archaeologists make comparisons between artifacts to identify similarities and differences and understand relationships between factors like origin, function, material, and iconographic style. Drawn from numerous sources, including museums, websites, and colleagues' photographs, the artifacts and representations that enable these comparisons are referred to as "comparanda." As one art historian succinctly defined, it "Comparanda are materials for comparison, which may come from the same period or the same place, use the same materials, or display the same iconography" (Hagan 2013). At both museums, a number of researchers I spoke with wanted to see all of the *x* at the museum, where *x* is a type of object, for comparative purposes. For example, at the Kelsey archaeological researchers wanted to see all of the decorative marbles collected by the museum over time or all of the ceramic finds from Karanis. At the Herbarium, botanical researchers wanted to see all of the available type specimens from the genus *Euphorbia*. Through visual comparison, researchers study the commonalities between the members of a set of objects to understand the range of variation among a group of artifacts or specimens. They can also determine where a new object belongs in the typology.

Researchers' comparative frameworks using the two types of objects differed greatly in breadth, however. Systematists studying the full range of variation in a genus would use specimens collected around the world, using each as a directly comparable example of that genus. Variation between specimens told them something about the way species adapted to specific ecological circumstances, and the types of variation they saw allowed them to make claims about how a species should be defined. In contrast, the artifacts archaeologists used for comparanda had a much more narrow geographic and temporal range, as researchers made claims about the function of artifacts within a region or settlement. This is due, in part, to the conceptual inseparability of artifacts and their contexts in archaeological practice (Hodder and Hutson 2003). While the contexts of both kinds of museum objects were important to data analysis in these research social worlds, for archaeologists they limited the scope of data used. For botanists, they did not.

These type-based inquiries also determine the scope of objects needed to fully explore a research question. In botany, type specimens are located at herbaria throughout the world. In order to see a wide number of types for a genus, botanists borrow specimens from multiple herbaria or visit herbaria. When available, they view type specimens online. They may also visit collections that have a strong representation of their genus. In contrast, archaeologists must visit the websites or the physical collections of museums with holdings from the specific sites or regions they want to study in order to see all the ceramic finds from Karanis (for example), but they can narrow down the number of museums based on their knowledge of the institutional relationships funding past excavations and where artifacts from those digs were deposited. In both cases, researchers follow indications of where to find the objects they need.

Taxonomist HR13 described her comparative work with specimens borrowed from several herbaria, including Michigan.

> [In] basing my revision of these mahogany plants I worked on about 10,000 specimens, all together. And what I would do was sort them into piles. So, everything I thought was the same, I would put it in a pile. And I would have permission to take some flower material off, boil the top, dissect and describe the flowers. I would also look at everything under the microscope because the microscopic details of the branch hairs on these plants contribute a lot to understanding the species' limitations. I would eventually decide which specimens belonged together as a single species. And there would probably be multiple names amongst those species, on those specimens. In fact, always, partly because things are being misidentified and partly because the same species […] can be named several times through its history.

By comparing the features of these 10,000 specimens, HR13 was able to sort them into groups based on morphological similarity, removing some material (and in that sense, consuming part of the specimen in her analysis) and using microscopic examination to see minute details. She used a basic pile sorting system (made convenient by the standard size of herbarium sheets) to manipulate the specimens themselves into new groupings.

During my observation with researcher HR4, I watched this researcher using type-based analysis as she sorted and attached temporary notations to the specimens with which she worked. As she arranged specimens in piles according to her assessment of the species to which they belonged, HR4 used removable notes to temporarily record the observations that led her to those conclusions. In Figure 5.1, the yellow note on the right side of the specimen depicts HR4's observation that the leaves on this *Euphorbia* specimen are glabrous – smooth and glossy, lacking bristles. By sorting specimens into piles and temporarily labeling them with her assessments, HR4 was able to easily move them into new categorizations while attaching her sorting criteria to the specimens themselves.

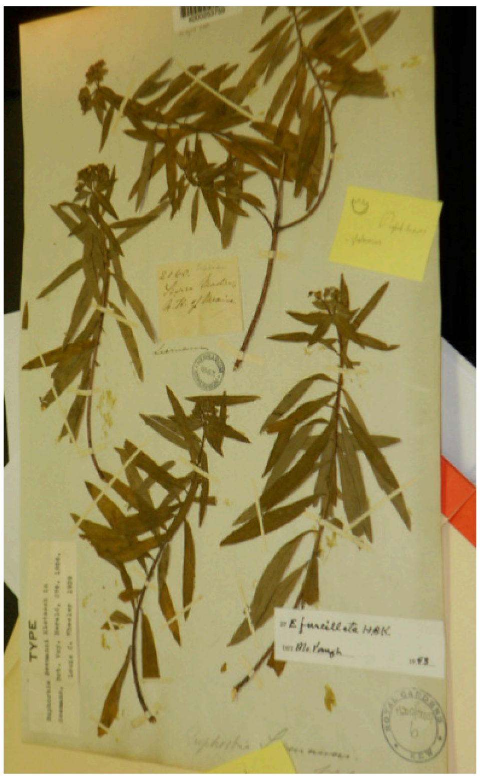


Figure 5.1 *Euphorbia furcillata Kunth* Karl Kunth, Mexico: Sierra Madre, Seemann 2160 (K)

In contrast, archaeologists using type-based analysis only had physical access to one museum's collection at a time, if at all. In addition, a number of archaeologists used publications and museum websites to compile comparanda. AR13, a doctoral student at Michigan, described how she located comparanda in her research about a particular Etruscan mirror in the Kelsey's collection for the purposes of an assigned paper.

> For [the Etruscan class], I worked with a mirror that's on display up there. So, I couldn't take it off display, to really turn it around and look at it. But I did what looking I could, and then did research on comparanda. […] It's the mirror, if you go up there, it's the one where there is a nude winged woman and […] she looks like she's holding a little thing in her hand. So I was doing research on what the

little thing could be. Are there objects that are very similar to this? Do we see this in other places too? And maybe I can make some guesses as to what it could be. […]

Interviewer: How did you search for comparanda?

AR13: […] It's a lot of stumbling. I'm sure that people who come up in art history have methods. I didn't. I had one art history class in undergrad, so this is all still kind of new to me. But, luckily for classicists, there are lots of published catalogs and things. […] There's a whole corpus of Etruscan mirrors, volume after volume after volume. And so, I just flipped through until I figured out that this... I mean, I knew nothing to begin with. Nothing. So, I see that, okay there are lots of mirrors with naked ladies with wings. So now, can I find some that are doing this with their hand and holding a little thing in it? And then I try to find more and more, and more, specific comparanda. Then, once I kind of know what I'm working with, and maybe by then I've stumbled onto an article that talks about it. Then I look in other media and see. So I found, in addition to mirrors, I found a teeny little figurine of a woman holding an egg in her hand and some tomb paintings of men holding eggs at funerary banquets. So yeah, I try to see if there's a big catalog, if somebody can save me the work of going through just everything. But sometimes you have to simply fish around.

AR13's strategy was to find increasingly narrow categories that matched the mirror she was researching. She immediately limited her search to objects of Etruscan origin, searching through published catalogs (presenting artifacts according to the typologies that had been developed by those authors) to see the range of iconography in mirrors. After limiting her search to images of mirrors bearing winged nude female figures, and seeing the scope of iconography in those objects, she broadened her search to Etruscan iconography of people holding objects, including figurines and tomb paintings. By finding similar iconography in those groups of objects, she was able to surmise that the mirror was an example of two types of Etruscan objects: mirrors with female winged nudes and images of people holding eggs. One noteworthy aspect of this description of searching for and using comparanda relates to AR13's social world affiliation as a classicist, rather than an art historian. Because she did not "come up" in art history, AR13 felt she was at a disadvantage using comparanda, not having been trained in the methods of that discipline. This example shows a researcher's identity frictions influencing her interactions with museum data in terms of the methods she is comfortable using (as AR13's perception of "stumbling" illustrates).

The classification systems that botanists and archaeologists use in type-based analysis function differently as standards in those social worlds. The type specimen is a discipline-wide standard, recognized by all botanists. The type specimen permanently attaches the publication in which it was cited to the artifact itself, and it is referred to in all future discussions of a species. As the physical evidence used to propose an alteration to the taxonomic structure of a genus, the type specimen is therefore intertwined with the larger classificatory system mapping all plant species. In archaeology, in contrast, type series exist as temporal and geographically bound classification systems. They define a single specialist or team's classification of the ways in which objects from an archaeological site or region in a specific era should be grouped and interpreted. As Bowker and Star note, "Classification systems may or may not become standardized. If they do not, they are ad hoc, limited to an individual or a local community, and/or of limited duration" (Bowker and Star 1999, p.15). Archaeological classifications of objects are ad hoc in the sense that they are created, modified, or adapted to meet the needs of a research project, serving as systems for understanding a group of artifacts and helping archaeologists to create inscriptions of their data. Archaeologists can choose to use typologies formed by their predecessors or develop their own, indicating both greater interpretive autonomy and a lesser degree of social cohesion that standardization can provide.

5.3 Provenance-based Analysis

The second strain of research I observed can be called "provenance-based." In these cases, the source of the object was the central concern of the research. Provenance metadata played an important role in the evidential cultures of the botanists and archaeologists I interviewed. For botanists, the most important part of the provenance of a specimen is when and where it was collected. Botanists record specimen metadata including collection date, location, and collector name in field notebooks and on the labels they submit along with their specimens for herbarium deposit. They may also use field notebooks to record additional context about the provenance of a specimen, such as geographic elevation and adjacent plants and wildlife. With this vital metadata, botanists and biodiversity researchers can make claims about changes to the habitat of a species over time and analyze how a species has adapted to its environment.

Provenance of archaeological resources refers to documentation of the artifact's source, whether that includes the paperwork that accompanied an artifact given to the museum or the voluminous records of an excavation, helping researchers pinpoint the origin of an artifact to a specific find spot within a site. In archaeology, the term *provenience* refers to "the specific geographic or spatial location (either in two-dimensional or three-dimensional space) where an object was found" (Childs and Corcoran 2000). Specific provenience metadata can allow archaeologists to interpret sites based on the proximity of objects to each other. Artifacts found in the same stratigraphic layer within a room can assist in dating as well as reveal how that room was used at a given time, for example. All artifacts in the Kelsey have provenance metadata describing their origins, but only those from excavations also have a provenience. The reliability and comprehensibility of origin, source, and location metadata is of central importance to botanists and archaeologists, as this chapter will show.

AR8, a researcher working on her dissertation on domestic religion in the Roman East, used find spot information to determine whether or not objects found at domestic sites had religious uses. She used an object list compiled by excavators to determine the physical relationships between excavated objects to make inferences about their use.

> […] I got from [collection manager AS1] a master object list that basically was listing every single object that was found at the site, and what year it was found and the specific place that it was found. So from there I could determine some things were found on the street, some things were found in a specific room of a house. So I could see what other things were found in that same room with that particular object and determine if there's, for instance, at least three objects like an incense burner, a small idol type thing and maybe like another figurine or something like that. Then I can kind of assume that maybe there was some cultic activity that occurred in that particular room.

For AR8, imprecise location data would mean that she could not infer relationships among objects, reducing their usefulness in her research.

Accurate location data was also an important piece of provenance metadata required by the botanists using herbarium specimens. HR1 explained that his distribution modeling work used only the species identification and location metadata from specimens. Translating location metadata into GPS coordinates and comparing them with other data sources in his biodiversity model allowed HR1 to derive details about a plant's habitat without necessarily referring to the specimen itself.

> Other data on the label come out by the way, like with the Geographic Information System, 'cause elevation, once you put a point on the map, it has an elevation. So that's kind of implicitly included. Habitat type, I mean there are [GIS] layers that you can get of the United Sates that have habitat types and then maybe coarser scale resolution of what you have on the label.
>
> But for my purposes that type of thing would be good enough such that I won't have to put habitat type for all of these into my dataset. And other things like about co-occurring species, I mean that just kind of comes out when you map things and you see that they have points close to one another. I mean a lot of the data on the labels is actually included […]

For this researcher, GIS technology has made much of the metadata on labels unnecessary. Using GIS layers from other sources, he can make inferences about co-occurring species and plant habitat that may or may not have been recorded on the specimen label. As a standardized way of describing a location, GIS allows the researcher to combine multiple datasets to learn more about a group of specimens by associating them with the places where they were found. Having an accurate and precise location, then, was the most essential metadata for his analysis.

These provenance-based inquiries highlight the need for metadata about how data were derived in order to use them for research. The importance of provenance metadata in the data reuse process has been identified by several earlier studies, which have asserted that the necessary elements of provenance metadata vary between disciplinary social worlds, according to the community's norms (Carlson and Anderson 2007; Fear and Donaldson 2012). These studies will be discussed in greater depth later in this chapter as I discuss researchers' evaluation of provenance metadata, comparing those findings to the data reuse literature.

Although research inquiries at the two museums can be based primarily on either type or provenance, the categories are not mutually exclusive. Many researchers required both kinds of information in order to complete their work. AR11, a doctoral student at the University of Michigan, described her use of comparanda in a research project culminating in an exhibition of funerary statues at the museum. Because she was concerned about the presence of fakes in her set of funerary statues, knowing the provenance of an artifact was important in determining which artifacts to select for comparison. Artifacts with a clear find spot would be most valuable in her analysis.

> I looked at the comparanda from other collections in other museums, the Louvre and the British Museum, especially. And then some other smaller, small-scale collections.
>
> Interviewer: And were those mostly in published catalogs or online?
> AR11: Both, both of those two forms.
>
> Interviewer: Okay. And so, in using comparanda, were you comparing the features of the figurines? Could you tell me about that?
>
> AR11: Sure. Well, unfortunately, to a large extent there's no findspot for a lot of these. They've been robbed, from the tombs they've been robbed over the course of centuries. And so they're on the market and so the museums, in many cases, don't have any background information up to a certain point. So, it is necessary to rely on, yeah, just comparing what the figurines actually look like with then, in some cases, where there is a provenance and provenience for them. But mostly it is stylistic or looking at other elements of this form.

While the categories *type-based* and *provenance-based* research shed light on some of the concerns driving researchers' use of museum collections, knowing how an object might be categorized and its origins were both important considerations for researchers. Researcher use of collections often emphasized one of these dimensions over the other, but both were important in addressing research needs.

5.4 Finding Data

Among my participants, I found a strong relationship between research question and data source: researchers without prior affiliation to the museums largely targeted their search to museums with strong collections in their area of interest. They learned about collection strengths through sources including literature search, recommendations from mentors, and databases. In this section, I discuss these methods for finding data and the ways in which they were used by botanists and archaeologists. The section ends with an analysis of the role of institutional reputation in the search process, a factor that incorporates collection strengths, but also relates to professional knowledge and the reputation of individual collectors associated with a museum.

5.4.1 Finding Data: Museum Collecting Strengths

Researchers' selection of the Kelsey or the Herbarium was a foregone conclusion in some cases. One archaeologist (AR1) was working with the ongoing excavation of a site that had, in the past, been excavated by a team from the University of Michigan. She knew that the Kelsey had the largest collection of finds from that site and that she had no better options for seeing the most physically complete terracotta figures to have been removed from it than by visiting the museum. She wanted to compare past ceramic finds at the site with the more fragmentary pieces that her team was unearthing, in order to link fragments to the correct iconographic styles. Broadening her comparison to other archaeological sites in the region was not a viable option. As she told me, "I see publications from other sites [in this region] and it seems like these are very regional styles, sometimes maybe even site-specific styles." Because she wanted to see material from this particular site, to perform type-based analysis on artifacts selected on the basis of provenance, the Kelsey was an obvious choice.

Likewise, botanical researchers had knowledge of the collecting strength of various herbaria with regards to the genus they studied. Below, HR3, a postdoctoral researcher at Michigan, explained his choice to visit the herbarium at Kew Gardens in London based on the quantity of specimens in their collection from the genus he studies, *Euphorbia*.

> They've got probably the best collection of *Euphorbia* anywhere. Because they've had so many... They've been there so long and so many people basically sending them stuff from all kinds of different parts of the world. So their […] new world collections in general are okay, not the best. Missouri Botanical Garden here would be a better source for that. But as far as Africa and Asia, Middle East, they have a wonderful collection.

Because HR3 was interested in the morphological variation among *Euphorbia* specimens, the Kew Gardens herbarium was an obvious choice. Research interests led AR1, HR3, and other researchers to seek out the collections with the greatest number of objects that would address their research questions.

5.4.2 Finding Data: Literature

While researchers external to the museums largely opted to use materials at the Herbarium and the Kelsey based on their knowledge of collection strengths, I wanted to know how they learned about the strengths of the museums. Both archaeologists and botanists used a small range of sources to locate the museum data for their research including literature search, recommendations from professional contacts, and database searching. Literature search was one of the most common methods employed, echoing findings from earlier studies (Zimmerman 2007; Faniel and Jacobsen 2010), but ways of using literature to locate data sources varied between the two fields. My archaeologist informants used dissertations, site reports, published catalogs of groups of objects from the Kelsey's collection, monographs, and published articles both to gain inspiration for research projects and to learn where relevant artifacts were held. As AR14, a student working on his master's thesis, told me:

> I learned about materials at the Kelsey when I was looking for a subject for my master thesis. […] And I found a note about Terenouthis in one of the books I read. It was... If I remember well, Bowman's *Egypt After the Pharaohs*, and that was just a short note about that stelae but it interested me because I think it's a good example of how different elements from Egyptian and Greek-Roman Hellenistic culture were connected. […] In this book, they have an illustration, a photograph of one of the stelae and there's a note that is from the Kelsey Museum. And the rest I was able to find by myself.

In this case, a book discussing Egyptian archaeology lead the student to approach the Kelsey with questions regarding their stelae, a request that launched his correspondence with collection manager AS1 and eventually turned into a research visit.

For researchers looking specifically for materials excavated at one site, published excavation reports were an important source. AR10, a professor of art history specializing in the ancient world, was specifically interested in examining figurines excavated at Seleucia, where the University of Michigan excavated over a ten-year period. Her initial knowledge of these figurines came from a report of finds called *Figurines from Seleucia*, published in 1939.

> I've looked at that catalog hundreds of times [...] I actually own it. I just decided to buy it so that I would have it. But yes, I looked in advance, looked through and figured out which figurines that I really wanted to make sure that I saw when I

> came in June so that I would able to get the right photographs for my publication. […] And then I emailed [collection manger AS1] the object numbers from the catalog and what I wanted to see, and brought the list with me as well. And then he's the one who pulled them up in the museum's catalog, and he printed out pages that showed what other information that they had on them, and then it told him where, in what drawer in the museum basement to go find it at.

For AR10, the catalog she used was central to the process of finding and selecting objects. Based on that publication (and therefore on an earlier researcher's selection and representation of objects), she chose the artifacts she would examine during her onsite visit.

Botanists used the professional literature in their field to learn about collections in several ways. First, they used specimen citations in the literature to learn which herbaria held which collections. Botanists cite the herbarium specimens they examine during their research visits using a clear format including standardized elements, such as the herbarium code and specimen number, which help other researchers understand and find materials. For instance, a recent paper in the *American Journal of Botany* concludes with an appendix titled "Voucher and GenBank accession numbers for plant materials used in this study." After giving the citation format "*Taxon*, Collection locality, Collection number (herbarium), GenBank accession" it provides a list of specimens used in the study, including several from Michigan, such as "*Euphorbia abramsiana* L.C.Wheeler, Mexico: Sonora, T. Van Devender 2006-644 (MICH), HQ645217, HQ650889, HQ645369, HQ645523, HQ645673" (Yang & Berry 2011). In this example the taxon is identified with its author's name (L.C. Wheeler, who first described the species), the location is given as "Mexico: Sonora," and the collector is identified as T. Van Devender, who collected the specimen in 2006, gave it the collector number 2006-644, and deposited it at MICH. The HQ numbers each correspond to an entry in GenBank, providing the results of the sequencing the paper's authors did with the specimens. These citations allow botanists to understand which specimens were used in a study and to find specimens that may be helpful in their own work.

Botanical researchers often mentioned using the literature to find specimens. When I asked UK based taxonomist HR13 how she first gained access to the collection at the Michigan Herbarium, she explained that she began with a list of type specimens she wanted to see, generated through a literature search.

> You do quite a lot of bibliographical searching, you look for the original publication of any name attached to the plant you're working on. And then you look at the original publication, and the description will cite specimens. And then these days, there's quite precise rules about how you cite specimens and what you treat as the single specimen that is attached to your name [...] The historical collections are much, much less precisely attached to specimens in particular herbaria, but they usually cite a collector […] and by some detective work, you can usually work out where the author was either working or whose collections he was using, because the other thing that herbaria do is lend specimens to each other. Also, with collections when they are first collected, they are obviously in one place, either with the collector or they get sent to a specialist before they are distributed because they're quite often collected in duplicate. So, what would have happened is that I, somehow or other, probably by sending around a list of the types I was looking for, the collections manager would have gone and found that after the list I sent around, certain specimens were in the Michigan Herbarium. And I had those on loan before I ever visited the Herbarium.

As HR13 notes, the citation record for older collections is not as reliable as it is today, and so botanists engage in a good deal of detective work to track down older specimens. Her story also illustrates the second way in which botanists use literature to connect to collections: to find the names of botanists who worked in their area of interest and determine which herbarium was most likely to hold specimens from that collector based on that person's institutional affiliation.

The role of literature search in helping researchers find and make sense of datasets has been explored by a number of authors studying data reuse. In Zimmerman's (2007) paper on ecologists' data reuse, her participants used bibliographic databases to locate papers that might themselves contain useful data, particularly for meta-analysis of multiple studies. Earthquake engineers similarly use their discipline's literature to locate data sources (Faniel and Jacobsen 2010). The participants in the present study also used their field's literature to locate objects they might use for their own research. Botanists using type collections had a known-item search in mind when they looked for type specimens of a given species and the standardized method for citing specimens in the botanical literature made this work easier. Similarly, archaeologists with provenance-based research questions studying a particular site that had been excavated by the University of Michigan could quickly narrow their search using reports from the excavation, often published by the Kelsey Museum. The archaeological literature also served as inspiration, particularly for novices, as described above by graduate student AR14. As he said, "it interested me because I think it's a good example of how different elements from Egyptian and Greek-Roman Hellenistic culture were connected." Accessing the literature of their discipline helped newcomers like AR14 understand the evidential practices of their research social world.

5.4.3 Finding Data: Mentors and Colleagues

Mentors and colleagues were a major source of introduction to collections at both museums. This was the case for both beginning researchers (students) and more experienced researchers who relied on social networks, some of which were long-established. Student researchers often learned of collections through professors, central role models in the acculturation of students to a research social world (Anderson and Louis 1994). AR8, a doctoral student working on her dissertation, described her professor's influence on her choice of research topic.

> Well, I had learned about the site of Karanis while doing some graduate course work basically, because one of my professors specializes in Copt Egypt: that usually involves Roman Egypt as well, and had learned about that site […] So when I was just kind of looking to get some ideas for where I'd want to work, I just kind of checked out some of the basic publications on Karanis and felt that there was enough there for me to possibly continue with.

Once she decided that she wanted to use the Karanis collections at Michigan in her research, AR8 had to gain access to them by introducing herself to staff members. Her academic advisor helped make that connection.

> In the case of Michigan, I had my adviser actually reach out to the director of the museum first to send out a feeler basically to make sure that this material was not being worked on by someone else: if it was possible that I would be able to work on it. She then said yes, and from there I contacted [curator AS4] who she recommended I contact as he's in charge of the Egypt stuff. He, in turn, referred me to [collection manager AS1], basically.

This vignette from AR8 shows the value of personal networks in introducing researchers to resources, both in terms of finding research topics and in gaining access to collections. With help from faculty in her department, AR8 learned about the Kelsey's materials and gained access to them through the museum's hierarchy.

Personal connections were an important resource for both beginning and more experienced researchers, although they tended to use them differently. While newer researchers, such as AR8, talked about gaining exposure to collections through their mentors, more experienced researchers mentioned career-long affiliations with museums whose collections they continue to use in their work. When I asked about other museum collections they had used in their research, several more experienced researchers mentioned the relationships they had had with various collecting institutions throughout their careers. AS4, a curator at the Kelsey, described the collections he has used in his research in terms of affiliations and professional connections.

> Interviewer: So you mentioned that you use materials at the Kelsey for your own research but there are materials in other places that you use as well. Could you tell me about the range of resources that you use?
>
> AS4: I was at [a Midwest university] as a graduate student and so all of my early museum research was based on material in the [university's archaeology museum's] collection and my dissertation is based on material from that collection, from excavation records and things there. So it's still... It's a body of material I know really well and I still go back to it from time to time. And I've had professional connections with various museums in the UK and The Netherlands, museums elsewhere in the United States where people would ask me to come and look at things or where I've gotten involved in projects, and I also do a certain amount of work on material in the papyrology collection over in the [University of Michigan] Graduate Library.

In AS4's statement we see a seasoned researcher returning to collections he knows well, which he has gotten to know either through his graduate training and research or through consultations he has done over the course of his career. His research choices are largely guided by social ties, forged through collaboration. Doctoral students affiliated with the Kelsey are making the same sorts of ties with that museum in the course of their work, by working with curators, researching artifacts, and contributing to exhibitions, that may also become resources they return to throughout their careers. The tendency to return throughout a researcher's career to people, museums, and artifacts with which the researcher has already forged connections is an important dimension of this social world, illustrating the close relationship between ties formed through practice and selection of resources.

UK taxonomist HR13 described a long working relationship with several researchers at the University of Michigan Herbarium that she first established through a former director of the New York Botanical Garden who had "been there for 25 years, so he has a very good network of contacts in the United States […] He put me in contact with them." For this researcher, too, social ties developed early in her career have influenced her selection of resources. HR13 sees herbaria as an open community, saying

> [T]he thing about herbaria is it's a wonderful international network. We have a dictionary of herbaria called "Index Herbariorum" and bona fide researchers can nearly always, just from Index Herbariorum, get the details of a contact, a director or collections manager, and especially, if you are already attached to a herbarium somewhere else, as I always have been, just contact them and ask to come as a visitor, and as long as they know they can trust you not to damage anything because, of course, these are very fragile specimens, then it's usually possible to reach and go to places where you have no personal direct contact.

In this statement HR13 talks about the ease of making contact with institutions for researchers who are "bona fide" and "attached to a herbarium." This conceptualization of professional stature, particularly institutional affiliation, was mentioned again and again by botanists, both researchers and staff.

In contrast with HR13's international characterization of the botanical network, HR6, a master's student in plant biology at a nearby university, came to the Herbarium with his research advisor, the Principal Investigator (PI) on the research project they were doing together. While the PI was at the Herbarium for a meeting, HR6 was able to use the Herbarium's specimens to gather occurrence metadata for the species he would be collecting for their project, as well as gain greater familiarity with the species.

> Interviewer: How did you arrange the trip to the University of Michigan Herbarium?
>
> HR6: My PI was going there to meet with somebody in the Herbarium. So we met the day before and we realized "Oh! We need to get this collecting trip underway pronto, you can come with me to the U of M Herbarium and we can get sample data there." **[…]** So it was kind of a spur of the moment thing, but I didn't arrange it.
>
> Interviewer: Okay. So you were able to just come along then. When you got to the Herbarium, what happened, did you just kind of get shown where the plants were that would be interesting to you?
> HR6: [The PI] knows people. […] He has friends there […] It was really cool to meet [curator HS1]. He's kind of a *Carex* celebrity. […] We went in there and got

> the specimens out […] wrote the stuff down as fast as we could. I think we probably only spent three and a half hours there, something like that. […] I wrote down virtually everything off the label that I could.

These examples show the importance of social relationships in accessing museum research infrastructure, where in the case of newer researchers, more experienced mentors were key to finding and gaining access to collections. While newer researchers were beginning to forge relationships that would help them navigate the research infrastructure, more advanced researchers were taking advantage of relationships they had already formed, bringing new researchers into those relationships and using bonds formed with museum staff to gain continuing access to collections for their research. The social worlds of botany and archaeology encourage researchers to form and maintain affiliations with museums: botanists should have a herbarium affiliation in order to be "bona fide" (as HR13 expressed) and in order to borrow specimens; archaeologists return to museum collections they made use of in graduate school over the course of their careers (as described by AS4). The associations researchers make with museums early on in their careers have a lasting impact on their selection of collections in research.

Faniel et al. refer to *human scaffolding* to describe the social resources used by novice social scientists to locate and understand data. These novices learn from "the community as represented in the literature and interactions with faculty advisors" in the process of data reuse (Faniel et al. 2013c, p.8). The concept of human scaffolding is useful for understanding the role that faculty advisors play in introducing novice archaeologists and botanists to their research communities as well. Through growing participation in research projects with more advanced researchers in their field, novices are introduced to and "learn how to interact" with outside organizations and individuals (Birnholtz and Bietz 2003, p.6). My data extend this concept of human scaffolding to show that the relationships built early in a career in archaeology or botany often remain with the researcher throughout their career, guiding their future research agendas, and consequently their selection and use of resources.

In addition to directing them to useful resources, researchers' relationships with institutions and senior researchers were critical to help them gain access to museum collections. Because specimens are loaned to herbaria and not to individual researchers, herbarium affiliation is a necessary precondition for a botanist wishing to borrow specimens, embedding the requirement for institutional affiliation into research practice. Obtaining other forms of access to museum staff, objects, and representations also came through relationships with institutions and more established researchers. AR8 was introduced at the Kelsey through her advisor, who reached out to the museum director, who forwarded the request to the relevant curator for approval, who then forwarded the request to a collection manager to respond substantively to the request itself. By coming to the Herbarium with his advisor, HR6 was able to meet curatorial staff with expertise in the plant family he studies and spend several hours taking notes from specimens. Whether or not these introductions from senior researchers are in fact *required* for onsite access to collections, they are sufficiently widespread to indicate conservatism in both research communities regarding who may gain access to museum collections.

5.4.4 Finding Data: Databases

Using databases to find research data was a different experience at the Herbarium and Kelsey, in part because of the different kinds of databases available at the two sites. While the Herbarium has databases available for type specimens and *Michigan Flora* materials, participation in data consortia means that researchers may access data without retrieving them from a database hosted directly by the Herbarium. In contrast, the Kelsey's online collection data is more comprehensive in coverage, but available only through the museum and the University of Michigan library system. The convenience of data consortia in locating specimen metadata was evident in the following passage from HR14, a curator at another university herbarium in the United States, as he discussed his institution's participation in a consortium database representing specimens of fungi.

> You go into a single location, a portal entry, and you type in whatever genus of species you are interested in. And that does it. From that database, you can pull out all the collections for that genus of species that exist in the herbaria for a particular area or a single herbarium if you want to just do one. But what you can do now is you can [...] Instead of traveling to a herbarium like we used to do- I used to go to Ann Arbor all the time to pull the specimens out. Now, all that I have to do is look at one of these databases and pick out the ones I want, contact the person in Michigan, and have them shipped. So, that's how it's done now. So, it's really now a much more open, totally accessible system and it's becoming

> more and more so, where people are just gonna be able to sit on their computer to look for things that they want to study. (HR14)

The ease of this process, where botanists can identify the specimens they would like to see online, then make a loan request, has clearly changed the research process for the better, in this curator's opinion. Notable, too, is the fact that he accesses Michigan data through consortia rather than through the Herbarium website databases. Because most herbaria have only a small portion of their collections represented in online databases, however, this access method may lead to greater reliance on the fraction of specimen collections that have been digitized or databased as researchers identify specimens to request for loan.

Given the completeness of the online catalog at the Kelsey, I was surprised to learn that it did not provide a starting point for any of the researchers I interviewed. While many used the catalog at some point in their research process to gather metadata about artifacts, they first became aware of the collections either through publications, referrals from other researchers, or because of their own pre-existing affiliation with the museum. For researchers outside the University of Michigan (10 of the 15 interviewees), the content lead them to the museum and not the other way around. After learning of useful artifacts within the collection from publications or colleagues, external researchers contacted a collection manager or curator (the latter group invariably forwarded the request to the collection managers) for more information. At this point collection managers sent them data from the catalog, photographic database, and other internal representations to give them a much more complete context for artifacts in the collection than the public online catalog provides.

For researchers outside the university, the collections themselves determined their interest in the Kelsey, and since the museum does not participate in database consortia, it is not, after all, surprising that a database was not the original source guiding them to the collection. Researchers at Michigan had a greater incentive to use the Kelsey in particular, since their institutional affiliation and geographic proximity afforded them greater ease in accessing the artifacts, relevant recordkeeping systems, and staff members' expertise.

The Herbarium's data consortium participation relies on several factors related to the botanical social world itself. First, botanists' propensity to share data is essential. From the practice of collecting multiple specimens of a single species to distribute to colleagues and herbaria through exchange, to procedures for loans between herbaria, a culture of data sharing has long been in place. Lines of inquiry that require access to massive data sets, like climate change studies, have emerged, providing justification and need for investment in data consortia. As with the natural science collections supporting numerous other biological sciences, funding programs to create digital collections of botanical specimens held at herbaria have seen a proliferation in recent years, bringing with them both resources and incentives to participate in data consortia (e.g. Integrated Digitized Biocollections 2013c). In addition, the adoption of data standards like Darwin Core and the development of additional fields in Darwin Core specific to plant collections reflect work by teams of herbarium staff at numerous institutions who are actively addressing the question of best practices for data sharing in their community (Rabeler and Macklin 2006).

5.4.5 Finding Data: Organizational and Individual Reputation

One final factor in finding data deserves mention here, because it was a recurring issue in botanical researcher and staff interviews: researchers' professional experience gave them an awareness of the Herbarium's reputation, closely tied to the reputations of individual researchers, which provided them with a general understanding of the collections available. When I asked HS7, the collection manager working with fungus specimens, how researchers find out specimens of interest, she mentioned two factors related to the organization: the legacy of researchers formerly affiliated with the Herbarium and the stature of the Herbarium itself in the botanical community.

> I have had a definite sense that at times, because of what was collected, that the database was consulted because material, specimens in general, worked on by [a well known mycologist affiliated with the Herbarium] but not necessarily cited in the publications by [him], were among those collected. And other times, I think, the requests come from the literature and there are times when people contact me and sort of ask me to go on a fishing expedition, "what might you have?" And there is interest even in groups that [the mycologist] did not publish upon simply because it's known that our holdings are extensive and formed by some other

good mycologists other than [him]. And also being a big institution, we have participated in the acquiring of reference collections called exsiccatae and as circumstances of having researchers deposit here who do not have their own herbaria to put material in, people who are interested sometimes contact us to say, "This is what I'm working on, do you have anything?" And sometimes we have to tell them no and sometimes we have unusual things. There was […] material from the Caribbean [collected by another U-M affiliated mycologist], and that's not in our database yet but we thought, "We'll give it a try." And this was an Irish researcher, and we ended up having six or eight of his collections to send him in the group that he was interested in and he was very glad to get them. […] So having had a lot of people prominent in their fields on staff here, being big, we in a sense have kind of gathered things to us and people do look upon us as a resource.

Collector and annotator name recognition was an important factor for a number of researchers, as illustrated in the section below related to annotations and selection criteria, but institution size also figured into researcher decisions about where to request loans, as HR5, a research scientist affiliated with a large herbarium, told me.

And I don't try borrowing from... You know, I don't know how many herbaria you can try to borrow from in the US you know, dozens. It's just not financially feasible or, you know, the time involved wouldn't be worth it. So, I tend to stick with the major places and work with their collections, unless there's some reason to look somewhere else.
Interviewer: […] What might that reason be?
HR5: Well, let's say if […] there was a collector who worked in say, Honduras or Nicaragua, and he worked at say, you know I don't know, University of Oregon or someplace like that, someplace you wouldn't normally go look, but […] if he did a lot of collecting, he may have material that nobody else would have.

For HR5, then, looking for material from larger herbaria was a pragmatic decision. Unless he was seeking collections from a researcher affiliated with a smaller herbarium, he generally would not approach one of those institutions with a loan request. Those cases did provide important exceptions, though. Smaller herbaria with specialized collections in a particular genus or region might "have material that nobody else would have" making research in that area more fruitful at a smaller institution.

These findings support other research that has identified reputation as a major factor in the decision to reuse data. In botany, specifically, Van House found that researchers' assessments of "the skill of the observer, the observer's relationship to that which is observed (e.g., expertise in a particular taxon or geographical area), and his or her certainty in making this particular identification" were important criteria guiding their selection of data for reuse (Van House 2002b, p. 236). HR5 and HS7 both associate a collector's experience in a particular geographic area and plant group with the selection of herbaria to approach for loans. Similar conclusions about the relationship between reputation and data selection have been reached in studies of ecologists (Zimmerman 2008) and novice social scientists (Faniel et al. 2013), whose knowledge of a data producer's expertise and experience influenced their evaluation of datasets.

Researchers have also examined the role of institutional reputation in the data reuse process. The reputation of an institution providing data for reuse was an important factor among environmental planners, who questioned the motivations behind some agencies' presentations of data (Van House et al. 1998). Yakel et al. (2013) studied the factors associated with trust in data repositories among zoologists, social scientists, and archaeologists, finding that social factors, including their sense of an institution's reputation within a community of practice, helped researchers decide whether to use the repository. While the participants in those studies often cited transparency in practices and guarantees of preservation and sustainability as important concerns, these factors were not considerations mentioned by the botanists and archaeologists in this study, who selected the museums as a result of their own ongoing relationships with them or due to their stewardship of particular collections.

For external researchers using the Herbarium and the Kelsey, institutional reputation and the reputation of data collectors were intertwined through the deposit of objects at the museum. Data collectors' reputations for field work at a particular archaeological site or collecting locality, or for expertise in a particular taxon (at the Herbarium) formed the basis for each museum's reputation for holding particularly valuable or important data.

5.5 Accessing Data

Once researchers found data sources to assist them in their research, they also had to secure access to the data. For the archaeologists, this meant getting metadata about artifacts from the museum and (in many cases) planning to make a visit onsite. For botanists, this meant either getting the physical specimens on loan from the herbarium or arranging a visit to work with them in person. In both cases, researchers engaged in a combination of interactions with people and information systems to gain access to the data they needed.

5.5.1 Staff Interactions

Of the researchers external to the two museums, fourteen of the sixteen archaeologists and fourteen of the fifteen botanists talked about the importance of their interactions with curators, and especially with collection managers, in helping them find and gain access to resources that were valuable for their work. In addition to finding out what collections might be useful, researchers used these interactions to arrange in-person access to the collections. At both museums, external researchers were first oriented to the collections storage area by a curator or collection manager. In the Kelsey, artifact storage is behind a locked door, requiring collection manager assistance to enter. Collection managers at the Kelsey pull artifacts for researchers, which they can examine in the collection storage room or a study area adjacent to the collection managers' office. At the Herbarium, researchers are permitted to locate and examine specimens on their own.

Interactions with collection managers also helped external researchers discover other sources that were important to their work. In many cases, these were information systems that the users would not have known about if not for their interactions with staff members. The importance of these communications is illustrated in the passage below, where AR1 described her interactions at the Kelsey with AS1 (who she incorrectly identifies as a curator—he is in fact a collection manager).

> The curator was just incredibly willing to spend time helping me. So all of the questions I had, he tried to answer as soon as possible. He said, "You might not know that we have this database of black and white materials from the actual excavations. Why don't I show you how to use this when you're done with what you want to do?" So there's materials that I don't even know existed that could be helpful to me. But if the curator just didn't want to spend time bothering then I would have gone home not knowing they exist. (AR1)

Access to source information about the artifacts prior to researchers' visits was an important aspect of their interaction with the museum. Once a researcher contacted the museum to learn more about artifacts in the collection, they began a series of exchanges, usually over email, with the collection manager, who would send them representations of the artifacts and their documentation electronically, consisting primarily of database query results, digitized photographs, and scans from excavation and other records documenting the provenance of the object.

External Herbarium researchers also benefitted from their interactions with staff, learning about the particularities of the people who built the collection. As HR7, an associate professor and plant systematist told me,

> You know, I haven't looked at field notebooks, but what I do all the time is I talk to the curators of those collections because a lot of times they are very familiar with the collectors who contributed a lot to their herbarium and they'll say "Oh, well I know that in 1981 [two collectors affiliated with the Michigan Herbarium] took this trip here, and here, and here, and here" and so it's clear that they have reviewed that information that I haven't looked at directly myself.
> Interviewer: Okay. Are there other things that you have learned from curators that you might not know just from looking at the materials?
> HR7: Yeah, the personality of the collectors. Because that can be really important. I mean sometimes you have these people who are basically nut jobs and their information or the way that they identify a specimen is sometimes sloppy or something like that. Or there is some idiosyncrasy that goes along with that particular collector and because a lot of these people have spent several decades curating these collections and they see people coming in and out, they know these little things and that can be really important. I was just down in Australia last summer and visiting some herbaria and going to a conference and sitting down and talking with the curators was just so important because they could even tell me, "Well, how old is that person? Is that person still alive? Is that someone that I should try to contact?" "Oh! This person would be really great about helping you find this site." "No, that person I know they've retired, I know they moved some place," and so it's like they're an incredible shortcut to contacting the people who maybe have made these collections or things like that.

This researcher's statement reveals two important kinds of information that botanists gain through their relationships with staff. First, they can rely on curators and collection managers to know the particularities of the collecting done by earlier botanists who regularly contributed specimens, including the details of when and where collecting took place. Second, they can use curators and collection managers as a shortcut to contacting data producers with knowledge of where to find species of interest. In this way, curators and collection managers function as links between researchers and data producers as well as the collections themselves. They hold informal knowledge about collectors that may not be available from other sources. A third important factor emerges here, related to the researcher's interactions with sources. HR7 uses curators as a proxy for field notebooks, expecting that they will have some familiarity with the content of those data sources, making it unnecessary for HR7 to consult them himself. This researcher has both a great deal of trust in curators to know their collections well and little concern with accessing field notebooks as a further source of information about the collections. Curators' content-based expertise, specifically in the provenance of museum objects and the social factors surrounding that provenance, was highly valued by researchers.

Access to herbarium curatorial staff is also essential in order to borrow botanical specimens. Researchers at Michigan who needed to borrow specimens from herbaria or researchers affiliated with other institutions needed the cooperation of curators at Michigan to facilitate exchanges. HR1, a doctoral student at Michigan, explained that botanical convention required him to make specimen requests through curators at the Herbarium.

> Interviewer: So do you have any materials that you have on loan from other herbaria right now?
> HR1: Right now, I don't think I do.
> Interviewer: Okay. Is that something that you generally do?
> HR1: Yeah, it's very common for anyone who's interested in a specific plant or group of plants to request loan materials. […] I'm trying to get loans from Asian institutions and Russian institutions, but its not really going so well. I don't know how well it's gonna go. It's harder to get loans out of some places than it is in others.
> Interviewer: How are you approaching the loans?
> HR1: Loans in the botanical world are completely dealt with through curators and it's largely not my place to be doing too much of the interacting with other herbaria. So that's [curator HS1]'s job. […] And I have to talk to him about that. I don't really know who he's contacted or how it's going.
> Interviewer: Right. It's always strange when you have to wait for someone to ask questions on your behalf.
> HR1: Yeah. I mean, it does help, if you know people. I mean, of course, it's gonna help you get things done.

This quotation from HR1 is interesting on several levels. First, it illustrates accepted botanical practice for obtaining specimens on loan: the researcher asks a curator from his or her institution to make the request, and correspondence about the loan takes place between curators or collection managers at the two institutions. The researcher who will actually use the specimens is not part of that discussion, unless he or she is also a herbarium staff member. Second, it hints at the importance of interpersonal connections in obtaining access to resources ("it does help, if you know people. I mean, of course, it's gonna help you get things done.") The importance of having contacts was further emphasized by HR1 as he talked about the prioritization in loaning out specimens that he sees taking place at herbaria in other countries.

> […] My feeling with institutions in China, in India, in Russia is that potentially if you don't have contacts you're not gonna get what you want. And I think over the past decade or maybe two, countries have become much more interested in keeping the information that they have to themselves. And there's not necessarily anything wrong with that. Or if you get information from species that occur within Europe, you have to collaborate with investigators in those countries. And that's especially strong in South America right now, and I think it's becoming worse and worse in the Asian region. So I mean it makes sense, but it's kind of unfortunate.
> Interviewer: People wanting to mine their own data?
> HR1: Right. I think there's a sense of just they should be able to have the priority of studying their own... The things that occur throughout their country, before someone else who's never been to their country, or whatever, can just take all of the information that they've collected and do something with it.

This statement about prioritization of access to specimens outside the United States is interesting, in part, because of what it says about this researchers' perception of the social world norms for access to specimens in *this* country – that access will be granted evenly, without respect to a researcher's nationality. This was the only statement I found among my researcher interviews that suggested unequal prioritization given to botanists. In fact, none of the botanist researchers I interviewed told me that they had experienced a denied loan request, unless a specimen was not available for loan because it was in use by another researcher. I'd like to contrast HR1's characterization of the international botanical community with the quote from HR13 (the UK researcher) given earlier:

> [T]he thing about herbaria is it's a wonderful international network. We have a dictionary of herbaria called "Index Herbariorum" and bona fide researchers can nearly always, just from Index Herbariorum, get the details of a contact, a director or collections manager, and especially, if you are already attached to a herbarium somewhere else, as I always have been, just contact them and ask to come as a visitor, and as long as they know they can trust you not to damage anything

> because, of course, these are very fragile specimens, then it's usually possible to reach and go to places where you have no personal direct contact.

While HR13 speaks of a "wonderful international network," HR1 says that in regards to loans from herbaria in particular countries, "potentially if you don't have contacts you're not gonna get what you want." The two speakers' context is different—HR13 is talking about onsite visits while HR1 is discussing international loans. In addition, HR1 is a doctoral student while HR13 is a research scientist with over 25 years affiliation with her home institution. Their differing levels of experience no doubt contribute to their differing views on the international botanical community. Affiliation with a herbarium is clearly essential to arranging a specimen loan, as the herbarium assumes responsibility for the condition and return of specimens. HR13 suggests that it is also necessary in order to arrange visits to herbaria, as well. My interview data support this view, given that 14 of the 15 botanical researchers I interviewed have an ongoing professional affiliation with a herbarium. The remaining researcher, HR12, is a former student of curator HS1 and arranges visits to the collection through him: her past affiliation helps her gain access. While staff members gave anecdotal evidence of community member and non-professional use of the Herbarium (as well as contributions of specimens, in the case of *Michigan Flora*), these users are clearly an out-group in the botanical social world, whereas professional botanists are affiliated with herbaria. Because herbarium affiliation is an element of social world membership, providing access to resources needed for botanical research, these institutions and relationships are a central part of the infrastructure of systematic botany.

Researchers at the Kelsey also had opinions about the prioritization of research access and publication permissions based on collections, although they tended to see access as granted on a first-come, first-served basis. AR3, a doctoral student from Australia writing about Karanis and another site from Roman Egypt, was not able to use a segment of the Kelsey's collection in her dissertation because another researcher was already working with the artifacts and had been granted permission to publish findings from that study. As she explained,

> I was halfway through my thesis […] suddenly my supervisor decided I should add footwear to it. It wasn't my decision for footwear. My last time [at the other archaeological site], I had to add footwear: shoes and sandals. At that point I

> wrote to [collection manager AS1]. There was nothing about footwear on the online catalog […] At that time, someone else had approached him to ask if they could study the footwear. He said, "We can't give you access at the moment. We have quite a photographic collection, which is online, but it's not made available to the public. I'm sorry I can't give you access to it because someone else has got priority." I said it's fine and I used what I'd done for publication.

The researcher was able to use her work on footwear at the other site for her immediate purpose, and was understanding that she would not have access to the materials until after the other researcher. In the end, though, the museum determined that the other researcher was not actively writing anything using the Karanis footwear, and gave AR3 access to the materials. Also of note here is the absence of information on footwear in the Kelsey's online catalog, although the collection does contain footwear. AR3's decision to contact the collection manager helped her determine the presence of relevant artifacts in the collection, which she would not have been able to determine relying solely on the public collection catalog.

Curator AS4 described the museum's perspective on permission to publish from the collection, emphasizing that the kind of permission the museum grants (exclusive or non-exclusive) depends a great deal on the extent of the materials that the researcher proposes to use.

> Interviewer: It's my impression that once you have permission to publish, it's sort of a priority, no one else can publish about that object.
> AS4: It depends on the type of permission. An exclusive permission, there is a priority. It does have a time on it. The term in the past has usually been five years after which this gets revisited. Sometimes, it takes longer [...] We do have to take into account a number of things, so if it's taking longer, we may not be able to extend the exclusivity of the permission. Some museums don't grant exclusive permissions at all. And I don't know if this where we might think about going in the future. It's a complicated thing because on the one hand, you want things published. On the other hand, it is a huge investment of time to do that and especially if you're a professional academic, you've got so much else that you have to do. I think we all are very sympathetic if someone is truly working on something. So it's kind of balancing. And it's also the case that if it is something that is going to take a lot of time, you don't want to invest that time if someone else is going to publish it. If permission is non-exclusive, I think you're much less likely to invest the time because someone else could then publish it and sort of take away your whole reason of devoting the time to it.
> Interviewer: So it's common for people to ask for exclusive permission?
> AS4: In general, yeah. I think that if you're publishing an object and in general [...] non-exclusive permissions I think, tend to come about more where people are

> looking at a large body material and in that case, we would probably be less… If someone said, "I wanted to publish all the glass from Karanis," the first answer would probably be no. But if they came up with a credible project, it would probably be in the form of some kind of non-exclusive permission just because it's hard to preempt such as a big body of material for one researcher. And with us in particular, there might be student projects. Let's say on the one hand you've got the researcher who wants to do all the Karanis glass. On the other hand, you have a student who's investigating a specific context from Karanis, from which there are two pieces of glass. In that case, I think [...] the non-exclusive permission for the bigger body would allow the student to publish the material from their context but not really interfere with the bigger project.

The many considerations used by the curators at the Kelsey to determine publication permissions, including project scope and goal, number of artifacts in question, and researcher role, show a nuanced decision making process. Having artifacts from the collection published is clearly an important goal to the museum, but researcher plans must also be taken into account. This decision making process was not made transparent to researchers, but AR3 showed sympathy for the outcome.

I believe that differences in approach to access and publication issues in the archaeology and botany museums I studied stem, in part, from the nature of the objects researchers use in the two fields. Because botanists often collect multiple specimens of a given species in a given location to distribute to colleagues and herbaria, each specimen is potentially one of several, each with comparable value. As the accessioning vignette in the staff chapter illustrated, when offered duplicate specimens, collection managers select the most "ample" one for the Michigan Herbarium, designating other specimens "for exchange." Each specimen is given the same label information and they all presumably have the same value to researchers. In contrast, each artifact in the Kelsey's collection, while some may be examples of the same type, has its own provenance or provenience, making it truly unique from a research perspective. Because artifacts remain in the museum as they are examined, two researchers could presumably work with the same artifact in the same time period, but depending on the scope of their research, they might not both receive permission to publish their analysis of the artifact. The uniqueness of each artifact, along with the time scale of research (publication permissions are granted for a five year term) both support the norm in archaeology of granting exclusive permission to publish.

Differences in the attitudes, norms and practices of sharing and withholding data in the social worlds of archaeology and botany must also be taken into account when making sense of the publication priority issue. First, data sharing is a well-developed norm in botany, where herbarium deposit of a specimen makes it citable within a publication, incentivizing botanists to share their collections, and where botanists collect multiple specimens to distribute to colleagues and herbaria as a matter of course. In contrast, archaeology is dominated by a tradition of personal ownership of data, where a dig supervisor controls access to data up to, and sometimes past, the time of publication. The length of time to publication in archaeology is often quite long as well, as AS4 suggested and as Harley et al. explained,

> On an archaeological dig, everyone has different publication timelines, which differ by subfield, age, and project. The time taken to analyze and publish an excavation can take as long as a decade or beyond, and scholars are further limited in their speed of dissemination by dig location (e.g., in Japan or Greece, researchers publish site reports yearly) and whom they work for (e.g., local funding bodies may hold first rights to the data). (Harley et al. 2010, p. 56)

With such a long time to publication, it is unsurprising that archaeologists do not have a tradition for data sharing, as they seek to extract their own analysis from a dataset compiled over the course of multi-year excavations.

Staff members are clearly important intermediaries in the research process at both the Kelsey and the Herbarium, providing access to objects and their contextual information (at both museums) and granting permission to publish portions of the collection (at the Kelsey). While public databases made some representations of the objects freely available, staff members functioned as gatekeepers to the physical objects in both museums. In order to access specimens or objects, researchers had to work with staff, beginning with curators, explaining their research question and content need, and presenting themselves as bona fide researchers, primarily through their institutional affiliations and through introductions from more established researchers. These connections were a tool for gaining access to data, helping researchers navigate the relevant museum and research social worlds.

Curators and collection managers acted similarly as intermediaries at the two sites, reflecting consistency in job roles within these two groups. At the Kelsey, external researchers often turned to curators first with questions about the museum's holdings. Curators knew which sets of artifacts were actively being studied and whether or not publication permission for a portion of the collection might be granted. They also had the authority to grant that permission. Next, they forwarded researcher inquiries to collection managers, who corresponded with researchers, providing representations of artifacts that were not publicly available and advising researchers about the range of resources they might use at the Kelsey to explore their research questions. Collection managers also managed research visits to the collection, coordinating visit dates with researchers, pulling artifacts for them to examine onsite, and leading them to sources of documentation available at the museum.

At the Herbarium the loan process was entirely mediated by staff: researchers at Michigan requested loans through curators or collection managers who initiated loans with other herbaria on their behalf. The specimens themselves were shipped and tracked by collection managers, who assumed responsibility for the specimens' movements. Researchers arranged onsite visits to the collection with curators and collection managers, who oriented them to the Range and the location of a particular genus within it. When auxiliary representations of the collections, like field notebooks, photographs, or spore prints, were needed, collection managers made them available to researchers.

The role of staff members at information repositories as intermediaries in the research process has been explored by a number of authors. In the cultural heritage literature, several authors have emphasized staff members' role as intermediaries between collections and users in their work as creators of the representations researchers use to access collections (Light and Hyry 2002; Ketelaar 2005; Thumim 2009). Learning how to approach these intermediaries has been identified as a major component to working successfully in archives (Yakel and Torres 2003; Johnson and Duff 2005). The archaeologists and botanists interviewed in this study showed little concern for the first form of mediation: they assumed that object representations were based directly on information from the collectors, however, as the next section illustrates, they understood that the completeness of these representations varied considerably. On the other hand, researchers valued their interactions with museum staff (particularly collection managers) in providing access to museum objects and information that was not available in public databases.

5.5.2 Interactions with Online Systems

Researchers at both the Kelsey and the Herbarium used online systems to access information about the museums' collections; however, their interactions were very different at the two museums. This is, in part, due to the completeness of the systems available at the two sites. Kelsey researchers had access to a public online catalog that represented the entire collection. Herbarium researchers could only access item-level records for a subset of the collection that staff had digitized or described in a database. Therefore, the scope of the online systems is quite different at the two museums. Researchers using the botanical and archaeological online catalogs had much to say about the benefits and limitations of using the systems, including the variation in quality between the records.

At the Kelsey, where the majority of the artifacts are represented in the public online catalog, researchers observed and commented upon the variation in specificity between catalog records. As AR10 explained,

> […]some of them are just described just like "figurine," or "figurine fragment" and it won't actually give more than that. So, it's kind of uneven because some figurines in the online Kelsey catalog will have long descriptions and some will say practically nothing or it will just say, "Figurine," or "Male figurine" or something like that.

In response to the variation in specificity, this researcher understood curators and collection managers were able to find things in the catalog in ways that she could not. AR10 remarked that once she arrives at a museum to do research with objects,

> I'll ask them when I get there if they can do a search and see if [there is] anything else, male figurine, Heracles figurine. And I'll have them do multiple searches 'cause I'd rather them pull out more objects and then I can make the determination than maybe miss something.

Because this researcher wanted to work with all statuettes of the god Heracles (including any that the museum may have not yet identified with the god), she asked collection manager AS1 to search the catalog on her behalf using broad search terms, knowing that his searches would retrieve a greater number of possible matches. At the Kelsey, this is a wise request because museum staff can access a more comprehensive version of the catalog than the one they make publicly available on their website. Although the collection catalog was useful to this researcher, it was not sufficient in helping her understand the artifacts. She needed hands-on access to an artifact to make her own determination of its identity, whether or not it depicted Heracles and therefore fell within the scope of her study.

The Kelsey's on-staff researchers, the curators, dealt with ambiguity in the catalog in a similar way, through hands-on interaction with the collection. AS4, a curator in the museum for almost two decades, explained that the physical organization of the collection is an important tool for finding artifacts.

> Usually this kind of thing happens in the context of preparing for an exhibition. So, if I'm looking for something, I know the cabinets where I'm likely to find it. And sometimes rather than searching through the database, sometimes it just helps to go downstairs and start opening drawers because sometimes you can find things that haven't been properly cataloged or recognized. When I was doing the music exhibition, we were looking for fragments of musical instruments, of which we have quite a few in the collection, and I was […] interested in finding stringed instruments because those are very rare from Egypt. And we didn't seem to have anything in there, but we did have these kind of odd little bone objects which look very much like Greek lyre plectra, you know, things that you would pluck the strings with. And going into the catalog they were identified as "pottery shapers, question mark." But I was able to find some good parallels to them, so they are in fact lyre plectra. I then had a musicology student come in and he actually showed me on these things, you can see how the person's hand wore impressions […] and he showed me exactly how they work. That was pretty amazing.

For this curator, the objects themselves suggested their identity, after finding "good parallels to them" (i.e. comparanda) among objects that others had determined to be lyre plectra. A student with knowledge of lyre plectra, who was able to identify signs of use on the artifact that were consistent with that determination, confirmed the curator's intuition. While in this case the catalog was not consulted in the finding process, the ambiguity in the record ("pottery shapers?") indicated to the curator that his colleagues and predecessors at the museum had not yet confirmed the purpose of the artifacts. This case also illustrates both the non-standardized nomenclature used in the Kelsey catalog, as discussed in the previous chapter, as well as the means by which an artifact record might be updated as the result of research. While I was unable to find records in the Kelsey catalog using the search term “plectrum,” I did find four items in the catalog made of bone and described with the functions “Domestic Implement” and “Pottery Tool?” suggesting that the catalog may not yet have been updated as a result of curator AS4’s discovery.

Botanical researchers at the Herbarium used online resources to access specimen metadata in a markedly different way. Because the Herbarium did not have a complete collection catalog, yet portions of the specimens in its collection had been included in several data consortia, these were the online resources used by external researchers to learn about specimens. Two online systems for accessing information about individual specimens were mentioned by many of the botanists I spoke with: the JSTOR Global Plants database (formerly known as Plant Science) and the Global Biodiversity Information Facility (GBIF). A major focus of the JSTOR product is digitized type specimens, high quality images of the individual specimens on which botanists have based new plant names, while GBIF provides occurrence records for plant and animal species throughout the world so that botanists, ecologists, and others can track changes in species distributions over time. I will discuss both systems in detail in the section on data aggregation.

5.6 Selecting Data

Once researchers decided to use one of the museums for their work, their selection of data was an important next step in the research process. At the Herbarium, researchers determined the value and usefulness of specimens in part by using the labels and annotations attached to the specimen sheet. Depending on the kind of analysis they wanted to do (particularly genetic analysis), the age of the specimen was also a selection concern. At the Kelsey, the origins of the materials were an important consideration for researchers. Whether they had been excavated or bought and the amount and type of documentation available with the objects led researchers to decide whether or not they would be useful. In this section, I discuss each of these selection factors, making the case that the research questions with which individuals approached museum data determined their selection criteria, reinforcing the structure of the research social worlds by following the parameters established within each social world. I address selection concerns in the Herbarium first, followed by the Kelsey.

5.6.1 Selection: Location Data

Herbarium collection managers and researchers talked at length about the importance of good documentation on a specimen. Labels generated by the specimen's collector and affixed to the specimen were of varying quality, which researchers equated with their level of detail. Herbarium researchers using the collection to help them locate live specimens (specifically HR6 and HR12) relied on the amount of detail on labels to help them find those species in the wild. HR12 looked for information about associated species – plants that grow near the plant of interest. As she told me,

> I also look at the cards on each Herbarium sheet that describe when and where the plant was observed. And the good cards talk about the actual habitat where it's found and list associated species. And so, sometimes I take notes on what other species grows with the target species that I'm after, because that can help you narrow your search when you're in the field. (HR12)

Knowing what species are frequently found together helps HR12 serve her clients who need to know if an endangered plant species lives on land they plan to develop. HR12 often consults the Herbarium to learn about species with which she is not yet familiar, and when she knows what associated plant species to look for she can find them more easily when they are present.

On the other hand, HR6 wanted to find Herbarium specimens with very specific locality data to help him find new specimens in the field. In his case, the specificity of locality data and the age of the collections were most important. When I asked what he looks for in locality information on a label, HR6 described very specific metadata elements that would help him pinpoint exactly where a specimen had been found.

> Interviewer: I'm wondering, in an ideal world, what other information about the specimens you used at Michigan would you have?
> HR6: To be honest, in an ideal world, they would have specific locality data, every single one, like instead of just like "moist hemlock forest," it would be like "moist hemlock forest, off of Martin Road," […] like how many miles down the road it is, like where they parked.

These detailed descriptions would help HR6 figure out where to park his car and which way to walk when collecting specimens, letting him retrace the steps of his botanical forebears. This kind of information is not always found on specimen labels, though. More often collectors have provided the township, range, and section at which they collected a specimen, pinpointing the location to within one square mile. Other descriptions of the locality, including how a collector reached it, may or may not be on the label. Global Positioning System (GPS) coordinates, widely adopted in the 1990s as a tool for pinpointing geographic location, are now frequently used by botanists to describe a collecting location. This specificity makes researchers like HR6, who are mainly seeking accurate location data from specimens they wish to collect in the field, more apt to use recent specimens, which are likely to use GPS to define a location.

Location data is also essential for researchers using specimens for niche modeling, to predict the distribution of a species over time. As HR9, a professor and herbarium curator at a Midwest university told me, the precision with which a location has been recorded is an essential element in his selection of data points for a model.

> If I'm really interested in using the information for say, niche modeling, then I generally want to have as precise a record as possible: a very small error associated with the imprecision. And so, if it's a record that was reported say just to a county or a state, that may not be adequate because the imprecision associated with that record may far exceed other environmental data that we use in the modeling. So, I may just throw those out and not worry about georeferencing them. But if it's something that has an uncertainty that's a few miles or tens of miles those may be okay and so I'll go ahead and georeference those, but I always have an estimate of the precision associated with each of those records, and so I can use that […] when I go through and decide which of these records do I want to use for purposes of modeling. […] They can be perfectly suitable for morphological studies, and they may be fine for just some of the coarse mapping that we do if we're just looking at general distribution patterns. But they may not be suitable for a lot of the detailed modeling that we could do with the specimens.

The assessment of whether the location data associated with a specimen will be useful, then, is dependent on the research question and methodology the botanist has in mind. For rough distribution patterns, location data at the county level may be adequate, but for niche modeling, more specific location information is desirable. For researchers using specimens to plan a collecting trip, helping them determine where to look for a species given its past locations, location data of a different sort is most useful: information that can be used as signposts in finding new specimens.

5.6.2 Selection: Annotations

In addition to label information, the annotations made by prior researchers were another important factor in the selection of Herbarium specimens for further research. In the textbook *Plant Systematics* Singh describes annotations in the following way,

> An expert visiting a herbarium may want to correct an identification or record a name change. Such correction is never done on the original label but on a small annotation label or determination label, usually 2 by 11 cm and appended left of the original label. Such a label, in addition to the correction, records the name of the person [who made the annotation] and the date on which the change was recorded. Such information is useful, especially when more than one annotation label is appended by different persons. The last label is likely to be the correct one. (Singh 1999, p. 73)

Annotations are important because they can change where a specimen sheet is housed, making it easier or harder to find by future users. At most herbaria, including Michigan, where the collections are not cataloged at the item level, the species name assigned to a specimen is key to its retrieval. This affects selection because a researcher cannot choose to use a specimen if he or she cannot find it. The workaround involves talking to curators and collection managers to figure out where something may be filed, as HS7 told me.

> The database, to the extent that the specimens are databased, it's what we call a filed-by system. We know what they're filed by, very—almost all the time. Someone who is making an information request, if they don't get the answer they expect, they will come back with synonyms. Sometimes even making the request from the get-go, they will say, "Well, this is what I'm looking for, but it could be also under this and this." And that may be in part due to the custom that in times past, a curator could choose not to accept someone's annotations, that they made up their own mind about it.

In other words, part of the knowledge expected of members of botanical social worlds is an understanding of what synonyms are applied to the species they study. Botanists know to use those synonyms when searching for materials and asking staff members for help. Finding and using specimens, then, requires a base level of expertise in a particular plant family, knowledge that the researcher is expected to have when they approach a herbarium for specimens.

Reputation comes into play when assessing the annotations that have been made by previous users, as HR9, a curator at another herbarium and frequent borrower of materials from Michigan, told me.

> You get a sense of the confidence that various researchers had with the collections that they're examining. And so most people who are professional systematists or taxonomists spend a lot of time working with their taxa. You've got a lot of confidence in the determinations.

As HR9 suggests, knowledge of the people working within the family of plants that one is researching and an awareness of their reputations is essential to judging the quality of their annotations. This belies Singh's statement, that "the last label is likely to be the correct one." While this may be a useful rule of thumb in interpreting annotation labels, it was insufficient for the researchers with whom I spoke. HR15, an experienced plant taxonomist and professor at another university, provided an example of judging an annotation by its author, in this case, a botanist who had been affiliated with the University of Michigan Herbarium.

> If I were looking at *Lobelias* for instance, and I saw that they'd been annotated by [a particular taxonomist…] formerly at the University of Michigan, I'd be much more confident than if they were identified by somebody I've never heard of. Because I know that he published a lot on *Lobelia*, and studied *Lobelia* a lot. And so, I'd be very much inclined to consider his professionalism as extremely likely to be reliable.

When reading annotations, then, it is important to not only know the plant family, in order to make one's own determination, but it is also important to know the identity of the previous annotators and their professional reputation, to decide how to assess their level of expertise in making that determination. Some familiarity with the people who have worked extensively on a given plant family and an understanding of their expertise, generally gained through knowledge of the botanical literature, is a valuable asset for botanists using herbarium specimens.

5.6.3 Selection: Type Specimens

Type specimens, as discussed earlier in the section on botanical social worlds, are the name-bearing plants for species. As Singh explains, "The names of different taxonomic groups are based on the type method, by which a certain representative of the group is the source of the name for the group. This representative is called the nomenclatural type or simply the type, and methodology as typification. The type need not be the most typical member of the group, it only fixes the name of a particular taxon and the two are permanently associated" (Singh 1999, p. 38).

Because of this permanent association between the plant name and the object, type specimens have a special importance for botanists. Researcher HR4, part of a collaboration working with the genus *Euphorbia*, discussed the need for access to type specimens.

> That's an important part of the work because the type collection is like the ID part of the plant [...] Without that you cannot be sure what is what. So you need to look at the original [....] And many of the old names […] their description is very short. It's now very detailed. So, looking at the actual specimen is much better than just reading the description from the old literature.

Comparing specimens that are suspected to be a certain species with the type of that species is the most reliable way, HR4 believes, to make a correct identification. Accessing types, comparing them to other specimens, and making annotations, is a major part of her research. In order to verify that the herbarium specimens she is using are correctly identified, she compares them with the types for those species, as she described below.

> The first thing we do is we look into this herbarium that we have here and take all the specimens from North America, right? Some of them were identified, some of them weren't. The ones that were identified, we needed to double check with the type, and then assign the rest of them to different species. So, you always have to go back to the type, the original description.

HR9, botany professor and herbarium curator at another university, echoed this emphasis, stating that use of type specimens in his taxon is part of his routine use of herbaria.

> Normally, when I visit a collection, I will ask to examine the types just to confirm, I mean, as a courtesy for that collection I will confirm that the material that they think is a type is truly a type specimen. And so, that's a courtesy that I provide, and that also helps me to get a better sense of the variation that exists within the type materials for named plants, and for any nomenclatural decision I would want to look at the type material before I make a decision. So, as a matter of routine, I will look at the type specimens, I will verify that they are type

> materials, I may take some measurements from the specimens, and then I'll make use of that in nomenclatural decisions.

Confirming type specimens in one's own area of expertise is described by HR9 as a professional courtesy that augments his own understanding of the plant group. Type specimens are also essential tools for this researcher in making nomenclatural decisions – applying a name to a specimen requires a review of the relevant type specimens, to assure that his concept of the species is correct. Given the centrality of nomenclatural assignments in botany and the importance of type specimens in understanding a species, it is no wonder that these objects have such great value to this discipline.

5.6.4 Selection: Age of Collections

Several botanists I spoke with preferred using more recent herbarium specimens for research, for example, researchers conducting genetic analysis of specimens (HR1, HR2, and HR7) and users who wished to return to a location to collect new specimens (HR6). For these users, newer collections were often most useful. HR6 told me he prefers specimens that have been collected more recently, under the assumption that these plants are likely to still be growing in the same spot. Although he uses age as a selection criterion, he also told me that older herbarium specimens have also lead him to plants he wanted to collect, saying,

> Here at [my university] a lot of the collections that were made of [my species of interest] are very old and I would like very recent collections, so I'm not wasting time for things that don't grow there anymore.
>
> Interviewer: Have you set some kind of cut-off date for when collections were made if you want to use those to find new specimens?
> HR6: It's more of like if I don't have anything else, I'll look there […] Last summer we had a collecting trip to Texas and we used […] specimens from the National Herbarium. And one specimen, the last time it was found was in 1926. And it was like two plants growing on the top of the mountain. And we climbed up there and it took some searching but it was still growing there. It's just this little plant, not abundant at all. So, I mean, you never know. I mean, if it's easy to get to, you might as well check.

While the example HR6 gave of climbing a mountain to find a plant which was not abundantly growing does not seem particularly easy to check, for collecting difficult to find species, this method of using herbarium specimens can be fruitful.

The age of specimens is also an important consideration for botanists wishing to conduct genetic analysis, due to the degradation of DNA molecules over time. As HR2, an advanced doctoral student at Michigan who does a great deal of work at the Herbarium told me,

> DNA is pretty stable as a molecule. It doesn't break down very easily, but […] over time it will. So, when you collect something in the field, you usually take a leaf, if there's leaves, or a bit of green stem tissue and dry it in silica, preserve it, and then you can extract the DNA from that, and it's in relatively good shape. From a herbarium sample, I guess the difference is that the quality or potential quality of the DNA that you get is more highly variable. So, it usually can be better if the specimen was dried better, was picked, was prepared better, in general, and if they're not as old, but still some people can get DNA from very old specimens.
>
> So, the success rate of actually getting any DNA is lower from herbarium specimens in general and just more variable. And then also the DNA that you can sequence—the length of the reeds is much shorter because the DNA molecules over time break down into shorter chunks. So […] you amplify a certain region by PCR, polymerase chain reaction, to get only the one region that you want out of the entire genome, and then you then sequence that—like get the actual sequence of that little chunk in a second step. So, the first step gives you the piece you want, that you're interested in, and that is limited from herbarium samples by length. So, the length of those amplification pieces or those pieces that are amplified is shorter from herbarium specimens because the pieces of DNA are generally shorter […] because they're older.

Botanists conducting DNA analysis may wish to make their own collections to ensure that they will have good data for genetic analysis, rather than relying on herbarium specimens. This measure can increase data quality, but may not be feasible, given the expense of collecting trips and frequent need for specimens from a broad geographic area. DNA analysts can use herbarium specimens for this purpose when the specimen has been well-preserved. Although HR2 is not generally using herbarium specimens for DNA analysis, he is using them to understand and describe the groups that DNA analysis reveals.

> So, it's been hard in the history of this group, of the study of this group, to produce a good evolutionary scheme of relatedness based on outward characters. So, we only use DNA characters at this point to do it, and they're much more reliable, because they're not subject to natural selection hopefully, the ones we've used. […] But, once you know the groups enough that you have a good estimate of the groups, then you can say, "Alright, well, what do these have in common?" And then you can look at herbarium specimens and say, "Oh, they're all kind of

> this general leaf shape, it turns out, or, they all grow here in this region or in these habitats." Or you can discern characters that do hold the group together that you could use to describe the group, or to make ecological inferences about the group, or to communicate the group's characteristics to somebody else.

In other words, botanists like HR2 use DNA analysis to understand the evolutionary relationships between the species that comprise a genus, but access to a large number of the specimens through a herbarium makes it possible to understand how the genetic differences between the species are manifested in their morphological traits. This example nicely shows the interaction of different data points and the divergent uses of evidence. Both DNA and morphological data are central to the dissertation HR2 is writing and with both of them, a greater understanding of the genus he studies is possible. In this example, we see that assessments of data quality are dependent on the research question and methods used to analyze specimens—data that are not suitable to one use (e.g. DNA analysis) may still be valuable for another (e.g. analysis of morphological traits). Even a botanist who decides not to use herbarium specimens for genetic analysis, given concerns about the freshness of the sample, may still rely on herbarium specimens for a fuller understanding of the species.

Because botanists deposit their specimens into herbaria as research vouchers, to cite in their publications, new collections made by HR2 and other geneticists are linked to DNA data, the results of which they deposit in GenBank. Some herbaria preserve samples taken for DNA analysis so that future researchers can run new analyses from these samples (e.g. Royal Botanic Gardens Kew 2013a), but this kind of preservation is still a rarity among herbaria. The University of Michigan Herbarium does not currently preserve DNA extraction samples.

The prominence of DNA analysis as a method has contributed to some identity friction between those who identify themselves primarily as taxonomists as opposed to those who see themselves primarily as molecular botanists. Molecular botanists were looked on with some derision by some taxonomists (who comprised the majority n=8 of my researcher interviewees compared to only three researchers who conduct genetic analysis). HR9, a professor and herbarium curator at a Midwest university, told me,

> A lot of times we don't have as much confidence in annotations that are associated with specimens that have been borrowed for molecular studies.

> Because there's not the intimate knowledge of the plants in the field and in the collections as we had with somebody who was studying these materials […] 20 or 30 years ago. And there is often a reluctance to annotate specimens by individuals who are borrowing specimens for molecular studies because they don't have that expertise, that knowledge. Often times they're relying on the determinations that have been made and are currently associated with the specimens and you can get a sense from talking to people when they're inquiring about the use of specimens, whether destructive sampling is allowed and whether they're gonna be required to annotate the specimens. Those sorts of questions from individuals who are going to borrow materials are usually telling.

For HR9, a plant systematist and ongoing contributor to the *Flora of North America*, researchers focusing on molecular studies often do not, in general, have the taxonomic expertise needed to make determinations of the identity of a specimen. Specifically, they lack detailed knowledge of the plants in the field and of collections that reside in herbaria. Because plant identification is a key aspect of herbarium practice, specimens collected by molecular botanists were suspect in the minds of some taxonomists. Collection manager HS3 echoes this concern, tying it to a shift in botanical research that emphasizes molecular work.

> [A lot] of people feel that, well, anything that's dealing with botany that's really cutting edge has got to be molecular. Well, the problem is unless you can identify the plants you're really working with, are you really... How can we be sure that what you've done with all these molecules is anywhere near right? And some people don't see it that way.

The kind of work HR2 does, described above, using both molecular data and herbarium specimens, appears to be rare among molecular researchers, who can isolate and analyze gene sequences in a specimen but may not be able to say with certainty to what species that specimen belongs. This conflict between taxonomic and molecular expertise can be addressed through collaboration (for instance, the collaboration between HR2, HR4, and HS6 to which the researchers each contribute in their area of molecular or taxonomic expertise), through training (as in the case of HR2, who has a background in both areas), or simply not addressed at all, leading to a further widening gap between members of these research subworlds.

5.6.5 Selection: Archaeological Materials

Curators, collection managers, and external researchers at the Kelsey spoke about artifacts using two categories related to their origins: excavated and non-excavated materials. While many other categories may guide researcher selection of artifacts (such as artifact type, area of origin, or the material from which it was fabricated), whether or not it had been excavated was a primary concern for all researchers because this, above all other factors, determined the kinds of analysis they might be able to do. Excavated artifacts generally had a greater extent and quality of documentation, along with metadata recording their provenience.

Excavated materials were a product of archaeological digs sponsored by the Kelsey Museum while non-excavated materials were the result of a gift or sale to the museum. Numerous types of documentation support the origin of excavated materials: lists of finds made at an excavation recording the provenience of each object down to the specific location within a dig from which it originated and the layer of soil from which it was drawn; photographs of the artifact *in situ*, before it had been removed from the ground; and lists of artifacts found within each archaeological unit are all forms of documentation that accompany many of the excavated materials at the Kelsey. Non-excavated artifacts are usually accompanied by a sale record showing where and when the object changed hands, but there may be little or no other documentation of these artifacts' earlier origins.

For the most part, non-excavated materials leant themselves most to type-based research while excavated materials were used more often in provenance-based research, although there were some exceptions. The group of marble researchers at the Kelsey (AR9, AR12, and AR16), for example, used this non-excavated collection in part to create their own typology: they were building a resource for recognizing various kinds of marble by their physical features. Another goal of their project, however, involved provenance: looking closely at the museum's records to attempt to conclusively determine the sources of the marble collection. In this aspect of the project, the researchers were interested in constructing a collecting history for the materials.

AR1 explained the value of the Kelsey's collection of terracotta figurines from Karanis for her research, specifically because they are from Karanis and are directly comparable to the other Karanis artifacts she is using in her research.

> The Louvre has a lot of pieces from Egypt that are terracotta figurines. Most of those are completely unprovenanced, they're all from the art market. There are a number of other museums in Europe that also have pieces, but it's actually quite spotty as to when any of these have anything similar at all to the Karanis pieces. So yeah, if I was in France, I probably would go and take a look, but I don't think it would be worth the cost for me to go and see the pieces since they're really not necessarily that comparative. So really, I mean, Michigan is *the* place where I would find the best material because it's from the same site. If there were pieces from other sites in the Fayoum, then that would be useful.

While figurines from other sites in the Fayoum region of Egypt would be useful for comparative purposes, those actually from Karanis were most valuable to AR1 because they were most directly comparable. Their shared provenance made them more valuable to her work.

Doctoral student AR11 also discussed making selection decisions based on provenance as she planned an exhibit at the Kelsey. She made her first selections of figurines based on visual appeal, but culled from that group according to the information available about each object.

> The first thing was looking at all of them and seeing what would be striking and interesting to a viewer. And then going back, having a number that we've chosen, and then doing some research about each of them, and saying, "We know exactly where this came from, great. We can provide some background information." Then there were some that were obvious fakes and we wanted to include those in another drawer that was about fakes and forgeries. And then there were some that we just weren't sure about, and even the specialist wasn't sure. So we did not include those. So there was that kind of background check.

The background check was based on records in the museum about each object's provenance. Assessments that the objects were fake stemmed from unclear provenance, (for those artifacts that had been purchased rather than excavated) and physical qualities of the artifact that were uncharacteristic for its purported type. AR11 also consulted a specialist (a contact of one of the museum's curators) and comparanda from other museums to decide which artifacts to include in the exhibit and whether or not they should be considered fakes. Comparanda were a vital resource in this case, helping

AR11 find examples of similar artifacts throughout the world that would shed light on the figurines. Selection of materials for comparanda, AR11 explained, relies on physical similarity, but is made more valuable when the comparanda have reliable provenance information.

> Unfortunately, to a large extent there's no findspot for a lot of these [figurines]. They've been robbed from the tombs. They've been robbed over the course of centuries. And so they're on the market and so the museums, in many cases, don't have any background information up to a certain point. So, it is necessary to rely on, yeah, just comparing what the figurines actually look like with then, in some cases, where there is a provenance and provenience for them. But mostly it is stylistic or looking at other elements of this form.

While comparanda helped AR11 determine similar figurine types, looking at their material, construction, and imagery, those figurines with provenience—an actual findspot—could allow her to say not only that a figurine was similar stylistically to one in another museum collection, but also that the two figurines may have had similar origins. Provenience information, then, can make comparanda more valuable in research. In her juxtaposition of provenance-based and type-based analysis, AR11 used the norms of her social world's evidential culture to justify her selection of artifacts for an exhibit. Validation by an external specialist further supported her analysis of museum data.

This section has reviewed some of the major selection criteria used by researchers at the Kelsey. Artifact type was important for the researchers working with the museum's marble collection, statuettes, and figurines. Archaeologists used physical characteristics of the artifacts to identify them as legitimate or fake and to identify their iconography. Provenance information was also an important selection factor – those artifacts without the detailed context provided by excavation records had more limited uses, since, in many cases, researchers could not definitively identify their origins. Artifacts without this detail were still usable as comparanda, providing representatives of object types, but if they could be compared with well-provenanced objects, they had more research value. In a social world where reliable contextual metadata is key to the construction and interpretation of evidence (Hodder 1999), archaeologists using museum data lacking clear ties to an original context often rely on comparanda. Through an analysis of the physical qualities of artifacts with typological similarities, archaeologists can make claims about patterns in their production, stylistic elements, and use.

Some interesting differences arise viewing the ways in which these botanists and archaeologists use provenance metadata to select data in comparison with the methods for data selection discussed in other studies. In Carlson and Anderson's (2007) multi-discipline study of data reuse, the most important aspect of provenance for their participants was metadata describing how a dataset had been created and manipulated. Similarly, in their 2012 study of proteomics researchers, Fear and Donaldson found that "provenance provided a foundation for evaluating a dataset's trustworthiness and the expertise of the dataset's source" (Fear and Donaldson 2012, p. 327). Proteomics researchers valued knowing the experimental parameters and instrumentation underlying a dataset to gauge its accuracy and a dataset's attachment to a publication helped them determine its authenticity. The provenance considerations that emerged in these studies concerned who created the data, how data were created and modified, how they were used to generate findings, and where those findings were reported.

Because the archaeologists and botanists interviewed in this study were involved in object-based inquiry, the provenance metadata they needed was different in character from that associated with a laboratory science like proteomics. Provenance metadata in both museums concerned the source of the object: who collected it, when, where, and under what circumstances. It was recorded directly on herbarium specimens and in documentation, such as field notes, provided by collectors at both museums. The presence or absence of such metadata determined how researchers could use an object as evidence in their work, but access to the underlying documentation of provenance was only available through interaction with collection managers. While the presence of a publication using an object was an important guide to collections they might use, it did not always validate the authenticity of an object's provenance (in contrast with proteomics researchers), since the object's collector and the author using it in research were not necessarily the same person. An interesting analogue for evidence of data manipulation in the Fear and Donaldson study might be the history of annotations attached to herbarium specimens. These annotations show how a specimen has been interpreted by other researchers over time. The analogy falters, however, upon consideration that the herbarium specimen itself does not change in that process (as a set of experimental observations does when normalized, for example), it simply bears that history transparently to users. Given that these objects bear their provenance through contextual relationships with recordkeeping systems, these issues are further explored in the coming section.

5.7 Understanding Context

Both archaeological and botanical researchers in museums needed to understand the context of an object, whether artifact or specimen, in order to use it in their work. Context is recorded differently at the two museums, giving researchers a number of places to look when they are investigating an object. For botanical specimens, context is recorded by the collector in his or her field notebook each time they make a collection. The collector copies this context (sometimes in an abbreviated form) onto the label they make to accompany the specimen when they deposit it at the herbarium. The context of archaeological objects is recorded in a large number of places, including (for excavated objects) ledgers of finds, photographs, and maps and locus numbers associating the object with a specific location. Both excavated and non-excavated objects have their context recorded in the Kelsey's database and object files. Many of the archaeological researchers I spoke with dug deeply into the records available to them, however, the botanists did not. In this section I discuss the resources both groups used (or did not use) to understand the context of these objects.

5.7.1 Botanical Context

All 14 of the botanist researchers I spoke with who actively collect specimens also keep a field notebook recording the details of when and where they found each plant. This is the first place where botanical context is recorded before it is edited and copied to create labels for depositing specimens to herbaria. Although they are connected to specimens through a collector number, researchers saw field notebooks primarily as personal recordkeeping tools. They consulted their own notebooks (several even did so during the interview, to jog their memories about their own collecting) but they rarely consulted field notebooks created by other collectors. In contrast, herbarium curators and collection managers (at Michigan and elsewhere) viewed field notebooks as vital records of botany, worthy of long-term preservation and use, and in some cases digitization. This was a notable discrepancy, worthy of delving into at length.

HR2, a doctoral student at Michigan, told me that for type specimens, the published literature is a source he has consulted for collecting information, but field notebooks are not.

> I don't think I've gone through actual field notebooks, although that would be helpful though. I can see how that would be very helpful in certain situations, but as far as type specimens, there's a protologue for every species, right, where they first described it and so that sometimes includes, "it was collected here on this day," and it gives a longer description of what they were doing or how they collected it. (HR2)

Several other botanists echoed this sentiment; important information was on the label or in publications, as in the following statement by HR15, an experienced plant taxonomist.

> Interviewer: I was wondering if you've ever gone back to field notebooks in order to verify what's on a specimen label, or anything else?
> HR15: Not very much. People don't usually put […] much in writing—or they haven't, maybe they should—anywhere but on the label or in a publication. The little gap in between, what's too big for the label, not considered important enough for the publication, or objected to by the editor, often doesn't get that well preserved.

The role of the field notebook in producing the botanical record was extremely evident in statements like that of HS4, a 20+ year botanical researcher in Michigan who is based at another university but works onsite weekly at the University of Michigan Herbarium. "To create the labels, I use the field book to assemble my information, get my numbers right, get my dates right, and get my location information." For HS4, the field notebook is a tool to aid his own recollection of his collecting. It forms the basis of the labels he produces for herbarium deposit. The field notebook to specimen relationship, along with the field notebook to label relationship, is one-to-many. Botanists collect multiple specimens of the same species at one location, giving each of the specimens the same collection number, as a course of practice. The field notebook records the details of that collection, including a tentative species determination, the date and location of the collection, and any notes they may wish to make about the habitat, along with the collection number. When they return from a collecting trip, botanists review that information and use it to generate labels for the specimens they will deposit at a given herbarium (usually one with which they have a professional affiliation) or send in exchange to colleagues or other herbaria. Field notebooks may or may not be deposited by botanists at the end of their career in a herbarium or other organization with which they are affiliated. It is not surprising, then, that researchers do not seek out others' field notebooks as a matter of course. The Michigan Herbarium houses the field notebooks of a number of the prominent botanists that have worked on its staff over the years, but use of this part of the collection is minimal.

There is one group of botanists that I consider to be an exception to this rule. Mycologists, those who study mushrooms and other fungi, tend to use records created by mycologist collectors to learn more about the state of the specimen when fresh, since fungi change in color, texture, and size as they dry. HR10, a herbarium curator at another institution and a plant taxonomist (although not a mycologist) explained that this group has a need for more extensive records than other botanists.

> Interviewer: Do researchers ever ask to look at field notebooks from collectors?
> HR10: Sometimes. Not so often, usually, if it's vascular plant material. But the ones who ask about those things more are people who are doing mycological studies, so people who study fungi. That's the group that I've had the most requests for field notes because sometimes the field notes will contain descriptive information that didn't get transferred onto a label. And so, there may be measurements, and colors, and odors and things that are written down in notes that could be important for identification, that may not be with the specimen on a label or something like that.

The personalized nature of botanical note keeping is abundantly clear in the fungi collection at the University of Michigan Herbarium. In my meeting with one collection manager, she showed me the different types of records available for the fungi collection of C.K. Kaufman, one of the prominent mycology collections at the Herbarium. As HS7 explained,

> Mycologists often painted or tried to photograph their fungus collections, even very early in the history of the camera […] Because the specimens are dried and change their shape often, mycologists would make a basic drawing of what the fresh specimen looked like.
> Interviewer: […] Would it be possible to find if he has a card [illustration] for the specimen you showed me earlier?
> HS7: If he did, he would have written probably on the label. The problem with this is that, I would look for one but I would literally have to begin a hand search […] And this is because not every specimen got anything other than this basic

> documentation that we can see here, which is a field label and a typed label. But Kaufman didn't paint all of his specimens and not always noted when he would. This is one of the problems of this being sort of subjective and on shelves in his office, and him being very comfortable about it.

While some contextual materials are available for some specimens in the collection, then, it is not consistent, even for the same collector. The paintings and drawings made or commissioned by mycologists of their specimens are not indexed by the Herbarium, so a mycologist wishing to access such materials would need to ask if they exist. If they do, collection manager HS7 will find them, scan them, and email the images to the researcher. She uses her systems-based expertise in this process, using her own understanding of collectors' recordkeeping systems to find representations, acting as a mediator between researchers and the specimen representations they need.

5.7.1.1 The Perceived Value of Field Notebooks

Although none of the researchers I spoke with had used other collectors' field notebooks at the University of Michigan Herbarium, the collection managers I spoke with considered them indispensable. They told me several stories about using them to verify location data for collections, which lead to updating specimen labels. Collection manager HS3 talked about using field notebooks to verify the collecting date of a specimen that had been considered a type. He said,

> One of things that many places will do, they'll just assume that if I mark the specimen as being a type, "Oh, it's got to be a type. He said so." But what if he's wrong? A good example of that I can point to now, I got a query about a week ago from an individual who said, "Can you check the date that this specimen was collected? I had labeled it as a type in your collection." I went back [to the field notebook]. "Oh, it's 1883. Oh, that's a mistake. The type was actually collected in 1884." This is a really peculiar situation where the same collector visited the same site on the same day in two different years. The labels look identical. One says 1883, the other says 1884. […] If you go to the description of the plant, if you go to the published description, the 1884 specimen was cited as being the type of that name. The 1883 specimen is not mentioned, so it's not a type. (HS3)

The field notebook is an important tool, then, for verifying the botanical record, but it is largely not considered a central part of that record. For most of the botanists I spoke with, the field notebook was a personal recordkeeping tool, to be used by the collector to record his or her research activities in the field. When they deposited specimens in herbaria, botanists used their field notebooks to create labels, attaching a reduced set of their research data to the specimen itself. Through this act of inscription, botanists extracted specimen metadata from the broader dataset they had recorded, which might include a range of measurements, counts, and other observations (Latour and Woolgar 1986). For collection managers the notebooks were valuable as the original, definitive records of botanical fieldwork that could be consulted to clear up ambiguities in specimen metadata, but for researchers, their broader documentary value was limited to the act of preparing a specimen label. This is a notable dichotomy between data collectors and collection managers in the perception of field notebooks and the extent of their utility for secondary data use.

The enduring value of the field notebook to the collectors themselves was evident to all of the botanists I spoke with. Reviewing a set of his own older field notebooks, HS8, a curator at the Herbarium, first explained that much of the information he had recorded when working on his dissertation was not appropriate for specimen labels. He said,

> This is a combination of collection information plus dissertation information, so there's like a lot of dissertation kind of collection data […] these were actually seed counts from pods that I was collecting when I was surveying.

While HS8 felt that his dissertation observations (such as seed counts) were extraneous to the specimen labels, the collection metadata recorded in his field notebooks became important years later. The following passage details the role of the field notebook in helping HS8 create labels for the specimens he had collected during his dissertation fieldwork years earlier. HS8 had deposited the specimens he had collected at a herbarium in the United States with which he was affiliated, but had never sent labels to go with them.

> When I made collections in [the field], I didn't have specimen labels. I just collected them, added the collection number, and I had all the information in my notebooks linked with that number. And then, so [the herbarium curator] contacted me like 16 years after I made these collections, and he said, "I found this amazing set of collections from [your collecting site]. They're beautiful specimens. All I have is your specimen number, if […] by any chance, you have the information on these specimens, we you could make labels for them and get these out." And so, fortunately, I have all the information. I went back to my notebooks. I transcribed them finally, they're on the computer. [During the

> collecting process] you typically cut the trunk with a machete, you smell the bark if it has a fragrance, some really beautiful fragrances just come out of members of the avocado family and you look at the color of the latex, of the inner bark. If you notice any pollinators, or anything that you notice about the natural history of the specimen, write it down. Part of it is for your own knowledge as you learn more about the flora. And in addition, you have the dates, you have a location, and so I could go through and then I could sort of remember all these individual collections […] And I had also my initial impression of what the species might be, what the family might be. And I sent [the curator] that list and he immediately had it turned into labels and had their mounters in [that herbarium] mount all these specimens. And he's sending a set of them to Michigan, so now I'm actually going to be able to do genetic studies on them.

In this passage, HS8 makes an interesting distinction between the collection metadata and research observations he recorded in his field notebooks. The floristic observations he made in his field notebook were for his "own knowledge," recording "dissertation kind of collection data," while the date and locality metadata were broadly useful to botanists and would be included on herbarium labels. While floristic observations are not always included on specimen labels, his sense that they would not be valuable to other botanists is contradicted by researchers like HR12, who use information about associated species to locate plants in the field. If other associated metadata, like seed counts from the pods HS8 collected, were routinely made available on collection labels, the research uses of plant specimens might expand further.

These quotations from HS8 show an interesting relationship between research observations in the field, specimen metadata, and data. While the collection metadata that would be included on a label (collector number, species, location, date) have an enduring value to botanists and are fundamental to the evidential value of specimens, his floristic observations in the field about a specimen's odor and seed count were dissertation data that had limited reuse value ("part of it is for your own knowledge"). This example shows one of the limitations imposed by the standardization of herbarium specimens—they can only be used to represent collection metadata, they cannot be annotated to reflect other data gathered in the course of research. These other data are only accessible through publications in summary form and through field notebooks, where they are presented in relation to the specimens to which they pertain. If they are ultimately deposited in herbaria, researchers can potentially mine them for those data, but because botanists perceive them as personal recordkeeping systems, they do so infrequently.

5.7.2 Archaeological Context

Understanding context is key to archaeology. As Hodder and Hutson explained,

> It is often claimed that material objects are mute, that they do not speak, so how can one understand them? Certainly an object from the past does not say anything of itself. Handed an object from an unknown culture archaeologists will often have difficulties in providing an interpretation. But to look at objects by themselves is really not archaeology at all. Archaeology is concerned with finding objects in layers and other contexts (rooms, sites, pits, burials) so that their date and meaning can be interpreted. (Hodder and Hutson 2003, p. 4)

Divorced from their contexts, artifacts cannot be interpreted as thoroughly as they otherwise might be. Once they have been removed from their context within an excavation site, archaeologists must rely on record keeping systems to document that context so that they may continue to interpret the artifact.

Within the Kelsey, archaeological context is recorded in a number of places, requiring the researcher to reconstruct that context as part of their work practice. The researchers I spoke with at the Kelsey used a wide range of materials to discover the context of the museum's collection, summarized in the following table. These included excavation records (maps, plans, notebooks, records of finds, and photographs); the museum's photographic database, accession books, and artifact database; and materials from other organizations, including archives at the Bentley Historical Library and comparable objects held by other museums. The table lists each of my archaeological interviewees, their research interest, and the information sources that they used at the Kelsey, as well as records and other materials they consulted from other sources.

Table 5.1 Documentation used by external researchers at the Kelsey

ID	Area of interest	Paper-based records at the Kelsey	Electronic records at the Kelsey	External resources
AR1	Karanis finds	Ledger of objects from U-M Karanis team	Photo DB from collection manager	Another organization's finds from the site

ID	Area of interest	Paper-based records at the Kelsey	Electronic records at the Kelsey	External resources
AR2	Karanis: Current excavation team member, looking at older glass collections from the site			1936 publication on glass finds from Karanis
AR3	Roman textiles: Karanis as a comparative site		Kelsey online database, private DB of images of footwear from collection manager	Publications on textiles at Karanis
AR4	Current excavations			Top plans, site plans, unit sheets (belong to project director, not museum)
AR5	Vault construction at Karanis (and Dime)	Excavation photos, notebooks, site sketches, "little books that correspond to the numbers in the sketches"	Scanned pages of excavation notebook, photo database from collection manager	Excavation report published 1938, unpublished manuscript at the Kelsey
AR6	Planning new excavation			
AR7	Funerary statues: What materials and fabrication say about the deceased		DB from collection manager	Publications on funerary statues
AR8	Domestic religion	Object list from Karanis	Photo database from collection manager	Unpublished manuscript at the Kelsey
AR9	Marble collection	Accession book	DB from collection manager	Archives at the Bentley Historical Library
AR10	Terracotta figurines from Hellenistic Babylon: Cross cultural interaction	Map, site report	DB from collection manager	
AR11	Terenouthis excavation site	Excavation notebooks, accession books, photographs		
AR12	Marble collection	Accession book	DB from collection manager	Archives at the Bentley Historical Library
AR13	Creating an exhibition for the Kelsey	Karanis records of objects	DB from collection manager	
AR14	Gravestones	(Has not been onsite)		Published catalogs
AR15	Funerary cones from tombs		Object and photo DB from collection manager	Dissertation from 2005 thanking the Kelsey, published catalogs

ID	Area of interest	Paper-based records at the Kelsey	Electronic records at the Kelsey	External resources
AR16	Marble collection	Accession book	DB from collection manager	Archives at the Bentley Historical Library

Notable in this table is the observation that many of these researchers used a database (DB) sent to them by a collection manager. As I discussed in the previous chapter, sharing databases with researchers is a standard part of AS1's interactions with these users. He makes portions of internal databases available to them as a matter of course, scanning and sending more detailed information as requested. Another notable (although less prominent) commonality is the reliance on public sources, including dissertations, published catalogs of objects, and other publications, for information about artifacts held by the Kelsey. The published record is a vital source of artifact representations for this group of researchers.

Unpublished records were also vital sources of context for researchers at the Kelsey. One group of researchers I interviewed and observed, AR9, AR12, and AR16 (two Michigan doctoral students and a classical studies professor at another institution), were investigating the marble collection at the Kelsey. Their goal was to study the collection and publish a catalog, for which they needed to verify the material (the marble type) and learn about the sources from which the marble fragments originated. The final product will be both a collecting history of the marbles (which were not excavated, but were obtained primarily through purchase by Francis W. Kelsey and others) as well as a visual identification guide and typology of the marble artifacts.

As I observed the team working with the marble collection, I saw them examining, measuring, and writing descriptions of the artifacts and recording that information in a project database. They used the accession number painted on each chunk of marble to check the record in the museum's accessions book, from which they copied all of the information into the project database, looking, specifically, for information about the source so that the team could reconstruct the artifact's collecting history. They used the Kelsey's online database as well, but only as a starting point to determine the scope of the marble collection and what was already known about it. As AR9 explained, When we started this last summer, [AS1] went to the overall museum database and he did a search. What did he search on? Just “marble.” And then he passed us the file of those entries. And I think there are 1100 of them. And that’s really very useful because we […] have the official museum information that we can cut and paste.

The information in the online database was necessary but not sufficient for this team, however. They needed to look at the accessions book where that information was originally recorded and to evaluate the entries listed there. Figure 5.2 shows the part of the accessions book the team was investigating during my observation.

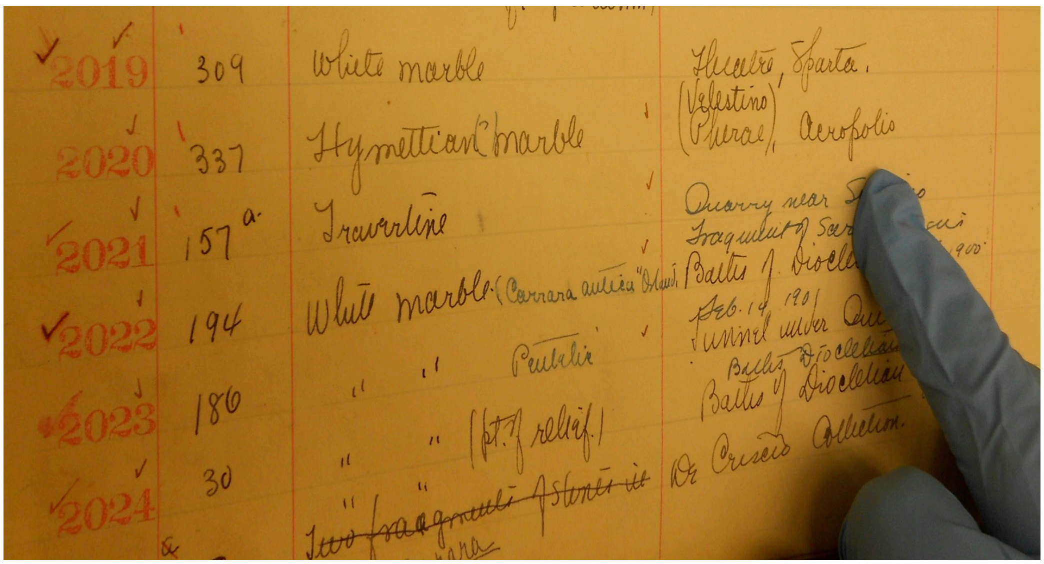


Figure 5.2 Kelsey Museum Accessions Book

Team members noticed that the entries for this group of marble pieces were written in several hands (by several individuals) and in several colors. They wanted to know when the various entries were made, but that information was not readily apparent. As AR9 said,

It’s a little tricky because we can’t sequence the blue ink, except for this, obviously not the first entry [pointing to blue ink written in smaller writing above a line of black ink]. But we don’t know when it was penned in. I think, essentially, we’re taking this as contemporary ‘cause there is a note from Orma Butler [the museum’s first curator] somewhere that they’ve been kind of able to figure out. And the entries are in multiple hands.

Since the accessions book has been annotated consistently by staff (primarily collection managers) throughout the years, they could not determine when the annotations were written, but decided they must be contemporary to the artifacts entering the museum by matching the ink and handwriting among entries. The team decided to corroborate the accessions book with archival materials at the Bentley Library, which collects records documenting the activities of the University of Michigan and holds papers for the Kelsey Museum and many of its associates, including Francis W. Kelsey. AR12 explained how the archives helped them track one marble source.

> A bunch of pieces came from this one address, a street address in Rome, but the dates when they were supposed to have been collected in the accession books—according to Kelsey's diary, he and his family were under quarantine for scarlet fever. So it was not clear who was picking these things up. But then we found by looking through [Michigan archaeologist] Van Deman's letters that she was living at that address. So, it looks like she must have collected those things and given them to him.

While the team had not resolved where these marbles came from prior to the street address in Rome, by tracing them to Van Deman they had resolved part of their inquiry. The researchers' background knowledge of Kelsey's collaborators suggested Van Deman's papers as a source of information.

Although research into the context of museum objects was variable between the two museums and along with the research goals of the user, several common themes emerge from these stories. First, staff members (and particularly collection managers) acted as guides to these records, in terms of both finding and interpreting them, providing knowledge of the collection gained through their experience working with it. At both museums, collection managers alerted researchers to available documentation and other representations, using their knowledge of the recordkeeping systems created by collectors to steer researchers to useful resources. Given the variation between individual collectors' recordkeeping practices, researchers were often unaware of the type and extent of such records and relied on collection managers to understand what was available. Second, botanists and archaeologists both occasionally questioned the accuracy of some records. Botanists evaluated the quality of contextual information in large part by assessing the expertise of the person who provided it. Their knowledge of the collector or annotator's reputation was the central factor in their assessment of the trustworthiness of specimen determinations. Archaeologists also sought to verify artifact metadata, however they did so primarily by using corroborating evidence.

Documentation of context was not always linked to a specific author and was derived from several sources including excavation and archival records.

5.8 Using Data Consortia

Although researchers at both sites engaged in their own aggregation of data, combining information derived from objects from multiple sources, the use of database consortia varied widely between botanists and archaeologists. While many of the botanist researchers reported using the Global Biodiversity Information Facility (GBIF) database and the JSTOR Global Plants tool, the archaeologist researchers reported no equivalent tool they used in their own research. In this section, I report the experiences of my researcher participants with data consortia, arguing that the presence or absence of such tools from these individuals' work lives is a factor of their research social world's approach towards data reuse.

The JSTOR Global Plants tool is an online database of high resolution scans of type specimens contributed by hundreds of herbaria throughout the world (including the University of Michigan). Users can see the specimen with its collector and annotation labels, zoom in on any part of the plant to examine morphological features, and take measurements of those features. Access is subscription based, allowing botanists affiliated with contributing or subscribing organizations to access the content. Type specimen digitization projects like JSTOR's are widely lauded in botany for making these specimens accessible without needing to go through the loan process. Research scientist HR5 explained that the morphological examination he does with specimens can be done using well-scanned images as well.

> This has been a big push in the last 10 years to digitize types. And the reason is that this way they can limit the number of times they have to send it places. So, if they're limiting the damage to types they can preserve them better. It's one of the main reasons. And in many cases, looking at the type or the image of the type, especially a good scan, is enough to give you the information you need to determine […] what taxon that type belongs to. So, this whole push for digitization of type specimens, especially getting everything databased, is a huge help […] Especially once it's online, you can just go online and see if they actually have what you're looking for. You know the specimens you're looking for, even if they're identified wrong or identified differently. So that's a big help.

The Global Biodiversity Information Facility (GBIF) was mentioned by three of the external researchers I interviewed (HS2, HS3, HS10) and three Herbarium staff members (HS3, HS6, HS8) as a valuable resource for mapping plant species occurrence data. GBIF provides specimen-centric data compiled from organizations across the world, and can be used to track changes in populations of organisms. The botanists I spoke with agreed that it was a powerful, valuable tool, but they found fault with their inability, as users, to verify the accuracy of the individual records in the database.

For taxonomists, knowing that a specimen in GBIF was properly identified was a challenge. Because the records do not link to specimen images, users cannot double check a specimen visually, as they can with JSTOR's Global Plants. Several botanists used the same workaround: by mapping a species, they can see if it was recorded as having been collected somewhere it could possibly grow. As HR3 told me,

> You can basically plot information for the ones that are geo-referenced and you can see a map [...] and you're just going to check if things look really out of place. In the map, if you just don't recognize those localities, if you know your group you can say, "Those were probably wrong." But otherwise, you just kind of have to trust that it's correct. It's extremely difficult, though, that's one of the major hurdles in using those. It's just the assumption that it's probably right, but you have no idea if it's not.

Curator HS6 echoed this concern in his discussion of GBIF.

> You're downloading data from a central repository and assuming that it's correctly identified. I mean, the reason why people want to look at specimens is because they want to verify that, right? So sometimes you can do that if they're images, but GBIF as far as I know [...] it's just the records and the georeferencing so you can map things easily. So some people are fine just doing that, it depends on the nature of their study. Other people will want to verify that so the data itself won't be enough unless they can really double-check it [...] So that's where again, it becomes an authority issue in how far you'd want to believe that data. And we find there are sometimes, not necessarily competing databases, but alternate databases that diverge in what information they provide or how they treat things [...] and then if you are the user it's not always easy to know who to follow, right? Or sometimes where their information comes from because they don't necessarily give you the metadata to interpret that, so then it gets tricky.

In systematic botany, a field where determinations may be contested between individual researchers and several understandings of the organization of a taxonomic group often exist simultaneously, being able to see a record of the opinions upon which a determination was made and to judge for oneself is highly valued and is one of the major ways in which herbarium data is evaluated. While GBIF offers aggregated specimen data, it does not provide users with the ability to verify determinations and to see the specimens themselves. In contrast, Global Plants offers images of type specimens that can be used to verify identifications, but with a much smaller dataset than that offered by GBIF. Botanists navigate trade-offs between the two with regards to their individual information needs, their comfort with ambiguity in a data set, and confidence in their own ability to find and root out incorrect data.

For the most part, archaeological researchers at the Kelsey did not use database consortia in their work. Several people mentioned individual museum websites they had consulted, including those of the Louvre and the Metropolitan Museum of Art, but only one source that could be considered a data aggregator, drawing from multiple collections, was mentioned: the Global Egyptian Museum. AR13, a doctoral student at Michigan, described using the site to generate comparanda for her research.

> There's this thing called the Global Egyptian Museum. It's a website that a number of European Egyptian collections are using. And it's not by any means exhaustive. It just has kind of the highlights from the collections. But it's pretty handy. So if you just wanna see wooden things, things made of wood from Egypt in this small number of collections, you can get images of some really great little things and I used it sometimes when I was looking for wooden objects. […] Do they have scribe statues, do they have ibises, do they have... whatever. And that's great because otherwise, if I didn't see something there that I liked, then I would go to the Louvre website and look there, and then the Turin Egyptian Museum website and look there and then the British museum and on and on... Boston, Met, Getty, you know, down the line. […] And not everybody, I mean there's no uniform standard for publishing their materials online. There're some museums that you would think would be online. You'd expect a smaller one not to and a bigger one to have everything up, and it's not all uniform and not all accessible.

The Global Egyptian Museum provides a simple user interface. Users can browse or search by object type, material, period, site, or museum, retrieving an object record that includes object details, a photograph, and a bibliography. As AR13 suggests above, it provides an easy way to access basic information about Egyptian archaeological objects, from one centralized source. While the archaeologists I interviewed appreciated online access to collection information, database consortia were not, on the whole, part of their research toolkit. Rather than accessing a single pre-existing source, archaeologists assembled their own data derived from multiple sources.

The issue of data aggregation did arise in my conversations with archaeologists who were involved in excavation. They were interested in tools for data sharing, but saw too many obstacles to sharing archaeological data. AR6, a research scientist at the Kelsey who was in the planning stages of a new excavation, showed a lack of familiarity with data sharing tools that was typical of this group.

> Well, I think now there's more and more of an expectation that you will share. [...] If you've got an NSF grant, for example, you're required to share your data somehow. And I don't actually know. I haven't gotten to that stuff yet, so I don't actually know how that's done. I know that there's a... There is a sort of an open source data bank for archeological... Have you run across this?
> Interviewer: There is one called Open Context.
> AR6: Open Context, okay. Yeah. I don't know how it works really, and I mean it's a great idea in principle. In practice, though, I have to think it's kind of a nightmare […] Because there's no quality control going on. You know, there's no standards of usability, there's no standards of the kind of information and how things are linked. So, even polished data can be very difficult to use. […] For example, you can a have a list of archeological contexts. Well, how do you display the stratigraphic and spatial relations among those contexts?

While using repositories for data sharing seems like an admirable goal to AR6, he is unclear about how it can be done, and has not yet investigated how he might share his own archaeological data. To the researchers I spoke with, museum deposit of archaeological artifacts was a given, online representation of those artifacts could not be expected, and sharing excavation data in some kind of centralized portal was an unobtainable ideal. In contrast, the botanist researchers used aggregated databases regularly. For these botanists, electronic access to representations of herbarium specimens had become a central part of their research infrastructure. For the archaeologists in this study, in contrast, some artifact data were available online, but those representations alone were generally inadequate for research use.

5.9 Staff Members as Internal Researchers

A great deal of research at the Herbarium and the Kelsey was performed by staff at the two museums. While I have included data from my interviews with staff at the two museums throughout this chapter, in this section I explicitly discuss the research use of museum data by staff members. In my interviews with collection managers and curators, I found that both groups performed research using museum data, but that the goals and outcomes of their research were different. Research by collection managers had two primary goals: creating accurate representations of objects in the collections and assisting others with their research requests. Their research work resulted in new or changed database representations and the furtherance of others' research using museum data. Curators also performed research that contributed to object representations, which collection managers considered to be authoritative. Curator research resulted in other products as well, most notably, museum exhibitions and catalogs (at the Kelsey) and publications geared towards audiences in their research social world. Collection manager HS3 at the Herbarium was the exception to this categorization—in addition to his collection management work, his content-based expertise made him an authority on a particular plant genus. He often contributed specimen annotations and performed some taxonomic research in that area.

Among the collection managers I interviewed, research work contributing to object representations consisted primarily of metadata verification, while curators offered authoritative identifications of museum objects. Herbarium staff were largely reliant on the specimen labels provided by collectors in their representations of data, since "Only the collector knows fully the circumstances of collection, and thus bears responsibility for sharing (on the label) what he or she knows about the locality, habitat, appearance, and attributes of the plant" (Voss 1999, p. 57). However, for some of the higher priority specimen collections, including types and plants collected in Michigan, collection managers went to greater lengths to verify data quality. Collection manager HS2 explained,

> We have an instance where we have obtained some historical collections, mostly with a little bit sketchy data but it will say something like, "Ackerman's Lake" and not give the county […] or somebody's farm is often mentioned. And we've gone to the old plat books and can find out where that farm is located and so we're going to add that information onto the label so that we can have more specific data.

Because the *Michigan Flora* project provides location data at the county level for specimens collected within the state, this historical collection received special attention to verify the collecting locality. Collection managers use a variety of resources for this kind of verification work, including plat books and authority lists of taxonomic and collector names accessible on the Internet, and the "Gazetteer of Obscure Michigan Place Names" database hosted on their own website.

At the Kelsey, AS1 perceived his role as a collection manager as creating only cursory records for undescribed artifacts, because of a lack of expertise in the artifacts themselves. He explained,

> Our backgrounds just so you know, the collections managers, […] we are both archeologists. We have knowledge of archeology. However, she and I [are] both new world archeologists, and this is all old world archeology here. We can research things to the point that we are the experts on the objects. We can research them and we can create very basic, cursory records for things or lists of things. Then it's up to the curators, whose job is to really look through those documents, they or their students who they assign to work on collections.

While the collection managers provided very cursory representations of the artifacts, including things like measurements and visual descriptions, more thorough representations were left to the curators and their students.

In my conversation with curator AS4 he described how he used the knowledge he gained through experience as an Egyptologist to identify objects in the Kelsey's collection, adding "more precise information" to their representations.

> As we go along, we try to add more precise information. […] There are hundreds of Egyptian gods, and very often you'll have a statue that's just indicated as an "Egyptian god statue." If I know what something is, I can usually give the more precise name to the god.
> Interviewer: I've been wanting to ask about how you would make that kind of determination. Is it based on the features of the god?
> AS4: Egyptian gods usually wear things that tell you who they are. Most Egyptians were illiterate so the gods usually had identifiable symbols. Until 1994, when I and my colleague […] were hired here, there had not been an Egyptologist on staff in a permanent way. So, a lot of the identifications in the database are vague, simply because the people who were doing this before didn't know some of this stuff. With sculptural representation, it's also often possible to identify the god by the pose. This is especially true for Graeco-Roman Egyptian gods where they are Egyptian gods, but they are being represented in traditional Hellenistic or Roman styles. That is sometimes the way. I mean if you've got a figure with its finger up to its mouth, you know it's the child god Harpocrates. But, yes, there are a number of things that you could use to determine who's being represented. […] A lot of what you use to identify objects, is something that comes over time. I mean, just from exposure to things.

Through "exposure to things," gained through his experience practicing as an Egyptologist, AS4 could confidently identify the gods depicted in Egyptian statuary. His content-based expertise resulted in more precise representations of artifacts.

Curators at the Herbarium similarly relied on their own content-based expertise to annotate specimens, updating their identifications as a form of data validation. By comparing one purported exemplar of a species with others, usually through direct visual comparison, curators (and collection manager HS3) could provide an authoritative determination of a specimen. They would use an annotation slip to record their determination, along with their name and the date, which would be attached to the specimen. Similar to the interview excerpt with AS4, above, expert knowledge in a particular plant genus enabled them to confidently identify a specimen at the species level, adding research value to that object through its authoritative determination.

Collection managers at both museums performed most of the research conducted in response to requests from external researchers. At the Kelsey they queried internal databases, exporting metadata to text or Excel files and sending them to researchers along with images of artifacts. This was the baseline response to researcher queries—AS1 explained "It's very likely they're interested in just photographs of things, so we'll send them jpegs or gifs, depending on what they're trying to do." For more complicated requests, AS1 searched the excavation and photograph databases, or made them available to researchers. If, after receipt of these representations, the researcher still needed to look at the artifacts (or the artifacts and archives) in person, the collection managers worked with them to schedule a visit.

At the Herbarium, because databases did not comprehensively describe all specimens, collection managers often did "hand searches" as HS7 termed it, going through specimens in storage to determine the extent of their holdings in the taxon requested. They rarely consulted field notebooks in response to researcher inquiries (as most researchers did not use field notebooks kept by other botanists), but they might search through representations made by mycologists whose specimens were at the Herbarium—the paintings, photographs, drawings, and microscopic examination notes that some collectors produced as they worked with fungal specimens, which change their appearance drastically as they dry. At both museums, collection managers' systems-based expertise helped them easily find these forms of object documentation. They knew who had created these materials and how they were organized, and mobilized that knowledge to answer questions about data holdings from researchers outside the museums.

Research resulting in exhibits (at the Kelsey) and publications (at both sites) was primarily the work of curators. Their descriptions of this research work were more complex than object identification, and often relied on a wider range of data types. Curator AS5 at the Kelsey described the research she conducted with a group of graduate students to create an exhibit on sculpture from Karanis. It was a provenance-based inquiry, requiring examination of a number of documentation sources from the excavation.

> I did a show on the sculpture from Karanis because sculpture was something I was interested in and we had a bunch of stuff from Karanis [...] I had three students, graduate students that were working with me on different components of the sculpture collection. We were trying to figure out which levels they came from, from the site, just from the information we had from the excavation records. What that meant about dating, where they were found, whether they were found in a house, in a temple, in a street, or wherever, trying to get a sense of the distribution of these sculptures over the site. Basically, we were doing an excavation report, an interpretative excavation report on the site and we published a small book about this, which was the exhibition catalog. And then we had the exhibition. […] Apart from the exhibition piece, everything else is what you would do if you were in Egypt because if this stuff wasn't here, you'd have to go there to study it. So, it's really no different. (AS5)

As an experienced excavator, AS5 described the research she and her students did with the Karanis sculptures and excavation records (which encompass a number of document types) as similar to the interpretation she would do at a dig. Collating information from multiple sources, they produced an exhibit and a catalog, giving students experience in interpreting excavation data and creating meaningful products for archaeological and public audiences, while teaching the students how to participate in an archaeological community of practice.

Herbarium curators, too, often relied on a broad range of data types in their research that resulted in publication. Curator HS6 described a research project he was involved in with a team of researchers.

> Now, we're doing several things, we're looking at one subgroup of this big genus. We've done molecular studies and that allows us to sort of break it up into subgroups. So we have maybe 20 subgroups that we call "sections." And we don't have every last specimen sample molecularly so there are a lot of species and names there that all we have are, say, herbarium specimens or their descriptions and sometimes those descriptions are not very informative. So, ultimately it comes down to looking at specimens to identify them and characterize them.
>
> And then for ones that we have not looked at sort of molecularly to sort of really say, "Oh, this goes here," […] we look at the specimens or their images to try to infer where they belong. So roughly we'll come up with this list for each of these sections of how many species they have and depending on the section sometimes half of those will be sampled molecularly so we can be really confident that they belong there and the other half we will have inferred that they belong there because of what we have been able to look at from the specimens and that way we sort of can accommodate everything into this grand system.
>
> Interviewer: And so it sounds like there is a sort of hierarchy of preferences from molecular data to a specimen itself to an image of a specimen?
>
> HS6: Somewhat. Yeah, you have to be careful at all stages. […] When you do molecular work, you need to also make a specimen. So that you know that you can go back and look at the plant that that came from. Otherwise, you don't know. So a specimen is always gonna be important. […] So it's a combination of all of those together, I think, that make the end product valuable.

This team used visual inspection of specimens (and images of specimens), molecular data derived from specimens, and published descriptions of species as research data, giving each a different kind of evidentiary value in their research. They formed the basis of their groupings on molecular data, but relied on visual inspection and published descriptions when molecular studies were not available to place specimens (and the species to which they belong) in various subgroups. The team assigned a higher evidentiary value to the molecular data, specimens, and specimen images they used, which they could directly examine, than species descriptions in the literature, which were sometimes "not very informative." Through this combination of data sources, used in different ways, they could develop an understanding of the taxonomic structure of the genus.

One major difference between research use of museum data from staff and external researcher perspectives was the kind of access they had to data. While external researchers relied on staff members to provide access to data, curators and collection managers could access data directly by visiting the object storage area and querying internal databases. In my interview with curator AS4, he told me about his process of finding documentation about a list of artifacts he wanted to include in an exhibit at the Kelsey, switching easily between information systems as he performed a provenance-based analysis of the artifacts' documentation.

> For things with the current exhibition, the context is very important. So basically I had to take an object list, search it in the excavation database, pull up the specific contextual information, then go to the photographic database to see what kind of photographs we have of the context. This then involved physically looking at the maps to try to find out where things were found and if we had an integrated database that had access to a body of material that was digitally available, you can just do that on a single computer. I mean there's some advantage to going around and messing with the actual archival records stuff. There's no real substitute for being around the objects. But it would make it so much easier, say for someone who isn't physically here. I mean this is the perennial problem that we have is the researchers decide they want to look at every piece of pottery from Karanis and find out about the context. But they want to look at all the excavation photos and that's physically impossible the way things are now. (AS4)

Through his access to artifacts, databases, and maps documenting the museum's excavations, AS4 was able to determine the context for a group of artifacts. He contrasts his access to data with researchers outside the Kelsey, who are cannot see all of these resources on a single computer because they have not all been digitized. Collection managers work to provide access to offsite researchers, sending database query results and digital scans, but, as AS4 states, "there's some advantage to going around and messing with the actual archival records stuff" and "there's no real substitute for being around the objects."

Proximity to specimens was also appreciated by Herbarium curators, including HS1, who used them to verify his specimen determinations, which was an ongoing curatorial activity.

> One of the great utilities of these specimens is [...] Well, I always tell people identifying plants is easy, it's getting them right that is the hard part. So, one of the great aides to being right here is the ability to go back into the collection and compare what you have just identified with other material and then you'll look at it and say, "where did I mess up?" or "yeah, of course, that's it." That's done a lot, mostly by people here, but also by visitors sometimes.

In this example of a type-based research use of collections, access to comparative material helps HS1 confirm that his species determinations are accurate. People affiliated with the Herbarium do this kind of confirmation more often than visitors, whose use of the Herbarium is constrained by time and familiarity with the collection. Regular onsite access to specimens allows Herbarium staff to examine a greater number of specimens more frequently, contributing to their own content-based expertise as well as the accuracy of their specimen determinations, which in turn increases the value of Herbarium data.

5.10 Researchers and Social Worlds Revisited

This chapter has examined the strategies used by researchers in approaching their work at the Herbarium and the Kelsey. I have discussed finding, accessing, evaluating, and learning from objects in these two settings, examining the influence of aspects of archaeological and botanical social worlds on museum-based research practices. Throughout, I have maintained that the individual researcher's questions, goals, and position within their social world are major factors guiding the research process. In this section, I expand upon my findings, emphasizing their social and infrastructural dimensions.

I began this chapter with the research question *What is the relationship between museum objects, their representations, and research use?* My interviews and observations with researchers have revealed varying reliance on museum representation systems and objects in the course of research. The need for access to objects, metadata, and documentation differed among both botanists and archaeologists, corresponding to the kind of analysis (type- or provenance-based) researchers intended to use. Type-based analysis required access to the object itself, or a high-quality image of the object, while provenance-based analysis could frequently be performed with access to metadata about the object retrieved from museum representations, database consortia, or published work. Provenance-based analysis was only an end point for a few botanists, those that used specimen metadata to inform species distribution models. Other researchers at both museums returned to the object, to examine aspects of its physical characteristics. Beyond this broad similarity between forms of inquiry in botany and archaeology, a number of factors related to the researcher's disciplinary social world and the collection management and representational practices of the two museums influenced researcher experiences at the two sites.

The relationship between an object and its context was of central importance for both botanists and archaeologists; however, context was much easier to interpret in the former group than in the latter. The herbarium specimen sheet is a site where museum and research practice directly intersects. Botanical context is created and recorded by museum staff and researchers in a single object, as they add annotation slips directly to a specimen sheet. The herbarium specimen itself functions as a boundary object, coordinating the work of researchers and collection managers as the former group studies and annotates the specimen and the latter group uses those annotations to update catalog records and manage the physical organization of the collection (Star and Griesemer 1989). At the Kelsey, context is attached to an artifact through the accession number written directly on it. To access that context, though, a researcher must use one of a number of information systems, including an electronic catalog, object files, and excavation records (depending on the object's origin). Simply knowing the range of possible resources in which documentation of an artifact's context may be found is a challenge that requires expert help from staff in using the systems available at the Kelsey.

Research practices at both museums revealed an interesting relationship between museum objects, metadata, and other representations as researchers selected and assembled the data they required. At the Herbarium, specimen metadata sometimes became the primary object of inquiry, where species name and collecting location and date were the pieces from which ecological niche modelers derived their data. For many other researchers, physical access to a specimen was necessary, to extract data based on visual, microscopic, and genetic examinations. These systematists needed label metadata and specimen access in order to perform their analyses. Data validation often meant verifying that a specimen had been correctly described at the species level. While botanists might doubt other aspects of specimen metadata, such as collecting location and date, species name was the only element of specimen metadata they would change, by adding an annotation. Digital representations of specimens could be used as research data if they met certain standards of evidential value, allowing the researcher to verify their accuracy visually, through digitized specimen sheets or mapping tools.

At the Kelsey, representations of artifacts played a major role in the research process, as many archaeologists relied on documentation of an artifact's origins to reconstruct its provenance. The information held in excavation records, object files, and archival records linked artifacts to their contexts, providing an essential part of the evidence needed in archaeology to construct data. In addition, both internal and external researchers at the two museums relied on their own content-based expertise, gained through practice, to identify objects by type. They recognized physical characteristics of objects, ranging from the shape and texture of leaves to the iconographic style of statues, and used those to interpret an object.

For external researchers in both museums, relationships with people and institutions were crucial resources. Advisors and mentors informed researchers of useful collections, facilitated introductions to museum staff, and vouched for the individual as a bona fide researcher who could be entrusted with museum data. Institutional relationships often lasted throughout a researcher's career, allowing them to spread their knowledge of specific collections to future students and providing them with support networks and collections from which to draw in future research. Particularly in botany, where one cannot borrow specimens without affiliation with a herbarium, the relationships between individuals and museums are strong, and are codified in the norms of that social world.

Researchers' methods of finding materials for their work reflected the individual's position in their research social world. For archaeologists and botanists that were relatively new to their field, recommendations from mentors and colleagues were an essential means for finding collections they might use in their work. They often selected their home institution's collections by default, as course assignments, exhibit opportunities, and relationships with curators guided new archaeologists to the Kelsey. In a similar vein, the need to deposit voucher specimens, as well as easy access to resources like equipment, the Range where specimens are housed, and staff assistance brought fledgling botanists at the University of Michigan to rely on the Herbarium.

In both museums, working with staff members was a central part of gaining access to collections. Collection managers controlled access to the objects themselves, and mediated access to contextual information beyond what was publicly available. For botanists, this included knowledge of collectors and auxiliary records of specimens, including field notebooks, photographs, and drawings. Archaeologists made use of a wide array of records that the Kelsey provided them access to, from a photographic database to archaeological drawings. Without help from collection managers, these detailed sources of documentation would be unavailable.

Researcher experiences with data consortia indicated a number of needs from these systems that should be met in order to make them truly usable by members of their communities of practice. In botany, the need to verify the veracity of data is paramount. In order to know that determinations were made correctly—that the data describe the species they are purported to—botanists, ideally, would be able to access a specimen image. In systems that do not provide specimen images, they use mapping tools as a verification mechanism. If the researcher knows the geographic distribution of his or her plant group, they can determine if plotted points are feasible. Up to date annotation data also helps botanists evaluate specimen identifications, based on their familiarity with the reputations of other researchers in their field.

Both of these mechanisms require a degree of content-based expertise, however. They assume that the researcher knows their taxon well enough to know where to expect it to grow, and that the researcher knows the literature of their taxon well enough to identify people who have annotated specimens and make judgments about their level of expertise. In this way, data consortia favor more experienced botanists, who have the background knowledge needed to verify data, gained from their experience in a research community of practice.

Archaeological researchers at the Kelsey used data aggregation tools primarily to find comparanda. Developing a corpus of objects similar to the one a researcher is studying is easily done on the Internet, although there was no overarching consensus on which sites were most useful for this purpose, in stark contrast to the botanists, who frequently mentioned a core group of tools, illustrating a developed set of online resources built by and for this community. Researchers using archaeological museum collections had low expectations that museum catalogs would be available online, or that the collections would be thoroughly described within them. The same was true among botanists in terms of their expectations of individual herbaria, but the centralized databases botanists used were well known throughout the field. Continued funding for herbaria to contribute to database consortia fuels the growth of these resources, but no similar efforts have impacted the archaeologists' research work. With the large amount of contextual information needed by researchers, connecting objects to their context in an electronic format would be a boon to researchers, but the work and resources required for digitizing, organizing, and managing resources like excavation records, accession records, object files, and photographs is daunting. Unless data sharing and reuse gain wider acceptance among archaeologists in this country, becoming norms of that social world, it is unlikely that the resources needed to do this work will be mobilized to create such research infrastructure from the artifacts, representations, and documentation held by archaeological museums.

Chapter 6

Conclusions

Substantial prior research has centered on data reuse, however, little of that research has focused on museums as data repositories and the reuse of the substantial amounts of data in their care. This study was designed to address this shortcoming in the data reuse literature, through a comparative analysis of the research use of two museums serving members of two different disciplinary communities. In this chapter, I summarize the study, including its major findings and contributions, discuss its limitations, and suggest directions for future work.

6.1 Summary of the Study

This study has examined data reuse in two museums from the perspective of museum staff who make data available and the researchers who use that data in the disciplines of botany and archaeology. This included an analysis of the practices of museum staff in making materials available to researchers, and the practices of researchers as they analyze museum data to meet their own goals. In the first chapter, I developed the conceptual framework guiding the study, using the concepts of social worlds and communities of practice to focus attention on the research infrastructure surrounding disciplinary communities and the norms uniting the work of their members. In chapter two, I explored the literature related to data reuse, museums as information infrastructure, and the history and research methods used in archaeology and botany, particularly as they relate to data reuse. I situated this study in the literature by considering museums as an important data provider in the research infrastructure of several disciplines.

In the third chapter, I described the study I designed to understand how museums function as resources for building the knowledge of a discipline: a comparative case study of the research process at two museums. I introduced the interview, observation, and data analysis methods I employed in the study. I used iterative coding of interview transcripts and observation notes to interpret the material from meetings with 14 museum staff members and 31 researchers using the collections at the two museums to address the research questions: *What is the relationship between museum objects, their representations, and research use?* and *what factors influence the practices of staff members as they describe and manage museum data?*

I presented my findings in chapters 4 and 5, dealing with staff work in making museum data accessible (chapter 4) and researcher work using those data (chapter 5). In chapter 4, I analyzed staff members' practices to facilitate research, including representing collections, providing access to them, and serving as an expert resource about the collections and the museums' information systems. My major findings centered around several different factors impacting representations of data at the two museums: the state of the discipline's data sharing infrastructure, the legacy of earlier information systems, and the influence of staff members' professional backgrounds. These factors influenced practices at the museums on three levels: disciplinary, institutional, and individual.

The larger infrastructure of the disciplinary social worlds served by the collections was an important factor in the museums' representation practices. In botany, the long tradition of loans and exchanges between herbaria along with the standardization of specimens (in their physical format and label information), have both supported the massive specimen digitization projects in which herbaria like Michigan's participate. Grant programs combining specimen digitization and intra-institutional research work strengthened relationships between herbaria, while guiding their digitization efforts. Pressing research issues in biology, like understanding and modeling global climate change, have driven the growth of these funding streams. This research environment impacts data sharing by incentivizing herbaria to adopt standards for data representation and to develop interoperable databases to aggregate and share data. In archaeology, data sharing is a difficult task, and it has not become a widespread practice. In this environment, data collections like the Kelsey's remain independent, with little incentive to build or join larger consortia.

At the individual museum level, the current information systems evolved over time. They were reliant on documentation provided by collectors, which staff members translated into the museums' database structures. Those structures, in turn, were based on previous systems used by the museums, and in some cases collection metadata was simply copied from one format to another (the Kelsey's online catalog, for example, was based directly on its card catalog). As (primarily paraprofessional) staff moved content into from one system to another, they reproduced the representations in each new system—the information captured remained largely the same.

In both museums, the extent of documentation provided by data producers (i.e. object or specimen collectors) directly influenced the representations staff members could create. Older records were generally less detailed, and while more detail about objects might be added through later research use, collection managers were careful to denote the source of newer information and to clearly record it as additive (rather than provided by the original collector). By recording the provenance of newer information, museum staff facilitated users' judgments about the validity of that data using criteria like reputation of the information provider. However, limitations in the information systems often kept that information hidden to external users. At the Herbarium, specimen imaging did not include annotations that had been made to a specimen after it was imaged and database records (when available) also did not always reflect those changes. At the Kelsey, staff did not provide the source of metadata in publicly available database records but would give more information about objects to researchers when requested. While the Kelsey's collection managers sent database records out to researchers, the original documentation was still needed and consulted frequently.

At the level of the individual, I identified ways in which a staff member's social world membership impacted their function in the museum's information infrastructure. Corresponding to their roles in the museum and the university, as well as their disciplinary backgrounds, social world memberships guided the way individuals performed their work in museums. Collection managers developed systems-based expertise while content-based expertise defined the curator role. Identity frictions experienced by staff members challenged the way things were done, as changes within botanical research practice were altering the makeup of Herbarium staff with the evolution of research norms. Staff members welcomed some shifts in subworlds, however, including a shift in collection management practices from a primarily archaeological to a primarily museum professional orientation, which is leading to an increased emphasis on data standardization at the Kelsey.

The systems-based and content-based knowledge associated with their roles also influenced the kind of assistance that individual staff members offered to external researchers. At the Kelsey, excavation records provided needed detail about the context of individual artifacts, but the variety of record keeping practices used at the sites (and in some cases, at a single site) made collection managers' systems-based knowledge an essential resource for using the materials. Systems-based knowledge at the Herbarium enabled collection managers to know the extent of collection documentation and easily lead researchers to useful auxiliary information. Content-based knowledge at both museums helped curators validate data by confirming or disputing the identification of some subset of the collection, an action that was prompted by researcher requests, curator research projects, or the arrival of new objects to the collection.

In chapter 5, I addressed the experiences of researchers using museum data in their own work. I characterized their research in museums as primarily either type-based or provenance-based, depending on their overarching goal in comparing similar objects or in making inferences about an object based on its original context. Type-based research was primarily comparative, where researchers used a group of objects of a similar kind to discern differences between them, while provenance-based research was primarily concerned with the source of the object, requiring certainty about an object's original collecting location (in botany) or documentation of its origins (in archaeology). Examples of type-based research included botanists who sorted specimens into piles based on morphological differences and archaeologists who grouped figurines together based on their iconography. Botanists using provenance-based research were often modeling the geographic distribution of a species or seeking new specimens in old collecting localities. Archaeologists engaged in provenance-based research were determining the relationships between objects based on their original juxtaposition at an excavation site or tracing the history of purchased objects at the Kelsey. While these two categories frequently overlapped in an individual researcher's work, they are useful in considering the dimensions of information that researchers wanted to derive from their use of museum data.

Researcher's social worlds influenced their means of learning about and accessing data. Researchers who were not previously affiliated with the museum used publications, mentors and colleagues, databases, and organizational reputation to locate data. They relied on interactions with curators and collection managers to access data. Researchers affiliated with the museum or with the University were often drawn to use the collections because of that affiliation. More established researchers maintained relationships with particular museums to work with collections repeatedly over the span of their careers. Junior researchers were generally introduced to museum collections by mentors, either through research collaboration or through recommendations based on the senior researcher's experience with museum collections and knowledge of their holdings. Relationships between institutions in archaeological and botanical social worlds are strengthened by generations of researchers guiding each other to the resources they themselves have used. Researchers used these relationships, along with available information in publications and databases, to find and access museum data.

Researchers relied on aspects of object metadata to determine whether or not particular museum objects would be useful in their work. Which metadata they used to make that decision depended on their research goals. Ecological niche modelers using the Herbarium and archaeologists studying the use of domestic space in the ancient Near East using the Kelsey both needed accurate location data in order to study the object's physical position in relationship to other location-based factors. Researchers conducting ecological niche modeling required location data at the appropriate level of specificity to work with their other data layers. Specimens bearing general location data, providing, for instance, only the region in which they were collected, might be excluded from a data model.

For researchers who used the museum catalogs to focus their work with data, staff decisions about the representation of objects in information systems had a major impact. Several researchers told me they had been unaware of some of the materials relevant to their research because catalog search results were incomplete. More experienced researchers, like AR10 in her search for a specific kind of figurine at the Kelsey, had a sophisticated understanding of the limitations of museum catalogs (both in terms of public access and the comprehensiveness of records) and used interactions with staff members to mitigate those shortcomings. While direct contact between researchers and staff helped alleviate the effect of incomplete coverage and inaccurate representations, more comprehensive and accurate information systems would help the research process, giving users a clear picture of the extent of available resources pertaining to their work.

The findings chapters examined how museum staff members make collections amenable to research and how researchers find and use museum data to advance knowledge in their own disciplines: archaeology and botany. I have argued that a number of similarities, and some important differences, emerged between the two museums because of characteristics of the norms and practices of the research social worlds they support. For example, while researchers in both fields wanted to compare objects with shared traits as they perform what I have called type-based analysis, botanists have developed widely-used digital data aggregation tools bringing together material from numerous collections to support this practice, while comparable systems for archaeological collections are still rare. The Herbarium participates in several data consortia and the Kelsey does not, reflecting the development of data aggregation tools in the disciplines they serve. In part, this difference mirrors the relative success of standardization in the two fields. Botanical data is replete with standards that span the discipline, from binomial nomenclature to herbarium codes and specimen citation formats. In contrast, archaeological data standards are often local to a particular excavation or a geographic region of study (e.g. object typologies). As institutions forming part of the information infrastructure supporting these disciplines, the Herbarium and the Kelsey Museum are shaped, in part, by the norms structuring the social worlds their collections support.

This study has used a social worlds perspective to characterize the norms and practices influencing museum staff and researchers. Members of a social world share activities, resources, and meanings of what membership entails. The evidential culture of a research social world defines how data are captured, described, validated, managed, and used as evidence. Within research social worlds, subworlds arise from groups of researchers with new methods of practice and perspectives on data. In the museums I studied, membership in multiple subworlds and the prominence of new subworlds created some identity frictions for members, who experienced tensions between competing demands and conflicting ideas about practice. Museum staff used shifts in evidential culture to shape their practice in the management and representation of data to fit the needs of their users.

6.2 Contributions and Implications

This research offers several contributions to the museum studies and data reuse literatures. In this section, I outline those contributions.

6.2.1 Contributions to Museum Studies

This study contributes something that is missing from the museum studies literature: an in-depth look at research uses of museum data. While surveys of museum staff have been conducted to gauge the extent of research use of collections (e.g. Merriman and Swain 1999), the experiences of people in the process of conducting this research have been overlooked. By exploring researchers' use of a range of museum resources, including objects and their representations, documentation, and the expertise of museum staff, this study offers a nuanced understanding of the ways that researchers find, explore, understand, and repurpose museum data, as well as the relationships between objects and their representations (including metadata) in the research process.

The qualitative methodology used here brings to light aspects of the research experience that would not have been exposed through quantitative methods like survey. During interviews and observations, researchers and museum staff revealed the relationships they perceived between museum resources, explaining how and why they were useful in their work. This project has demonstrated the value of interview and observation methods in gaining an in-depth understanding of museum-based research.

Museum collections have both internal and external research audiences. Curators and other staff, with unparalleled access to collections, had different perspectives on the research process from unaffiliated users. With access and proximity, they became expert in the objects and information systems for which they were responsible, reflecting their functional roles in the museum and their content knowledge. The research work of curators included authoritatively identifying objects related to their field of expertise, correcting and adding detail to database representations of objects, and creating often complex data assemblages from multiple sources to come to new conclusions about the taxonomic structure of a genus or the interpretation of an archaeological site. The research work of collection managers, in contrast, provided more complete collection catalogs, verifications of metadata elements, and support to external researchers, in response to requests about available data sources. They mobilized their knowledge of information systems in the museum to respond to questions, often referring researchers to resources of which they had not been aware. This study has disambiguated staff research with museum data from research use by those outside the museum by showing how research by staff members supports the collection, the research of others, and contributes to new knowledge in a research social world. With continued access to data, staff members increase their expertise with the data and systems for which they are responsible. They feed new knowledge of the objects back into the representations they create and manage.

Through the disambiguation of internal and external research use, this study has also spotlighted the role of institutional affiliation in facilitating museum-based research. An institutional affiliation with a university, research organization, or museum enabled outside researchers to present themselves as bona fide users, which helped them gain access to collections and, in some cases, form career-long relationships with museums. Understanding the ways that researchers perceive institutional affiliation can help museum staff strategize about ways to increase research use of their collections by strengthening pre-existing institutional relationships, developing new relationships, or taking steps to encourage use by researchers without institutional affiliations.

The study has revealed strikingly different needs for documentation in the research process in archaeology museums and herbaria. Many of the archaeologists I interviewed required a broad range of documentation from various sources inside and outside of the Kelsey, from excavation records to archival materials. In contrast, most of the botanists (with the exception of mycologists, who found a range of records useful) only needed the information that was available on the labels attached to the specimens they examined. Researchers viewed field notebooks documenting the collection of specimens as an individualized form of recordkeeping that would seldom need to be shared with others. These findings suggest that archaeological researchers would benefit more than botanists from the digitization of records documenting collections. Unfortunately, digitizing archaeological records and representing the connections between them is a daunting task, given the broad scope of relevant materials.

The importance of museum representational practice to research use has been confirmed by this study. Collection databases helped archaeologists gain a preliminary understanding of the scope of available resources, once they had determined that the Kelsey had relevant materials. Botanists could use databases to access scanned images of some specimens, which reduced the need for hands-on access to the specimens themselves. The granularity and completeness with which staff members had created representations of the collections impacted the success of their searches. While they found these systems useful, however, many researchers understood that they were not complete and should be supplemented through direct conferral with museum staff. As tools for discovering the extent of relevant collections, then, catalogs of the collections were necessary but not sufficient. The vital role of collection managers, as the people who both maintain information systems and help users to bridge the systems' inherent gaps, would be difficult to overstate. This study highlights the central role of these individuals to research use of the information infrastructure of museums.

In this digital era, when scanning, imaging, and three-dimensional imaging of collections are goals for many museums, there remains a great deal of value to all of the objects that may never be seen on exhibit, have not been digitized, and are stored away, awaiting use. These hidden collections can be used to answer questions that advance knowledge of the human and natural world. This study contributes to the museum studies literature by speaking to the value of collections for research, demonstrating the importance of museums as a component of research infrastructure.

6.2.2 Contributions to Studies of Data Reuse

Although the data reuse literature is continually growing, there is little within that literature focused on the reuse of museum data. While Van House's work (2002a, 2002b) deals with data derived, in part, from museum collections, her focus is on users' strategies in establishing trust in networked digital data—it does not deal with museum contexts explicitly. By examining data reuse in museums, this study expands the discussion of data repositories and their use. Within museums, data are often related to physical objects, and research may involve interaction with the original object itself, a (digital or analog) representation, or documentation about the object. In contrast with research modes where an inscription may be kept and the original materials not retained (Latour and Woolgar 1986), in museums both physical objects and their representations remain important. The researchers I interviewed valued both digital and analog materials in their work, recognizing that both formats were useful in meeting different research needs. At a time when reuse of digital data is a focal point for many researchers, this study provides an understanding of the relationship between digital data and the underlying objects from which they were created. In addition, it contributes an understanding of researchers' selection criteria, when considering using an object or its representation in their work.

Museums hold vast amounts of data that is essentially locked, from a research perspective, through relative inaccessibility. The more we understand data reuse practices in museums, the more we can unlock that data, by using information about how people navigate through it to make it more accessible. In this study, I contribute to that effort by documenting and analyzing data use. Museum data are a mix of objects, representations, and metadata, used in numerous ways to answer various research questions. While access to a museum object allowed researchers to perform analyses that would not otherwise be possible—including close examination, measurement and description—metadata derived from the object, if properly verified, could fulfill some research needs, particularly for the botanists in this study. Original documentation had a great deal of evidentiary value for archaeologists who required an understanding of an object's provenance, but it was rarely consulted by botanists. Aspects of the object and its representations (in metadata and documentation) functioned as research data in relation to the research question asked by the user. In addition to expanding the portion of their collections that are included in their databases, as the Kelsey and Herbarium continue to do, museums can unlock collections to research use by making their documentation more readily accessible to researchers. Given researchers' need to consult original documentation, digitizing these materials is a logical (though challenging) next step. Systems that knit together different kinds of documentation for the same object, linked by elements of provenance such as collector, location or find spot, and temporality, can allow researchers to access the entire web of information they need about an object. Systems permitting user feedback or annotation would enable researchers to record links between objects and outside documentation (such as the archival materials consulted by the group of marble researchers at the Kelsey). Users might add their own interpretations of objects to these systems, adding value directly to museum collections through their reuse.

This study also has implications for the design of data consortia. In archaeology, efforts at creating data consortia have focused on recently produced digital data rather than their historical counterpart: research records from older projects, like those attached to many museum collections. This is wise from a practical perspective—working with recently produced data means that curators of digital repositories can collaborate with data creators to capture needed contextual metadata as they ingest content. However, legacy data from completed archaeological projects should also be included in these systems. Collection managers' systems-based expertise will be an essential component of these efforts. Data consortia projects should begin working with museums to ensure that legacy datasets are appropriately ingested, to unlock museum data for research use.

In botany, where data consortia have become a major part of the research infrastructure, this study offers several contributions. First, it has demonstrated the value of high-quality specimen imaging to researchers. JSTOR's Plant Science database reduces researchers' need to consult type specimens directly because the specimen images and tools provided by the interface allow them to do the close morphological analyses they need to perform. However, the comparative analysis botanists do with physical specimens, sorting them into piles and annotating them with post-it notes, suggests several ways to improve the online experience with digitized specimens. Providing the ability to compare specimen images side-by-side onscreen would be a valuable digital analogy for the pile-sorting botanists do, as would the ability to add tags to specimen images and share those tags with the colleagues they designate. Second, the botanical community is still figuring out the best way to represent some of the more complex aspects of their data, including multiple annotations (particularly those made after a specimen has been imaged); multiple collectors for a single specimen; and associating specimens in different herbaria that share a collector number. Data consortia are appropriate venues for experimentation with techniques for communicating these aspects of specimens digitally, where best practices and new standards may emerge.

6.3 Limitations

As with any research study, this project has some limitations. In this section, I discuss the limitations to this work due to research method, sampling, and study design. Because this is a comparative case study, it deals in depth with two cases, but the findings may not be generalized beyond the cases themselves. As university museums, the two sites are not typical of museums as a whole, and as museums at the same academic institution, the University of Michigan, they share a single institutional context. The two case studies provide little variety along those dimensions. The museums do vary in the disciplines they serve—however, without a broader comparative viewpoint afforded by studies of other archaeological museums and herbaria, it is unclear how typical the two museums' practices related to representation and research may be within their disciplinary communities.

Another limitation stems from my participant recruitment strategy. Because my researcher recruitment strategy relied on museum staff to direct me to interviewees, I contacted people who had determined that one of the museums would be useful to them. These individuals had already planned or made a visit to the collection or arranged to borrow specimens from it (in the case of the Herbarium). In this way, the study only deals with somewhat successful instances of research. In the absence of unsuccessful examples of research, where the researcher determined that the museum would not be useful to them, I was unable to observe the full spectrum of research experiences at the two museums.

In addition, the study does not deal with data reuse that was not mediated through an interaction with museum staff. The study lacks insight into the research processes of users who did not require access to museum objects and did not contact the museum for more information, but were still able to use publicly available data from the museums. In that sense, it may overemphasize the importance of physical contact with museum objects as well as the importance of staff assistance during the research process. I respond to several of these limitations by discussing possible future work in the next section.

6.4 Future Work

In this section I explore several approaches to further investigate the research use of museum collections. These approaches address the limitations of the present study, suggesting research methods that fill in some of the gaps left in our knowledge of the museum research process.

One tactic to address the absence of "unsuccessful" researchers and those who did not require assistance from museum staff is the implementation of a web-based survey distributed through the online representation systems containing data from the museum. For the Kelsey museum, this would mean adding a survey to the museum's online database and the University of Michigan Library's instantiation of the database, but in the case of the Herbarium, a survey targeting all users of the museum's web-accessible data would need to be added to the Herbarium's online databases and the numerous data consortia in which it participates. Such a survey would be complex to administer through multiple web portals, but it would elicit information from users about their experience using data from a particular source and could be used to recruit participants for more in-depth data collection methods including interviews and focus groups. This kind of study would illuminate the research process from the perspective of users who do not seek (or may not require) physical access to collections in order to perform their work.

Another tactic to explore data reuse in museums involves replicating the study at a broader range of museums, varying by museum type, institutional affiliation, and collecting focus. The types of collections held by the museums selected for study is a particularly interesting dimension of variation. To learn more about the research of botanists, for example, botanical gardens are useful resources to study. How do botanists use living collections in research, and how does that differ from their use of herbarium specimens? Variation in terms of the research communities served by museums could be achieved through the selection of different sites, comparing, for instance, the research methods of historians and anthropologists using various museum collections.

6.5 Summary

As we seek to make research data more amenable to reuse, particularly through the growth of cyberinfrastructure, it is essential to understand the data reuse practices of researchers, as they work with multiple forms of data in numerous contexts. With this study, I have made contributions to our understanding of the reuse of museum data, a heterogeneous mix of objects, their representations, and their accompanying documentation. I addressed both the practices of museum staff that guide the management and description of research collections, influencing research use, and the practices of researchers in finding, accessing, and understanding museum data. I used the concept of social worlds to situate the approaches individuals take to these practices, based on their role within the museum and their training and adherence to the methods of a research subworld. As research subworlds emerge and change within the disciplines supported by these collections, the staff make-up of the museums changes as well, influencing the kinds of expertise available internally for work with collections. These changes caused some identity friction for staff members, who had to balance competing demands on their time and practices. I identified two forms of expertise related to management of museum collections: systems-based expertise (requiring a deep understanding of the information systems used by collectors and the museum itself, over time) and content-based expertise (fluency with the content of collections and subject expertise that facilitated authoritative determinations of objects). Using transactive memory (Wenger 1986), museum staff easily located the appropriate expertise throughout the organization to address questions about the collections.

In researchers' engagement with data at the two museums, I found two kinds of inquiries at work: type-based analysis, which involved a comparison of similar objects to discern differences among them, and provenance-based analysis, which required access to information about an object's origins. Type-based research was an exploration of categories, whether it involved an examination of morphological or genetic differences between specimens in the Herbarium or iconographic, material, or stylistic differences between artifacts at the Kelsey. Provenance-based research relied on accurate and appropriately detailed information about an object's origins to permit the researcher to make associations between an object and its source. While archaeologists often required access to the original documentation of an object's origins, botanists rarely did, trusting in a specimen label as an accurate representation. Provenance-based research in archaeology was a much more complex process, suggesting the need for sophisticated representations of data for this community.

An understanding of the role of institutional affiliation in the research process was another major contribution of this study. Newer researchers were frequently introduced to research collections by their more experienced mentors, through the latter individual's knowledge of museum collections and relationships with museum staff. The recollections of more experienced researchers, in turn, suggested a career spanning relationship between researchers and museums, as they returned to the same institutions again and again for their research needs. Museum affiliation is an important part of the research infrastructure for archaeologists and botanists working with these collections.

Finally, a major factor shaping the data sharing mechanisms at the two museums was the orientation to data sharing of the larger discipline served by these collections. The community's history of data sharing, the complexity of research material, and the prevalence of funding mechanisms for building data sharing systems influenced the practices of both museums. This study has indicated several avenues for future research into the reuse of museum data, including exploration of different disciplines, sites, and ways of accessing information about collections. Through an increased understanding of the research use of museum data, provided by this and future studies, we can determine how best to incorporate museum data in the data-sharing infrastructure of research communities.

Appendices

Appendix A: Semi-Structured Interview Protocol: Museum Staff

Introduction

Thank you for taking the time to speak with me today. Learning about your work with museum collections, their description, and their use by researchers will be an important source of information for my dissertation, which is investigating the relationship between the representation of museum objects and their use in research. Your participation in this interview is strictly voluntary- you may stop the interview at any time or decline from answering any particular questions you wish. Anything you say today will be anonymized and de-identified in my writing about the project.

Background: Work context

Please tell me a bit about your job, particularly in terms of your interactions with those who contribute objects to the museum, produce content held by the museum, or conduct research based on materials belonging to the museum.

Background: Collections/ data context

What materials make up an accession for the museum (objects, documentation including notes, field notebooks, photographs, metadata, etc)? (ask about computer programs used by researchers too- what from them is kept by the museum?)

Collections/ data processes

1. How do these materials come to the museum? Who is involved in this process *(collectors and museum staff)*?
    a. Where do accessions come from? Where did the most recent accession come from?
    b. How are new materials added to the collection? If possible, please refer to a specific example.
    c. What description takes place when artifacts are accessioned?
    d. Who is involved in the description of artifacts?

e. How has the description of artifacts changed over time? What methods has the museum used to record those descriptions? Can you show me examples of the changing descriptions?
f. Do you have procedural manuals for the description of objects (current or past procedures)? May I see them?
g. What standards do you use?
    i. When were they introduced to the museum and how?
    ii. Have you done retrospective cataloging to bring order records up to those standards?
    iii. Are there any secondary sources I should look at, about your collections or the methods you use to process them? (guides to the collection that have been published?)

Collections/ data use

1. How are the museum's materials used for research, and by whom?
2. What do researchers want when they use the museum's collections, and other research materials maintained by the museum?
    a. What is the range of research questions that researchers have when they approach the museum?
    b. What types of collections are they after?
    c. How do they use those collections?
3. Does specific content have specific research audiences? Which communities use what content?
4. Do researchers contribute to any of the collections of objects and information as well as using them? How does this take place?
5. Do researchers contribute metadata about the content?

Generic research process/ patterns of use

6. How do researchers find out about materials?
    a. What are you doing to increase knowledge of your collections among researchers?
7. How do researchers request access to content?
8. Who grants permission, and on what basis?
    a. Have you heard of requests for access to content being denied?
9. What does a typical research visit consist of?
10. How do researchers interact with the materials they use? (Where do they work, what analysis tools do they use?)
11. Can I have copies of any forms or rules you have for researchers?
12. How do people use the metadata, in your opinion?
    a. Are there researchers who JUST look at metadata and don't use the objects?
    b. Do they give you any feedback about the metadata? What comes of that feedback?

13. (If time for a specific incident) What goal did the researcher bring to using the collection? Do you think their goal was satisfied?

Request for more information: Describing materials

(If work entails describing materials) Would you be willing to be observed in the process of describing materials? If so, I'd like to ask you to do a "think aloud" exercise, explaining your thought processes and work procedures as you do your work. We can schedule a separate appointment for this purpose.

Request for more information: Research

(If work entails research of museum materials) Would you be willing to be observed in the process of doing your own research with museum materials? If so, I'd like to ask you to do a "think aloud" exercise, explaining your thought processes and work procedures as you do your work. We can schedule a separate appointment for this purpose.

Is there anything else you'd like to tell me about the research process?

Who else should I speak with about collection management and research at this museum?

Appendix B: Semi-Structured Interview Protocol: Researchers

Introduction

Thank you for taking the time to speak with me today. Learning about your work with museum collections in the context of your research will be an important source of information for my dissertation, which is investigating the relationship between the representation of museum objects and their use in research. Your participation in this interview is strictly voluntary- you may stop the interview at any time or decline from answering any particular questions you wish. Anything you say today will be anonymized and de-identified in my writing about the project.

Background: Work context

Please tell me a bit about your current work and the role of research within the context of your work. Is research a primary part of what you do?

Background: Research context

What is your general research area? How long have you been working in this area (*get an idea for their level of experience and career trajectory*)? Please tell me a bit about your research, including the types of information you use and how you obtain them. What is the research question you are bringing to this work? How does your research at this museum fit into this work overall? Is this your first time using collections at this museum?

Identifying the Data

1. What materials from the museum are you using for your current research? *(probe for specific information about artifacts/ specimens and their metadata and other representations)*
2. How did you learn about these materials?
3. What about the materials indicated to you that they would be useful in your research?
4. How did you arrange access to the collections?
5. What did you do to prepare for your visit? *(In terms of background research, etc.)*

Collections/ data use

1. How, specifically, do you use the materials?
2. How are these materials relevant to your research questions?
3. How do you derive information from them? What information do you derive from them? If possible, please show me how you use them for your research.
    a. Do you ever just use the metadata rather than museum objects?
    b. What is your interpretive framework?
4. What auxiliary information do you need in order to use these materials? Where do you get that other information? (both inside and <u>outside</u> the museum)
    a. How do you use the metadata associated with museum materials?
5. How does the use of museum objects compare to other types of research in your field?
    a. Is it a common practice to use this kind of data?
    b. What other data collection methods are common in your field?
        i. Are some methods more commonplace or well accepted than others?
    c. How did you learn to do research with this kind of material (museum material)?
    d. Is this your usual mode of data collection? What other methods do you regularly use?
6. How would you evaluate your use of these specific museum materials?
    a. Did they help you address your research question? Why or why not?
    b. Did you have sufficient information about the materials to use them in this case? In an ideal world, what other information about the materials would you like to have?
7. What do you expect to be the outcome of this research (book, published paper, etc.)? What other kinds of information are you using? How do you expect them to fit together in the final product?

Request for more information: Research

Would you be willing to be observed in the process of doing your own research with museum materials? If so, I'd like to ask you to do a "think aloud" exercise, explaining your thought processes and work procedures as you do your work. If you have time, we can do this now, or we can schedule a separate appointment for this purpose.

Is there anything else you'd like to tell me about the research process?

Appendix C: Data Analysis Code Book

Code	Definition
Access	Who has access to what materials and how they obtain access, in reference to gatekeeping/ permission, in particular [Also use for loans]
Accessioning	What the museum does with new objects or information, to make them part of the collection, describe them, and/or preserve and make them accessible
Aggregation	Looking at metadata from more than one source for analysis, also, institutions working together to provide access to their respective collections
Archival materials	Use of archival materials (notes, letters, photographs, etc.) in research [does NOT include field notebooks]
Audience	Audience for a given product, whether a scholarly audience, the general public, members of a university community, or other
Collecting focus	Mention of collecting focus for an individual or institution, now or in the past
Comparanda	Materials used for the purposes of comparative analysis (Particularly object collections- may be a comparison of collections at two or more institutions)
Condition of object	Statements about preservation of objects and in what condition they enter and re-enter the museum
Consultation	Consulting with others around data, research, or objects
Data entry	Entering data into a database for internal or consortium use- also discussion of data entry standards and procedures
Database	Use of database, whether public or only available to staff (Also use to refer to information pulled from internal databases and given to researchers)
Description- collector	Description created by the collector of an object or recordkeeping done as a part of collecting
Description- museum	Description created or formatted by the museum, including discussion of standards used
Description- user	Use of the collections by researchers feeding back into the museum's descriptions or changing its records in some way [including annotation of specimens]
Destructive analysis	Destroying as a part of analysis, in reference to removing a sample from an object or disturbing context during excavation
Discipline	Description or evaluation of a discipline, specifically archaeology or botany, including how it has changed over time
Discipline/ museum contrast	Distinctions made between disciplinary and museum practices
Evidence	What comprises evidence, how it is constructed in a discipline, OR role of object in the production of evidence, process of learning from objects
Exhibition	Direct mention of some aspect of an exhibition
Expertise	A researcher, curator, or staff member's specific knowledge within a field OR statement about how much someone (self or other) knows about a topic or process

Code	Definition
Field documentation	Documentation created in the course of field work- includes use of field notebooks
Field notebook	Use of a field notebook as documentation of the source of an object
Field work	The role of fieldwork in the research process OR discussion of how things are done in the field
Finding resources	Process of finding out about available materials [museum objects and other materials used in research]
Images	Value of images in documenting collections OR creating images for research OR reliability of images [includes but not limited to drawings and photos]
Interpretive framework	Basis upon which research materials are analyzed
Knowledge of collection	What, or how much, people know about the collection and particular objects [Person(s) with knowledge may be internal or external to the museum]
Knowledge of community	What community members know about each other- particularly who specializes in what and collecting strengths of institutions
Locality	Where an object was found [in archaeology, may include stratigraphic and/ or room information assigned to the site in which an object was found]
Museum deposit	The process of giving material to the museum, whether objects, metadata, or supplementary material
Organization of collection	Grouping of objects in collection, whether for storage or exhibition purposes
Other organizations	Discussion of using materials from organizations other than the museum at hand
Outreach	Museum staff's interactions with some kind of public audience, through exhibitions or publicity. May have an educational goal.
Prioritization	How priority is determined, for processing collections, who may publish on a collection, or for obtaining access
Protocol	Written statement of how things should be done
Provenance	Discussion of the history and origins of an object, or the importance of such information
Purpose of collection	The purpose of particular museum collections, whether defined as research, education, or other [particularly useful for discussion of materials that are not good enough for one purpose but are suitable for others ie. teaching collections]
Research area	An individual's research agenda in general- how a specific project fits into an overarching agenda OR topic or question(s) guiding a particular research project OR the question motivating interaction with a collection
Research- curation	Research explicitly related to an individual's curatorial duties, including creating an exhibition
Selection- accessioning	Criteria used to select materials for accessioning into a collection
Selection- publication	Criteria used to decide what is publishable [including findings or data sources]
Selection- research	Criteria used to select materials for research use

Code	Definition
Serendipity	Finding information one didn’t know was there
Specificity	Level of specificity of metadata and/or description
Verification	How information is verified by museum staff or researchers

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