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Essay
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Works Cited.pdf

Final Project
Thesis.pdf

Personal Essay

My thesis experience, including the research component, was more akin to a winding path than a straightforward road, despite my expectations. From the end of junior year to midway through the first semester, I had been researching my chosen topic: Late Woodland burial practices of Native Michigan tribes. Although I was happy with my topic and the progress of my research, I didn't feel like I was making a big enough contribution to the academic community. I wanted to research something new and important. Fortunately, I was approached by the Collections Manager of the University of Michigan's Museum of Anthropology. The museum had a collection of human remains that were infested with mold, rendering them useless for any kind of analysis. The Collections Manager was in a predicament; she did not have the time or a trained staff member to clean the remains, and there were no published guidelines on how to clean mold infested remains. I asked if I could make this problem my new thesis topic, and my research was approved by the Museum of Anthropology Director. For my new thesis topic, I decided to test and develop a "best practice" for treating and preventing the mold infestation of human remains.

After six months of researching a completely different topic, I had to start at square one. Although I am an Anthropology student with a Archaeology concentration and experience with human remains, I had no knowledge of conservation theory and application. Archaeological conservation was a pursuit germane to my field, but also completely foreign. After a few cursory searches on the MLibrary page and Google Scholar, I could not find anything specifically related to cleaning mold infested human remains. I decided that the best course of action was to consult real professionals. I emailed the two conservators at the Kelsey Museum of Archaeology and forensic anthropologists at MSU and University of Indianapolis about my research and experiment. These initial emails were crucial in providing me a list of seminal works to read and bibliographies to pull form. With a few recommendations for topics to search and academic journals to peruse, I started searching Mirlyn and ArticlesPlus. Still frustrated by a lack of results, I decided to broaden my focus. I split my research efforts into two different aims: first, I needed to gain an understanding of the conservation field and to see how my thesis would fit into a broader picture; and second, I needed to learn more about human remains conservation.

I had a lot of initial luck with the first research topic. Using terms as simple as "conservation" and "museums," I found lots of books and edited volumes on the topic of conservation. These resources provided a lot of contextual information on the historical development of conservation and the current state of archaeological conservation. I began to learn how conservation fits into archaeology, and the importance of combining these two scholarly endeavors to provide the best care for excavated materials. However, as I began to collect more and more research and notes on general conservation, I noticed a distinct lack of texts written from the archaeological perspective. None of the authors writing about conservation and its interaction with archaeology were archaeologists, and I did not want my thesis to become biased to the plights and opinions of only conservators. I emailed my thesis advisors and the Kelsey conservators, who supplied me with an unpublished article of theirs that surveyed archaeologists' opinions on conservation. Their unpublished manuscript became the only source representing archaeologists' viewpoints in my thesis, and it really highlighted the importance of thinking critically about ones' resources.

Research on human remains and human remains conservation proved to be a more difficult task. As I would learn through my research, human remains conservation is an incredibly underdeveloped topic, and human remains collections have suffered as a result from this lack of attention. There were two edited volumes at the University of Michigan that discussed human remains conservation, but the sources were mostly theoretical. The Kelsey conservators recommended a book written by ASU conservators, and this edited volume turned out to be the keystone of my human remains research. Unfortunately, the book wasn't in the university library collection, so I had to use ILL to access it. Once I had this book, I was able to use its bibliography, along with the "Cited by" and "Date" functions on Google Scholar, to find other important resources. Surprisingly, all of the books I used to study human remains had to be located with WORLDCAT and then requested through ILL, so I became very familiar with this process. In addition to the books on human remains conservation, I found several online resources, included PDF guidelines from various labs and museums, as well as government published conservation newsletters.

In the end, my research could easily be categorized as a collective effort. The personal communication with forensic anthropologists and conservation professionals provided me with recommendations for research and how to set up my experiment. When I needed to learn more about mold, I consulted biology and science literature and corresponded with U of M's mycology curator. My research pulled resources from many different fields, including sociology, physical anthropology, mycology, and chemistry. By using information from a diverse group of resources and fields of inquiry, I felt that my thesis really dealt with the entire picture. Through my research, I learned how to frame my topic within the important history and interaction of conservation and archaeology. My research allowed me to contextualize my thesis experiment within a growing epidemic of museum issues. I was able to give equal emphasis to all of the different aspects my thesis touched on, from conservation to safety measures, archaeological fieldwork, and current affairs in the museum world. The most important thing I will take away from my thesis experience and with me into the next stages of my graduate school career is how to utilize a variety of resources to conduct scholarly research.

Treating Bones
The Intersection of Archaeology
And Conservation

Stephanie Berger
Honors Thesis in the Department of Anthropology
University of Michigan
April 30th, 2013

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Abstract

Developed to house and preserve the world's material heritage, museums and other collecting institutions currently store billions of artifacts in their reserves. Unfortunately, the objects in museum storage, especially archaeological specimens, are continually deteriorating, and the aesthetic, cultural, and scientific value of these resources are threatened by the dismal state of museum storage environments. Traditionally, the care and preservation of these artifacts have been the responsibility of archaeologists and conservators; however, these professional fields have a long history of separation and misguided interactions that prevent archaeologists and conservators from working together to achieve the optimal preservation of these priceless collections. The precarious state of collections care is especially problematic for human remains, a unique category of archaeological artifacts that can offer unprecedented insight into ancient populations.

Even in museum storage, human remains serve important scientific, religious, and cultural purposes, and it is imperative that collections care professionals, including archaeologists, develop rigorously tested guidelines to preserve these artifacts. In order to identify the best practices for the care and removal of mold from infested human remains, I analyzed the University of Michigan Museum of Anthropology's human remains collection from Senegal, Africa, to contribute to the growing field of collections care standardization. Mold is a pervasive problem in museum environments, with all organic artifacts at risk for infestation, including human remains. The results of this thesis provide a series of recommendations for archaeologists and conservators to both prevent and treat the infestation of human remains.

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1. Museums, Bones, and Mold

Every year, a significant portion of the United States population visits museums, libraries, galleries and other institutions an estimated 2.5 billion visits per year to view the unique collections they house (Heritage Preservation 2005). When viewing these pieces of art or artifacts, few people realize that the objects on public display almost always represent only a fraction of the institution's collection, with an estimated 4.8 billion artifacts being held in public trust by these institutions (Heritage Preservation 2005). Although not on display, the thousands of objects in museum holdings are a vital resource for research, education, and public engagement.

Given the importance of their collections, museums have been dedicated to the preservation of their holdings since their inception; however, museum collections, especially archaeological specimens, are in a precarious state of continual deterioration. Dealing with the preservation needs of thousands of objects is a real challenge, and despite their best efforts, museums all over the world are failing. The results of several recent surveys have shown that many prominent institutions, such as the British Museum and the U.S Army Corps of Engineers, have collections of millions of continually degrading artifacts whose associated scientific and aesthetic values have been threatened or destroyed; without immediate action, many of these objects will disintegrate and be lost forever (Bawaya 2007; Heritage Preservation 2005; Knell 1994).

The current state of collections care is especially problematic for archaeological collections. The collections of artifacts and documents from excavations constitute an irreplaceable record, without which archaeologists cannot access the past for research, interpretation, and education (Childs 2003). Because archaeological collections have an "incalculable value" (Podany 2003:203), archaeologists have long emphasized the benefits of preservation work and included statements on the importance of preservation in their ethics guidelines (Joyce 2003). However, the alarming state of many museum and university collections indicates that archaeologists and conservators have not always been able to live up to these ideals and need to improve their preservation efforts.

One category of archaeological materials, human remains, has vast potential to reveal new information about the human past (Swain 1994). By studying human remains, researchers can address important questions about a past individual's health, diet, occupation, activity, etc. that cannot be answered using other material records. With scientific advancements and new technologies such as DNA sequencing and isotope analysis, human remains have the potential to contribute to future research and the interpretation of topics such as past migration, descent, and disease transmission patterns (Buikstra and Gordon 1981; Hunt 2001; Palkovich 2001). Surprisingly, excavated and archived skeletal collections receive the least amount of attention and collections care management in many institutions (Cassman and Odegaard 2004). The intervention of trained conservators in the recovery and care of human remains in both field and museum settings has been limited, resulting in a detrimental lack of protocols and best practices for the cleaning, handling, treating, and packing of human bones (Janaway et al. 2001). Skeletal material is at risk throughout excavation, analysis, and storage phases, and these organic remains are susceptible to the dangers of a museum storage environment (Janaway et al. 2001). One specific threat to human remains, as with all organic materials, is mold. Fungal conidia, airborne spores that act as seeds for new fungal growth, can be found on object surfaces in museums all around the world. Although benign in their dormant state, these fungal conidia can be easily activated and infest any organic artifact, potentially destroying the aesthetic and scientific value of an object (Florian 1997). Despite the universal problem that biological agents present to organic collections, there are no established best practices for dealing with mold-infested objects, including human remains.

Due to the precarious condition of human remains in many museum collections, Janaway et al. have called for the development of "best practices" for the care of human remains (2001:204), part of a broader goal of scientific rigor and standardization within the field of conservation. In response, I have designed an experiment to test the best methods for treating and preventing the fungal infestation of archaeological human remains using the University of Michigan Museum of Anthropology's human remains collection from Senegal as my case study. As I elaborate in more detail below, these remains were infested with mold during transport to the Museum of Anthropology after excavation in 2006-2007, and they are a perfect example of the problems that can arise when archaeologists do not discuss the care of artifacts with museums professionals such as conservators and collections managers. Using previous case studies and professional recommendations, I test several treatment methods on the Senegal collection to determine what method is the most effective and suitable for mold removal. In addition to developing a "best practice" procedure for treating human remains, I make recommendations for how to prevent future outbreaks by developing a standardized method for safely packing, transporting, and storing human remains.

The Museum of Anthropology case study highlights the ever-present threats to archaeological collections and emphasizes the importance of collaboration among archaeologists, collection managers, and conservators to preserve collections for the future. One way to achieve a more effective integration of conservation and archaeology, as well as to ensure the best possible care for collections, is the adoption of standards or "best practices" for collection care. Collections care standards would establish guidelines for archaeologists, collection managers, and conservators to follow in their treatment of archaeological remains, as well as in their interactions with each other (Childs 2003). Developing proper standards of care and protocols for conservation is especially important for skeletal collections, which often receive less collections care management than other materials despite their distinctive ethical, cultural, and scientific standing (Janaway et al. 2001). The Museum of Anthropology case study contributes to the management of museums' irreplaceable resources by developing and evaluating the best active and preventive conservation methods for cleaning mold-infested archaeological human remains.

2. Equal but Separate? Archaeology and Conservation

In the Archaeological Institute of America's (AIA) Code of Professional Standards (2008), archaeologists are described as the primary stewards of the archaeological record who are responsible for preserving all aspects of this irreplaceable information. Like the AIA, most archaeological organizations, such as the Society for American Archaeology and the World Archaeological Congress, recognize in their ethical principles the importance of the care of the collections that their fieldwork generates, as well as more traditional endeavors such as excavation and publication. Similarly, the field of conservation is dedicated to the preservation of the aesthetic, historic, and physical integrity of objects and sites (Matero 2000). Conservation, as defined by Caple (2010), is the care and preservation of artifacts that includes all aspects of object and collections management, from storage to display, cleaning, and repair. Both archaeologists and conservators facilitate access to the past through material objects, so it is logical to assume that archaeologists and conservators would be united in their mutual pursuit of caring for these artifacts (Watson 2010). Although conservators and archaeologists share a desire for the preservation of the archaeological record, a long-standing disjunction between the two fields has contributed to frequent collections mismanagement (Joyce 2003).

2.1 Historical Development of Conservation

The relatively recent development of the field of object conservation arose out of the culturally and scientifically recognized importance of objects, and the importance of objects was a catalyst for the creation of museums. The "cabinets of curiosities" and "wonder rooms" of the 17th century displayed collections of art, rare objects, and artifacts, leading to the institutionalization of museums designed to assemble, curate, and exhibit objects. Collections are the basis for many museums' existence and activities; museum collections are used for research, exhibitions, publication, outreach, and education (Bradley 1994; Keene 1996). In most cases, museum collections are unique and irreplaceable, and without these objects, museums cannot function and achieve their goals. Therefore, the preservation of collections is fundamental to all other museum activities (Knell 1994; NPS 1996-2012). In order to protect their finite collection resources, museum professionals and associated academics began to develop the field of conservation, an area of specialization concerned with the material well-being of objects and the use of scientific knowledge to combat the processes of aging and deterioration (Matero 2003).

Before the 19th century, most “conservators” tried to combat the processes of aging and deterioration by cleaning objects to make them visually appealing . Men like art writer John Ruskin and architect Eugene Viollet-le-Duc wanted to see objects in their presumed “original” condition, so craftsmen used their knowledge about an object’s materials and production techniques to restore it to its former glory (Muñoz Viñas 2005). The restorative emphasis in conservation began to wane in the 19th century (although it still exists, especially in the fine art context), when professionals realized that cleaning and restoration destroyed much of the scientific information embedded in material objects (Caple 2010). Italian architect Camillo Boito was one of the first professionals to recognize the importance of monuments and objects as historical documents, and that information on their life histories could be lost through inappropriate restoration (Muñoz Viñas 2005). Archaeological research played a large part in establishing a philosophy of preserving the context and integrity of objects, which helped lessen the popularity of the restoration movement and introduced the possibility of using archaeological objects for scientific analysis. Thus, rather than washing carbonized food remains from the interior of a painted pot, today’s archaeologists now study those materials to learn about what the pot once held. Archaeologists became primarily concerned with promoting the scientific recovery of artifacts, since the poor excavation techniques and disordered nature of 19th century Antiquarian-oriented archaeology caused the loss of many artifacts. Early conservators also used haphazard, untested processes and materials, such as arsenic and steel wool, that resulted in disastrous losses until the 1930's (Caldararo 1987).

Fortunately, the ideological shift concerning preservation (restoration vs. context) coincided with the scientific awakening of the 19th century, when academics looked to the empirical procedures and investigative methods of experimentation. Scientific conservation slowly developed as researchers began to systematically test methods of object preservation that would become the basis of modern conservation (Plenderleith 1998). Archaeologists and conservators alike began to appreciate the unique record of the past encoded in each object, and in the 1930's and 1940's, they began to study the causes of deterioration that would prevent future researchers from accessing this information (Matero 2000). Although archaeologists, conservators and museum professionals recognized the need for collaborative work as early as the 1950's, the integration of these fields is still far from realized. The first conservation training programs developed in the United States during the 1970's were art conservation programs, and the goals of art historians often do not coincide with the goals of archaeologists since art historians focus more on the aesthetic properties of the object, whereas archaeologists emphasize physical properties and context (Greene 2010). For example, an art historian might wish to reconstruct the many fragments of a broken pot to study the beautiful complete vessel, while the broken fragments allow the archaeologist to 'look inside' to examine how the vessel was made, broken, and eventually deposited. The initial disjunction between the priorities of trained art conservators and archaeologists negatively impacted their relationship, and some of the current tensions and misconceptions between the fields are a direct result of that mismatch. An archaeological conservation specialization eventually developed later in the 20th century, but a rift had developed between the two fields, and archaeological conservators have been trying to reconnect with archaeologists ever since (Caldadaro 1987).

2.2 The Separation of Conservation and Archaeology

In a 2010 study, archaeological conservators Suzanne Davis and Claudia Chemello (2012) found in a survey sample of 346 archaeologists that the majority did not direct field projects that employed conservators, either for consultation before fieldwork began or for on-site needs. Although there are other confounding variables that will be discussed later, the lack of attention to conservation is indicative of a larger trend in the archaeological world; namely, the belief that conservation, which includes general collections care, is somehow "ex-trinsic" (Bucellati 2003:73) to the actual practice of archaeology (Caple 2010). Even though the professional bodies of archaeology emphasize the importance of preservation, conservation often remains separate from the real-world application of archaeology and archaeological analysis (Joyce 2003). Many archaeologists are unaware of the important information that conservators and other collections professionals can contribute to preservation and analysis, and conservators have suggested that this leads archaeologists to view collections care as a subordinate service to more important activities like excavation (Keene 1996). The historical development of conservation as an independent discipline has played a large role in creating the "ex-trinsic nature" of conservation, and several other factors help to inhibit the integration of archaeology and conservation: namely, the creation of separate training courses; seemingly different goals/ emphasis in study and resulting theoretical frameworks; and separate literature and vocabularies.

In the United States, the field of conservation has struggled to integrate archaeological theory and application into its students' education and training. Until the 1990's, there were no conservation training programs that focused on archaeological conservation. As noted above, early conservation training programs focused on preserving fine art objects[1], creating a void of conservators who had the skills necessary for archaeological conservation (Greene 2010). Even now, there are only two to three graduate level programs designed to prepare students for archaeological conservation specifically (Davis and Chemello 2012). Archaeological conservators need comprehensive training to prepare them to support and understand archaeological research goals, as well as first-hand experience of the archaeological process, including the realities of archaeological excavation and how archaeologists use the context of sites and artifacts to generate data for their interpretations (Davis and Chemello 2012; Keene 1996).

On the other hand, archaeologists are equally uneducated about conservation. In the late 19th and early 20th century, archaeology became an academic endeavor of the university setting, and archaeologists moved out of the museum space, losing contact with the collections care professionals working in those settings (Thomas 2000). The physical separation of archaeologists and conservators helped to reinforce the intellectual separation of these two fields and removed archaeologists from the primary context of collections care. In the 1970's, only 10 out of 37 anthropology departments in the United States mentioned conservation or preservation in their curricula (Caldararo 1987). Although things have improved, archaeologists remain inadequately trained in archaeological collections management and conservation. Even where some information on collections management and conservation is addressed in coursework, the traditions and history of conservation theory are often overlooked entirely, leading to a general misunderstanding of the goals shared by conservation and archaeology (Childs 2003; Matero 2003).

The lack of cross-discipline education has led to the development of seemingly different frameworks for the interpretation of material objects. For a long time, conservators studied objects as physical entities only, focusing on their materiality and fabrication (Caple 2010). Conservators placed emphasis on the aesthetics and physical

[1] The focus of this thesis is limited to object conservation and does not consider architectural conservation.

integrity of an artifact over other aspects in order to properly preserve the object (Cassman and Odegaard 2004). However, archaeology has shifted emphasis from a solely physically oriented understanding of objects to a post-modern philosophy that studies objects as cultural signifiers. Archaeologists today are more likely to emphasize aspects other than (or in addition to) materiality when studying objects, such as how objects function as symbols and historical documents of past societies (Caple 2010).

At first glance, these frameworks seem to represent two different levels of sophistication in analysis and understanding of material culture, but that is not the case as conservation theory continues to mature. Developed recently and in a somewhat isolated fashion, conservation theory has lagged behind archaeological debates. However, conservation theory is continuing to evolve and engage with archaeology on a deeper level (Matero 2000). Now an intellectual pursuit similar to archaeology, conservation theory recognizes the transmission of cultural knowledge, memory, and experience through material culture. Conservation "extend[s] these past places and things into the present and establishes a form of mediation critical to the interpretive process" (Matero 2003:56) of archaeology. An increasingly popular trend in conservation is the focus on the cultural context of information and the social meaning of objects, suggesting that the theoretical frameworks of conservation and archaeology are becoming progressively similar (Federspiel 2001).

Unfortunately, the separate literature for archaeology and conservation has inhibited communication between the fields and helped fortify misconceptions about the "ex-trinsic" nature of conservation. In the 1930's and 1940's, shared publications allowed archaeologists and museum professionals to discuss new treatments and practices in the field and lab. Shortly after, publications like *Curator* and *Museum Work,* specifically tailored to museum-focused concerns like conservation, appeared and helped define conservation as a practice occurring outside archaeology (Caldararo 1987). Conservators began to focus on scientific approaches to understanding objects and their processes of deterioration, though these discussions often did not include standards for general application that could be used by archaeologists. Compared to archaeology and anthropology, conservation is a more recent field of study, and the initial conservation studies were published in a slow, haphazard manner that did not allow for easy dissemination and circulation within the archaeological field (Matero 2000). Given the scattered publication of conservation texts and lack of standard treatment protocols to apply in the field and storeroom, archaeologists have been relatively uninformed about conservation work and all that it entails, from treatment procedures to standard collections care recommendations (Caldararo 1987).

In the latter half of the 20th century, conservation, like many other fields (including archaeology), became increasingly specialized. As conservators focused on certain material types or preservation issues, their specialized concepts, information, and vocabulary became increasingly hard to digest by a broader audience, including archaeologists (Rotroff 2001). Without general texts to expose archaeologists to trends in conservation research and treatment standards, many archaeologists did not know how to incorporate conservation into their practice. Davis and Chemello's 2010 survey illustrated this lack of understanding when most of the surveyed archaeologists, some working for upwards of 15 years, expressed a desire for more information about conservation (Davis and Chemello 2012). Traditional publications are not the only method of information dissemination; conservators and archaeologists have also failed to engage at conferences and online. Davis and Chemello's (2012) survey found that 74% of participants did not know what the AIC, the American Institute for Conservation (the professional body for American conservators), was, let alone attended their conferences or visited their website.

2.3 Professional Interactions and Tensions

The separation of archaeology and conservation at the levels of education, theory, and publications has led to a breakdown in communication between these fields, creating entrenched misconceptions about the other profession. These misconceptions have colored the interactions between archaeologists and conservators for most of the last 50 years, and these misconceptions must be challenged before conservators and archaeologists can realize a more complete integration of their fields (Caple 2010). However, all of the studies about the relationship between archaeology and conservation that I could find were written by conservators. Clearly, archaeologists do not agonize about the archaeology-conservation relationship in the same way conservators do, and it is interesting to consider why only conservators focus on the dynamics of their interaction with the archaeological field. Given the authorship of the following cited literature, there is an inherent bias towards the voice and opinions of conservators with little rebuttal by archaeologists, and therefore, these sources do not provide a nuanced view of the relationship between archaeologists and conservators.

Many of the misconceptions regarding conservators stem from notions about conservators' devotion to maintaining the integrity of the physical object. Henderson (2001:103) has found that conservators have been traditionally viewed as "poor team players" who implement restrictive measures and are seen as "negative spoil sports," (Henderson 2001:103). One curator interviewed by Caple (2010:5) compared conservators to Fire Prevention Officers in terms of their "inconvenient zealotry" and "lack [of] understanding of the underlying issues." When working on an interdisciplinary team, Cassman and Odegaard (2004) interviewed their colleagues about previous experiences with conservators, and the archaeologists cited negative experiences because conservators put up "roadblocks" to accessing objects. Cassman and Odegaard (2004) call this the "adversarial role," in which conservators become obstacles to accessing the object in order to optimally preserve it, placing the conservation needs of the artifact above the research needs of colleagues and other interested parties (Clavir 1996). Although the stabilization and preservation of objects is a goal that archaeologists and conservators often share, this mutual goal becomes problematic when conservators deny access to these objects, which archaeologists collected for the purpose of scientific examination and analysis, which can, at times, result in object destruction (Bradley 1994). The idea, and sometimes the fact, that conservators work at cross-purposes to archaeologists is problematic, and because of the entrenched nature of this idea, conservators may not be asked to consult on archaeological projects, further increasing the rift between archaeology and conservation (Wellman 2010).

The "technical role" is another misconception that is not explicitly problematic, but still limits conservator's productive potential (Cassman and Odegaard 2004). In this scenario, archaeologists are willing to work with conservators as long as their involvement fixes a specific problem and does not interfere with their access to the object. Archaeologists view this kind of participation as temporary and limited to addressing a specific conservation problem. Due to the misunderstandings of conservators' functions, archaeologists may erroneously believe that any work relating to the integrity of the artifact (sampling for analysis, removing wrappings, etc.) should be performed by a conservator (Cassman and Odegaard 2004). As a result, archaeologists ask conservators to perform tasks that are better suited to other specialists and do not utilize their full potential. Green (2010) says the "conservator as a technician" works alone on a menial, somewhat shallow task in a supporting function to a more important archaeological process, like the interpretation of the object. Framing conservation as a subordinate endeavor to archaeological analysis suggests that conservators and archaeologists work on different levels, instead of viewing conservation as a complementary step in achieving a shared goal of preserving an object to understand its meaning (Keene 1996). Defining conservation in such restrictive terms limits conservators to offering remedial solutions to archaeologists' technical problems, instead of allowing conservators to contribute to other important discussions about an object's cultural and historical record (Matero 2003). Davis and Chemello's (2012) survey found that the most popular form of conservation service is artifact processing, with only 6% of the archaeologists using conservators for other purposes like investigative analysis. The "technical role" also firmly places conservation within the museum or lab setting, something separate from archaeological fieldwork that occurs after an object has been removed from its context and needs treatment, instead of allowing conservators to inform all stages of the archaeological process (planning, excavation, etc.) (Buccellati 2003; Matero 2003).

Conservators have their own embedded misconceptions about archaeologists that can also negatively inform their actions. Caple (2010:5) says most of the misconceptions highlight archaeologists' apparent "recklessness and lack of professionalism." Many conservators believe that archaeologists' lack of attention to the preservation of objects blatantly disregards the very founding purpose of archaeology and that archaeologists should be equally concerned with the physical integrity of objects, in conjunction with other aspects like context and scientific value (Bradley 1994). When professional archaeology organizations conceptualized stewardship for inclusion in their mission statements, it mostly addressed the need for site preservation (Rotroff 2001). Conservators like Podany (2003), Bucellati (2003) and others were concerned these guidelines caused archaeologists to focus on site preservation to the detriment of individual objects. Podany (2003:201) even went so far as to say that archaeologists have "gotten too used to the idea that excavation means destruction," allowing them to ignore and mismanage the objects surviving excavation. Ultimately, the concept of stewardship built into the guidelines of professional organizations like the SAA and AIA derived from the model of ecological conservation, meaning that conservation must apply to the whole ecosystem, down to its smallest component (Rotroff 2001). At an archaeological site, one of the smallest components are individual objects, and thus, archaeologists have a professional and ethical imperative to preserve both sites and objects.

Many conservators believe that archaeologists misunderstand the role of conservators and how they can provide assistance in preserving collections. In their survey, Davis and Chemello (2012) found 59% of their respondents did not use conservators in the field. A number of respondents stated that their excavated materials did not need any conservation attention, indicating to the survey's authors that many archaeologists do not understand all of the aspects encompassed by conservation, including basic collections management. All objects, including those usually considered stable such as ceramics and lithics, require attention, although there is a lot of variation in how much preservation is required; efforts can range from remedial treatments like consolidation to simple recommendations for excavation tools, packing materials, and cleaning methods (Davis and Chemello 2012). Archaeologists need to address the preservation needs of all archaeological materials, and conservators and collections care managers can provide necessary information and services, some seemingly insignificant, that have a profound impact on the future preservation of artifacts and collections. Similar to the field, objects require collections care and conservation during their long-term storage and curation, and Caldararo (1987) and Childs (2003) state that many conservators believe that archaeologists do not properly anticipate and plan for the collection management and preservation demands of their collections after excavation. Since excavation is a destructive process, archaeologists need to ensure that the remaining artifacts of a site are cared for in a comprehensive manner (Podany 2003).

After analyzing the interactions of archaeologists and conservators, the idea that archaeologists and conservators all too often work side by side, but not together, emerges as the prominent theme (Rotroff 2001). Young (personal communication 2013) states that many archaeologists view conservation as a last priority, an afterthought often not included in the research plan. Many archaeologists view conservators as outside their professional work and unable to contribute in a meaningful way to their research goals, and this disregard for conservation's contributions creates an environment counterproductive to interdisciplinary initiatives (McGowan and LaRouche 1996). In fact, a major theme of Davis and Chemello's (2012) survey was a general misunderstanding about what conservators are and what they do, indicating an ignorance of what conservators can contribute to archaeology.

On the other hand, conservators need to come to terms with some of the realities of archaeological analysis, such as the compromise of an object's physical integrity for scientific gains (e.g., destructive analysis). Conservators also need to acknowledge some of the difficult realities of archaeological fieldwork (e.g., cost, limited time, limited resources, vast quantities of materials recovered), particularly in the developing world, that make it impossible to achieve the optimal preservation of each object, even though that may be the goal of the archaeologist. It is also important to note that some of the studies I have cited above are outdated, and there has been improvement within the field; however, there is still room for progress. Instead of focusing on the deficiencies of each field, a more productive discussion would detail how professionals can overcome all the previously mentioned obstacles to foster a collaborative environment that enhances preservation and analysis.

2.4 Working Together: The Benefits of Collaboration

Archaeologists and conservators are only beginning to realize how their fields offer complimentary approaches to the study and preservation of the archaeological record. At their core, archaeologist and conservators, along with many other museum professionals such as collections managers and registrars, share a common goal: the care and preservation of archaeological collections. The next step in achieving an integrated partnership is recognizing all the benefits professionals stand to gain through more effective collaborations, as well as improving our ability to realize these goals of preservation (Rotroff 2001).

Conservators have long contributed their technical expertise of materials to the preservation of archaeological objects, and conservators continue to develop their knowledge base (Greene 2010). The practice of investigative conservation is a growing trend within the field that looks into the properties of artifacts and conservation materials, akin to the way experimental archaeology enhances the theory and methodology of its field. Continuing to improve the technical knowledge within the field is important, as such research allows conservators to provide artifact-processing services and advice to their colleagues (Davis and Chemello 2012). As conservators gain a better understanding of how archaeologists use objects to create a narrative about the past, they can provide valuable information beyond their technical knowledge of deterioration (Caple 2010). Watson (2010) states that conservatorial investigation can help reveal information about an object's context in ways that can facilitate a better understanding of the past. Conservators can enhance many avenues of standard archaeological analysis, such as the study of production technology and comparative studies of decorations and morphologies (Muñoz Viñas 2005). Conservators are becoming more aware of the symbolic, communicative properties of the objects they work with and this broadened understanding of objects opens up new collaborative opportunities with archaeologists (Muñoz Viñas 2005). Matero (2000), a strong proponent of the interpretive abilities of conservation, reminds archaeologists that conservation is a means of accessing and preserving the form and meaning embedded in an object, so conservators are inherently dealing with cultural constructs such as knowledge, memory, and experience represented in material culture. Conservators are well suited to provide a different objects-based, but complementary, approach to answering complex cultural questions of interest to archaeologists (Matero 2000; 2003).

When conservators, collection professionals, and archaeologists collaborate in a productive, interdisciplinary manner, not only can they gain increased understandings of the objects they study, they can also provide comprehensive care for that object. Preservation should begin at the moment of excavation, either through adherence to simple collections care recommendations or more intensive conservation treatments like stabilization. Collections care professionals and conservators need contribute to an archaeologists' pre-excavation planning stage to anticipate problems, and when feasible, conservators should be on-site help to address preservation problems as they arise during excavation (Watson 2010). Collections care "best practices," drawing on conservatorial expertise, also need to inform all of the resulting phases, from artifact processing to packing, transportation, and curation in storage institution (NPS 1996-2012; Swain 2010). Even after an object is placed in storage at an institution, the continued collaboration between archaeologists and museum professionals is necessary to ensure that the artifact is properly stored, handled, and sampled in a way that allows for successful long-term curation (NPS 1996-2012). Cooperation between conservators and archaeologists is paramount at this stage to make sure that everyone's needs, including accessibility, are being addressed without compromising the preservation of the artifact (Richoux et al. 1994).

Although conservators and collections managers have defined standards for object care that utilize the best scientific techniques of their field, they have not been successful in circulating these standards to archaeologists (Clavir 1996). If archaeologists do not know how to implement the best preservation procedures, then object management will continue to be compromised. Conservators need to better communicate their standards of practice with archaeologists in accessible ways, such as at archaeological conferences, in archaeological journals, or with general texts and on websites (Davis and Chemello 2012). In order to improve communication, it is essential that conservators involve archaeologists in the process of developing mutually understood and practicable standards for providing the best care for objects and collections (Cassman and Odegaard 2004; Swain 2010; Watson 2010;). When archaeologists and conservators work together, they can share their knowledge and skills in ways that both professions can endorse and build into the nature of their fields' conventional practice (Swain 2010). Preservation should be an important priority for archaeologists, and the more conservators can engage them in the development and application of standards, the more archaeologists and conservators will work together to develop and implement best practices for the care of archaeological artifacts and collections (Childs 2003). Human remains, an important archaeological resource, especially need mutually developed and adhered to standards of care, or these significant materials will lose their scientific, cultural, and religious value.

3. A Unique Collection: Skeletal Remains in the World of Archaeology and Conservation

Archaeologists and curators have been collecting human remains since at least the 19th century, and they have captivated both the scientific and public imagination (Walker 2008; Thomas 2001). Human remains are a "venerated element of the highest form," (McGowan and Laroche 1996:110) in many cultures, and their unique nature and preciousness often enhance their cultural importance. Like other rare and precious objects, the inherent value of human remains makes them valuable to collecting institutions and museums. However, human remains do not only, or even primarily, have an aesthetic appeal; archaeological human remains are also important resources for scholars and descendent communities alike. In the United States, the Title 36 of the Code of Federal Regulations dealing with the curation of federally owned and administered archaeological collections states that human remains collections must be available for scientific, education, and religious uses (McManamon 2006). In order to meet these needs, human remains must be protected and preserved. The degradation of human remains destroys their potential to serve a variety of purposes, from research to religious ritual, and inherently decreases their value (Bekvalac et al. 2006). More importantly, professionals cannot justify the ethical retention of human remains (or indeed any remains) in collections if they cannot properly care for them, especially with increasing pressure and concern from the public and indigenous communities about human remains curation (Janaway et al. 2001). Professionals have an obligation to care for human remains in order to preserve their inherent value to multiple stakeholders, justify their retention, and show dignity and respect to the deceased person (Pye 2001; Cassman and Odegaard 2007; 49-77).

3.1 The Importance of Human Remains, Present and Future

Beyond their capability to fascinate, human remains provide invaluable opportunities to study ancient individuals in ways unique among archaeological materials (Hunt 2001). Human remains are the only materials that allow for the biological, and sometimes social, study of ancient individuals, and the study of human remains is relevant to a broad number of fields (Bekvalac et al. 2006; Panagiaris 2001).

The analysis of human remains is crucial to understanding human origins, and collections of hominid fossils and skeletal remains provide the means to chart the pathways of evolution and adaptation from past humans. For archaeologists, the study of human remains can contribute information about the sex, age, dentition, pathology (the study of disease), migration patterns, medical care, demography and diet of past individuals and communities; many of these fields of inquiry cannot be addressed by other materials (Bekvalac et al. 2006; 60-70). Forensic scientists also use archaeological techniques designed to conduct bio-profiling of past peoples in medico-legal contexts. Part of forensic anthropology's refined understanding of taphonomy, the multiple processes that affect a living organism after it dies, and identity assessment come from the study of archaeological human assemblages (Bekvalac et al. 2006; 60-70). Human remains not only record the trajectories of ancient disease, but also can inform the understanding of modern diseases and health issues. The study of ancient health provides valuable information about long-term trends in trauma and violence, the health of diverse biological or geographic communities, the co-evolution of pathogens, population genetics, degenerative joint disease, etc., that inform current health practices and knowledge (Cassman and Odegaard 2004; Steckel et al. 2006; 111-116). When human remains are properly conserved and retained in research collections, they have the potential to contribute even more scientific information as new methods of analysis are developed (Panagiaris 2001; Quigley 2001).

With the advancement of analytical technologies, scientists continue to unlock new information from human remains (Hunt 2001). In the past few decades, new technologies like stable isotope analysis, digital facial reconstruction, and ancient DNA sequencing have already provided so much additional data about past peoples that it is easy to imagine how much future technologies will uncover from collected human remains (Pye 2001; 171-176). Collections of human remains also play a role in helping to teach future osteologists, physical anthropologists, and forensic anthropologists how to recover all of this interesting information, and professionals like Jane Buikstra and Claire Gordon (1981) argue that skeletal teaching collections are crucial hands-on resources for training future researchers. Thus, human remains are an incredibly important teaching and scientific resource, providing relevant information about the past and present and answering new questions into the future as professionals and scientific technologies continue to develop.

However, it is important to remember that human remains are the physical remnants of an individual, and these remains often have sacred and religious significance beyond the scientific value ascribed to human bones (McGowan and LaRoche 1996). The physical remains of individuals are imbued with a variety of meanings and attachments to peoples of the past, present, and future, and it is critical that everyone with an vested interest in human remains has a voice in determining their curation in museum institutions (Pye 2001:171-176; Quigley 2001).

With the passage of laws such as the Native American Graves Protection and Repatriation Act (NAGPRA) in the United States and the Aboriginal Heritage Act (AHA) in Australia, museums are legally required to address indigenous values and ethics concerning the care and treatment of at least certain categories of human remains (i.e., Native American and Native Australian, respectively) (Cassman and Odegaard 2004). Beyond the legal obligation to acknowledge alternative viewpoints regarding human remains, museums and anthropologists have begun to recognize the validity of the aspirations and rights of affected indigenous populations, as well as other interested parties, like the general public, who have strong sentiments about the curation of human remains (Sadongei and Cash 2007:97-101). The actions of researchers, curators, and conservators greatly affect ancestral remains that are meaningful to these people, so academic and museum professionals should respect the authority of indigenous populations in deciding how these remains are handled (Muñoz Viñas 2005).

While the treatment and collection of human remains is still an emotionally charged topic, many stakeholders are recognizing that different goals (research vs. reburial) have value, and in many places this is contributing to the development of a collaborative, interdisciplinary approach, that acknowledges the inclusivity of all interested parties and the respect for multiple voices (Cassman, Odegaard, Powell 2007:1-3; McManamon 2006). Conservators are one of these voices, and they have the potential to play an important role in navigating the goals of indigenous groups, the public, and researchers (Cassman and Odegaard 2004). Legislation like NAGPRA has forced museums and institutions to focus more attention on their skeletal remains, including important conservation and collection management improvements like re-inventorying, sorting out records and associated files, and improving storage conditions. In many instances, indigenous groups have also indicated that they want the best standard of care and conservation for their ancestors' remains and associated objects while housed in museums, and this shared goal creates a common ground for scholars, museum professionals and indigenous communities (Clavir 1996).

Several priorities can be defined. In terms of storage, human remains should be housed in the best quality materials (determination of what is best can vary depending on the tribe or population and need not always conform with conservators' ideas of what is best) and in an area with environmental controls to best protect them. Human remains should be housed as complete individuals to respect the integrity of the person (as well as to maintain archaeological context), with associated burial objects, and in isolation from unrelated collections (Sadongei and Cash 2007:97-101). Most indigenous groups believe that human remains should be minimally handled with no conservation intervention at all, coinciding with both archaeologists and conservators' avocation for non-intervention, one of the foremost tenants of modern conservation. However, there are some instances when treatment may be necessary to preserve the remains, and this can result in conflict between the museum and indigenous communities (McGowan and LaRoche 1996; Panagiaris 2001). In instances when condition mandates potentially offensive treatment, conservators usually adhere to their ethical principles, but they should execute treatment in a way that is as respectful to the object's creators or their descendants as possible (Clavir 1996). "Caring for something expresses appreciation for that object, and very often, for what it symbolizes," (Muñoz Viñas 2005) and although conflicts occasionally arise, conservators believe that they show their respect for other cultures by caring for their human remains to the best of their ability.

Many groups are interested in human remains for various reasons. Among the most vocal are researchers who seek to analyze human remains for scientific and social purposes and indigenous groups looking for respect and a voice in how their ancestors' remains are handled by museum institutions. However, the needs of these groups cannot be met without the proper care and treatment of the human remains. Despite the value of human remains, several leading archaeological conservators have noted that skeletal material receives the least amount of standardized collection care management in museum contexts (Cassman and Odegaard 2004; Cassman, Odegaard, and Powell 2007: 21-28; Janaway et al. 2001). Museums and institutions in the United States currently house over 200,000 skeletons in their collections, yet there are very few accessible, published resources or standards that outline the preservation of these incredibly important materials (Cassman, Odegaard, and Powell 2007:21-28).

Indeed, when the conservation literature mentions bone, it usually pertains to the excavation of non-human bones. Conservators have paid little attention to the concerns of excavating human bone, and even less attention to the future laboratory and long-term curatorial concerns of maintaining human remains collection (Cassman and Odegaard 2004; Janaway et al. 2001). The intervention of trained conservators has been minimal, leading to the development of isolated protocols for collections care with no clear, up to date, unambiguous sets of standards applicable to the majority of human bone (Janaway et al. 2001). Very few standards exist for the excavation of human remains, and when archaeologists encounter human remains, they often seek the advice of paleontologists instead of trained conservators (Cassman and Odegaard 2004). Once excavated, archaeologists send the human remains to museums or other institutions; however, most institutions do not have standard practices for the housing and maintenance of skeletal remains. Although accepted methods exist for assessing the condition of human remains collections, many museums have difficulties implementing these methods to monitor their collections. The Heritage Health Index (Heritage Preservation 2005) found that 70% of United States institutions do not have a current assessment of the condition of their collections. These assessments can provide important information about the causes of deterioration and how collection managers and conservators can recommend better practices to prevent further damage. However, conservators cannot make these beneficial suggestions without baseline condition knowledge (Cassman and Odegaard 2007:29-47). Very little information detailing the proper cleaning, handling, and research of human remains exists (Cassman, Odegaard, Powell 2007:21-28). No housing standards for human remains are publicly available either, although storage provides the most direct contribution to preventive care and the mitigation of deterioration (Cassman and Odegaard 2007:103-123). Similar to preventive care standards, there are few recognized guidelines for treating human remains; as such, further research and publication is necessary before best practices can be circulated and adopted (McGowan and LaRoche 1996). The uncared for and overcrowded conditions of many osteological collections throughout the country reflects the lack of standards and guidelines for properly preserving human remains, and fits into the larger picture of collections care challenges facing many museums (Cassman and Odegaard 2004).

How is it possible that valuable resources like archaeological human remains receive such inadequate preservation attention, let alone standardized collections care? Cassman, Odegaard, and Powell (2007:21-28) believe the liminal nature of human remains has played a role in their neglect; human remains are not regular artifacts, but they are not untouchable pieces either. A common response is to ignore the collections in order to draw the least amount of attention, both positive and negative, to the remains as possible, especially as human remains curation has become more contentious. The lack of education and training for both osteologists and conservators is another important reason for underdeveloped human remains collection management standards (Cassman and Odegaard 2004). Few training programs for researchers specializing in human remains address even basics concepts of preservation, let alone preservation methodology as it applies to human remains. Standard texts for osteologists rarely include preservation topics and concerns, and there is a significant lack of information about conservation in physical anthropology literature. On the other hand, very few conservator education programs include segments that focus on preserving human remains in the field, laboratory, or the museum, and there is a similar lack of discussion on preserving human remains in conservation literature (Cassman and Odegaard 2004). Given the absence of information on and prioritization of human remains conservation, it is not surprising to learn that only 6.4% of American Association of Physical Anthropologist members work at an institution with conservators. Out of those individuals, over half reported to having a working relationship with conservators, and only a quarter of the respondents characterized this relationship as a satisfactory collaboration (Cassman and Odegaard 2004).

A lot of the scientific, cultural, and religious value of human remains is correlated with their physical condition, so it is crucial that conservators develop comprehensive ways to document, treat, and curate human remains (Janaway et al. 2001). Conservators need to actively develop and disseminate standard conservation procedures to anyone dealing with human remains to preserve their value. Such procedures need to take into account cost, efficiency, ease of use, and accessibility to maximize the likelihood that all related professions accept and follow these measures; otherwise, human remains will continue to receive haphazard, substandard care (Janaway et al. 2001). Human remains are a fragile resource, and without proper management, perilous museum and curation environments will silently destroy these collections.

3.2 Dangers of the Museum Storage Environment

Despite claims that bone is a relatively resistant material, the occasional studies detailing the deterioration of bone in museum contexts indicate that bones are not as stable as often thought. Institutionalized human remains collections are subject to a variety of deterioration factors that can ensure that decay continues even after an object has been placed in a stored collection (Cassman and Odegaard 2007:29-47). Excavation poses the greatest risk to human remains, but many forms of destruction persist after the bones have been moved into storage settings; in fact, human bones fare worse than equally fragile artifacts excavated and stored in similar settings (Janaway et al. 2001). Museum environments often do not reach the ideal standards depicted in museum theory, so despite the goals of collections management, skeletal remains can still be exposed to the physical, chemical, and biological damage processes typical of an institutional storage setting (Clavir 1996; McGowan and LaRoche 1996). In Table 1, I summarize general museum deterioration factors, which affect both human remains and other categories of museum collections.

Archaeology and conservation both suffer from a shortage of resources. All over the world, archaeologists grapple with inadequate funding that directly affects their ability to conserve and protect their collections (Childs 2003). Time constraints and

Table 1. General Museum Storage Deterioration Factors

Agents of Deterioration	Effects	Example
Physical damage	Structural damage, surface damage, disfigurement	Storing too many bones in one container causes them to rub together and abrade off surface flakes
Radiation	Disfigurement, surface damage, chemical damage, physical weakening	UV radiation can cause the fading of paintings or the yellowing of pages
Fire	Major structural damage, surface damage, disfigurement, chemical damage, loss of the object	Fire can completely destroy entire collections, like archived books or textiles.
Human Interaction*	Major structural damage, surface damage, disfigurement, chemical damage, loss of the object	Thieves can steal objects. Visitors can touch objects on exhibit and damage then. Anyone can displace an artifact's documentation, damaging the context and value of the object.
Water	Major structural damage, surface damage, disfigurement, chemical damage, biological damage	Water sitting on metal artifacts will cause corrosive reactions like rusting that damage the object.
Pests*	Major structural damage, surface damage, disfigurement, loss of the object	Moths will eat entire textile collections, and dermestid beetles eat any dry animal or plant material.
Contaminants	Surface damage, disfigurement, chemical damage, biological damage	The poison arsenic has been used to preserve collections, but makes them very dangerous to handle.
Incorrect Temperature	Major structural damage, surface damage, disfigurement, chemical damage, biological damage	Freezing temperatures can cause fragile artifacts like bones to crack or split.
Incorrect Humidity*	Major structural damage, surface damage, disfigurement, chemical damage, biological damage	Moist conditions can cause fungal infestations of organic objects like paper that will eat away at the object and stain it.

***These are the factors affecting the Museum of Anthropology remains from Senegal**

budgetary demands are the norm in archaeology, and archaeologists often have to compromise on optimal practices, to the detriment of the resource, in order to achieve their research goals (McGowan and LaRoche 1996). Most human remains are not high-profile archaeological finds, and therefore, the archaeologists dealing with human remains often receive less funding, and saving money for conservation is often the last priority. Indeed, 77% of institutions in the United States do not have specifically allocated funds for preservation in their budgets, with more than 68% of institutions devoting less than $3,000 to conservation and collections management within a fiscal year (Heritage Preservation 2005). Funding institutions also fail to appreciate the long-term needs of a human remains collection, so they provide resources for excavation, but not for the long term care these objects require (Caple 2010). Without enough money, museums and archaeologists cannot employ the proper staff necessary to carry out object conservation or collection management. Facing major funding reductions, museums everywhere are being asked to do more with less, and that means a minimal budget to hire trained collections managers, curators, and conservators (Caple 2010; Childs 2003). In their 2010 survey, Davis and Chemello (2012) found that the lack of adequate funds was the most common reason that archaeologists did not employ conservators for their field projects. In a 2005 study, the Heritage Health Index found that 80% of collections holding institutions did not have paid staff dedicated to collections, and 71% of the staff existing at institutions needed additional training and expertise to care for their collections.

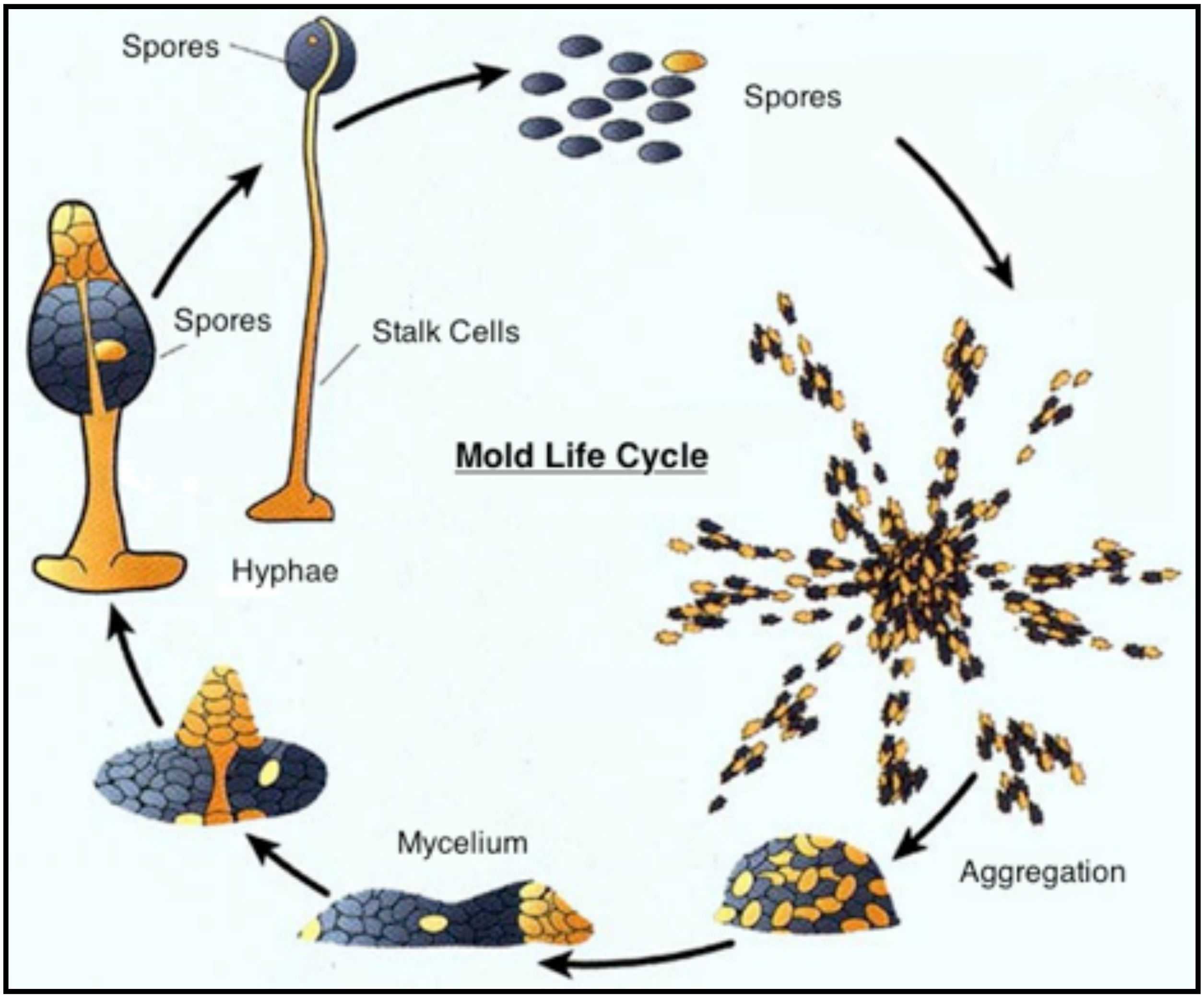
Without funds to provide for conservation and a dedicated collections management staff, human remains often fall prey to a host of institutional storage threats. Improper packaging and storing is one of the primary causes of post-excavation damage to human remains. Bones are often packed with inappropriate storage materials (acidic cardboard or paper) and placed incorrectly into generic boxes (Janaway et al. 2001). All too often, the storage facilities reserved for archaeological remains, including human remains, is characterized by substandard conditions; improperly stored human remains are stuffed into storage rooms, often overcrowded and not properly maintained (Clavir 1996). Results from the Heritage Health Index (Heritage Preservation 2005) show that 59% of institutions have the majority of their collections stored in areas too small to accommodate them appropriately, and as a result, 65% of the United States' collections have experienced damage due to improper storage. Finally, the curators, researchers, and students who access these remains can mishandle them and cause further damage. Cassman and Odegaard (2007: 29-47) have argued that the mishandling human remains is the primary source of damage to these objects, but without dedicated conservators and collections management staff to address this problem, the deterioration caused by mishandling the remains often goes unchecked (see also Janaway et al. 2001; Richoux et al. 1994).

After excavation, archaeological materials, including human remains, must adjust to a radically different environment in field labs and then permanent storage facilities, which leaves them vulnerable to rapid deterioration. Once objects are permanently stored, they also suffer from fluctuations in the storage facility environment (NPS 1996-2012). Since extreme changes and fluctuations in environmental conditions can hasten degradation, museums have emphasized the importance of installing climate control systems to stabilize the storage environment. However, climate control systems are expensive. Smaller museums and institutions often cannot afford this technology, putting their collections at risk. The Heritage Health Index (Heritage Preservation 2005) showed that 26% of collecting institutions have no environmental controls to protect their collections. Studies have shown that even well-known and well-funded museums cannot maintain ideal climate conditions for their collections all the time, so most museums have to deal with the threat of environmental dangers (Clavir 1996). Poor climate control puts fragile archaeological human remains at a great risk for both physical and biological damage. The complicated molecular structure of bone makes it highly susceptible to deterioration from negative environmental conditions, and its hygroscopic nature (its ability to hold water) reacts especially poorly with extreme highs and lows and fluctuations in relative humidity and temperature (NPS 1996-2012). Physical damage to the bone, like warping, cracking, and flaking, is a characteristic result of changes and extremes in temperature, while high humidity encourages microbial activity (Janaway et al. 2001; McGowan and LaRoche 1996). Even though the relative humidity of the environment should not exceed 50%, there are many sources of excess water during the excavation, processing, and storage phases of collections curation; in fact, the Heritage Health Index (Heritage Preservation 2005) found that 53% of the collections in the United States have been damaged by moisture. Excessive moisture and humidity can create ideal conditions for fungi to grow (NPS 1996-2001).

Mold Damage

Fungi are simple-celled saprophytic microorganisms, meaning they feed on living organisms or dead organic matter by digesting the substrate (surface) on which they grow, creating a visible, furry growth called mold (Guild and MacDonald 3004). Fungal spores are always present in the air and soil around the world; the most common soil genera, *Alternaria* and *Cladosporium*, colonize the leaf litter of temperate regions, while *Penicillium* and *Aspergillus* can be universally found in indoor air environments (Zaitseva 2009). These four genera of mold have been found on objects in museums around the world, and their presence results from multiple processes, including the acquisition of freshly excavated materials, the return of contaminated objects, contaminated materials used during the object's fabrication, and contaminated air circulation (Zaitseva 2009). The majority of fungi that grow on artifact surfaces in museums are called conidial fungi, because their growth is initiated by airborne conidium (Florian 1997). Conidium, asexual spores, germinate on the surface of the artifact and after a vegetative state, they begin to produce masses of conidia which are reintroduced into the air. After the release of conidia, sexual spores form on the surface of the mycelium, producing the visible fungus/mold growth on the object's substrate. These sexual spores, called hyphae, secrete enzymes that digest the structure of the object, causing permanent damage including staining or the total destruction of object(s) in museum collections (see Figure 1) (Florian 1997; Thacker et al. 2008).

Figure 1. Mold life cycle as it occurs on an object's surface (adapted from NSF 2003)



Even though museums recognize the need for proper environmental procedures and monitoring, infestations still occur in museums around the world (Clavir 1996). In order to grow, fungi merely require heat and humidity, and these environmental conditions are often present in museums, so institutions everywhere risk the biodeterioration of their collections (Florian 1997; Thacker et al. 2008). Since fungi require organic materials to supply nutrients for growth, organic museum objects such as human remains are an ideal food source to support biological activity (NPS 2000; NPS 1996-2012). As with other artifact types, fungi can stain, damage, and completely destroy human remains (Thacker et al. 2008). As previously discussed, human remains receive the least amount of general collections care. Therefore, it is not surprising to learn that there are no standard procedures for dealing with the fungal infestation of human remains, even though fungi pose an acute threat to archaeological and natural history bone collections (Thacker et al. 2008). Given the universal presence of fungi and their easily achieved environmental conditions for growth, it is imperative that conservators begin to test and develop standardized procedures to deal with the fungal infestation of archaeological human remains in order to protect these important resources from losing their scientific, cultural, and religious value for all interested stakeholders.

4. Summary

As I have reviewed above, conserving archaeological materials is a difficult endeavor, fraught with many challenges, yet it is a critical obligation of archaeologists and museum professionals. A host of issues, such as a lack of training, paucity of general published resources, and residual misconceptions, can negatively affect the preservation of important artifacts and collections. However, the fields of archaeology and conservation are continually progressing and their practitioners are learning to work together to achieve an optimal level of preservation for, and enhanced theoretical understandings of, objects. In this thesis, I argue that this effective collaboration is especially important for human remains. Human remains are a unique artifact class, full of scientific and cultural value (and ethical sensitivity), that require the utmost attention and care of both archaeologists and conservation professionals at every step of the excavation process, from planning to long-term storage.

However, despite best intentions, optimal preservation cannot always be achieved; field work is difficult and archaeologists need to negotiate a variety of demands. Funding is a huge hurdle for all archaeologists. While the excavations of head-line worthy archaeological finds, such as Egyptian mummies or Roman gold hoards, receive a lot of attention and funding, most archaeologists operate on a smaller budget. The majority of an excavation budget is allocated to crew members and materials, and the funding resources are usually limited to the period of excavation (Caple 2010). As Davis and Chemello (2012) discovered in their survey, one of the most prominent reasons archaeologists did not employ conservators was due to the lack of adequate funds. Along with the budgetary demands inherent in excavation, archaeologists also have to deal with time constraints; a field season, which requires the managing of personnel and environment, runs for a limited time and during that period, archaeologists have to prioritize goals of extensive recording and removal (Green 2010). After excavation, archaeologists have even fewer resources to allocate to the long-term storage of their collections, as many funding institutions do not recognize the lifetime of care these objects require (Caple 2010).

Since conservation must work within the framework of archaeological practice, conservators also have to deal with these demands. In a field situation, it is rarely feasible for conservators to devote all of their attention to a single object or perform extended research on the best kinds of equipment or treatment (Greene 2010). In some instances, even though the conservators and archaeologists might know the optimal equipment and methods for treating artifacts, these resources can be limited or impossible to acquire in the field. Conservators need to learn how to compromise with the realities of archaeological field work and provide the best conservation care within the limits of each situation.

The difficulties of conservation and collections care continue after excavation, and fit into a larger trend of inadequate resources for museum institutions (McGowan and LaRouche 1996). The minimal funds for conservation and collection management has resulted in inadequate storage space, professional staff, accessibility, and preservation treatment (Childs 2003; Richoux et al. 1994). Museum practice is far from the ideal, and conservators, as well as other museum professionals, constantly navigate the difficulties of providing the best care for objects while meeting both the demands of interested parties and reality (Clavir 1996).

With all of the challenges facing archaeologists and conservators, professionals cannot always provide optimal care for their collections, even though preservation is a shared ideal. In these situations, conservatorial intervention may be required to stabilize and prevent the total deterioration of these artifacts after damage has occurred. The case study from the University of Michigan Museum of Anthropology, which is the focus of this research, represents one such situation when optimal preservation could not be achieved due to problems created by improper packing transport from the field area, and inadequate communication and resources once the remains had entered the museum environment.

5. The UMMA Case Study: An Investigation of Human Remains Conservation

In 2005-2006, a University of Michigan curator excavated an Iron Age burial site in Senegal, Africa. After unearthing the human remains in June, the field crew wrapped them in toilet paper, placed them in plastic bags, packed them in cardboard boxes stuffed with wood chips, and shipped the remains back to the University of Michigan's Museum of Anthropology. The remains then arrived in Detroit for inspection at the airport's U.S. Customs Office, and the curator transported the boxes to the Museum of Anthropology's laboratory space on the University of Michigan campus. The curator then left Ann Arbor, and the remains sat unattended in their boxes for two months because the Collections Manager had not been notified of their arrival. When the curator returned and began unpacking the boxes, he noticed that many of the bag interiors were covered in mold (O'Brien personal communication 2013).

Upon inspection, it became obvious that the bones were damp when packed, and the toilet paper absorbed the moisture but had little chance to dry in the sealed plastic bags. This combination, in addition to the warm temperatures, created a microenvironment with ideal conditions for fungal activity. After several months of transport followed by sitting in the lab, the mold had ample time to develop, reproduce, and colonize the interior of the bags and their contents. Since the Museum of Anthropology does not have a conservator, the Collection Manager consulted with a private conservator who recommended putting the bags, with the bones still inside, into a freezer until they figured out how to clean the remains. Because the collections staff at the Museum of Anthropology did not have the time or resources to clean the remains, the collection remained in the freezer for the last five years. Recently, the curator who excavated the remains transferred institutions and has requested the transfer of all the collections from the Senegal excavation to the new institution (O'Brien personal communication 2013).

The Museum of Anthropology example perfectly demonstrates some of the difficulties of archaeological excavation and the importance of ongoing collaboration and communication between archaeologists and collections care professionals, including conservators. While the excavation took place in a remote location in Africa, limiting available materials and personnel, the curator did not consult the Museum of Anthropology Collections Manager for any collections care advice or recommendations. When the remains returned to the Museum of Anthropology storage, the curator did not prioritize the unpacking of his collections, let alone notify the Collections Manager about their arrival; as a result, they were kept in adverse conditions for several months. Due to budgetary restrictions, there was no conservator at the Museum of Anthropology, so they consulted with a freelance conservator who only made short-term storage recommendations.

My case study aims to remedy the condition of these human remains, as well as to meet my larger goals of contributing to the development of standards of care for human remains. Within the fields of collections care and archaeology, professionals are recognizing the need to develop effective and easily implemented standards of care for their collections, which numerous surveys like the Heritage Health Index (Heritage Preservation 2005) indicate are continually deteriorating. Among the few studies that have focused specifically on human remains, Cassman, Odegaard, and Powell (2007) and Janawey et al. (2001) argue that the development of standards is especially important for human remains collections, resources that have previously received little collections care attention, despite their scientific and cultural value. These authors (Cassman, Odegaard, and Powell 2007; Janaway et al. 2001; Wellman 2010) want professionals, including conservators and osteologists, to develop the best standards for human remains care, including both active and preventive treatment, that are scientifically tested, published, accessible, and easy to utilize in field and lab settings. The Museum of Anthropology case study will provide scientifically tested guidelines for the removal of mold from archaeological human remains. Specifically, I tested five different solutions to determine the most effective and easily implemented procedure for the eradication of active and dormant mold spores. While this case study focuses solely on mold-infested human remains, a specific conservation predicament,this problem is not unique. As such, my research is an important contribution to the growing body of standardized collections care protocols.

5.1 Cleaning Remains: Previous Case Studies

As previously discussed, human remains are a fragile resource whose scientific and cultural value often depends upon their physical integrity. Therefore, any conservation treatment for human remains needs to be carefully considered for possible consequences. Plenty of harmful treatments have been used in the past, often because the conservators did not really understand how the chemicals could potentially harm the artifact or people handling the artifact. For instance, in past decades professionals commonly used bleach to clean bones, until they learned that it leeched away the calcium from the bones, rendering them into bone-meal during long-term curation (Fenton et al. 2003). Professionals now recognize another commonly used chemical, Formalin, as a dangerous carcinogen that also impedes the extraction of DNA from bones (Fenton et al. 2003). With no published data on the treatment of mold-infested archaeological remains, I turned to two different kinds of case studies that could provide relevant information and suggestions: forensic cleaning case studies and general collections care case studies.

Forensic Case Studies

In forensic anthropology, professionals deal with recently deceased human remains that need to be cleaned and prepared for analysis. Cleaning methods are designed to remove tissue, lipids, and any other organic substances to decontaminate the bone, make trauma markers visible for forensic study, and prepare it for long-term storage (Fenton et al. 2003). While working at the Human Identification Laboratory in Tucson, Arizona, Fenton et al. (2003) found that they needed a fast, safe, economical method to expose bones while preserving the evidentiary material on the skeletal remains. The goal was to preserve the skeletal elements and produce durable specimens for analysis, documentation, and curation. After numerous tests, Fenton et al. (2003) decided on a powdered detergent solution (20 mL to 2 L water) or a sudsy ammonia (150 mL to 2 L water) solution to degrease (remove organic lipids) and clean human remains of any remaining tissue. Their cleaning method involves repeated episodes of submerging the bones in the detergent or ammonia solution, placing them over heat to simmer, and then rinsing the bones with running water until all the soft tissue and grease has been removed (Fenton et al. 2003). Although untested by Fenton et al. (2003), it is possible that these cleaning methods could kill fungal spores since the solutions effectively kill other biological contaminants. While these methods were developed for recent remains, they meet very important requirements for the Museum of Anthropology case study: namely, they will not compromise the scientific or cultural integrity of the remains; they are non-toxic; and they can remove biological contaminants.

Work by Stephen Nawrocki (personal communication 2012), another forensic anthropologist, with gorilla bones in Rwanda provided a second useful comparison to the Museum of Anthropology case study. Between field seasons in Rwanda, the crew stored the bones in a box in a shed with limited air flow and a relatively humid environment. When they returned, they discovered the gorilla bones were covered in mold. The bones needed to be cleaned without destroying the integrity of the remains for future histological and microscopic examination, as well as permanent museum curation. Nawrocki (personal communication 2012) recommended a powdered borax and water solution (20 mL to 2 L) to clean the bones and remove any of the organics that could provide the nutrients for fungal growth. The Rwanda crew soaked the bones in this anti-fungal bath, brushed them off, and successfully stored them without damaging the bone's integrity or stability. Like Fenton et al.'s (2003) recommendations, Nawrocki's (personal communication 2012) case study demonstrates that powdered borax was a safe, effective method for cleaning mold-infested gorilla remains that could be translated to archaeological human remains.

General Collections Studies

Since fungal spores can colonize any organic object, museum professionals have developed techniques of mold removal for other types of objects that have become infested in museum collections. Natural and synthetic pesticides, insecticides and fungicides have been used in the past to treat objects suffering from biodeterioration; however, these chemicals have caused a great deal of harm to both the objects and people handling them (Florian 1997). More recently, conservators have dealt with mold outbreaks in other types of collections; one case study (Thacker et al. 2008) is particularly relevant. The Natural History Museum of Los Angeles County's ichthyology and herpetology collections were infected with fungus after a period of wet weather conditions that caused fluctuations in temperature and humidity. After thorough consultation, the staff decided to use 70% ethanol to clean the animal bones because it is non-toxic, effective, and inexpensive (Thacker et al. 2008). The staff chose a 70% ethanol solution because it preserved the integrity of the animal bones and enabled future tests, including the extraction of DNA. The artifacts were immersed in the ethanol solvent, which killed all of the active mold and prevented any future mold growth (Thacker et al. 2008).

Conservators often recommend lab grade ethanol for the cleaning of biologically contaminated artifacts, since it is an extremely effective biocide that is non-harmful or corrosive. Claudia Chemello (personal communication 2012), conservator at the University of Michigan's Kelsey Museum of Archaeology, recommended a 1:1 ethanol and deionized water solution to clean the Senegalese human remains and kill any active or dormant mold on the remains. The solution would also be safe enough to ensure the preservation of the bone's integrity for future analysis and testing (Chemello personal communication 2012).

Florian (1997:27) has observed that "conservators have an ethical responsibility to be sure that any treatment undertaken on an object will not destroy its aesthetic or physical integrity, or compromise its research potential." Every active treatment has the potential to damage an artifact, so it is important to ensure that a treatment is minimally invasive and absolutely necessary to prevent the further deterioration of the object. As with other aspects of museum work, conservation treatments need to be approached thoughtfully and critically (NPS 1996-2012). The Museum of Anthropology's human remains collection needed immediate conservatorial attention, including treatment, to ensure their future preservation. It was imperative to find treatments that were safe for both the bones themselves and for anyone handling them, and that would kill all mold spores. Therefore, I looked to both forensic case studies and general museum collections care practices. While none of these was a perfect correlate, they do provide potential treatments suitable for removing the mold from the Museum of Anthropology's human remains collection.

5.2 Preparation of the Human Remains

Before any work began on the human remains, important safety precautions and procedures had to be outlined. Many species of mold are non-toxic irritants and possible allergens, while some species can be more dangerous to humans; for example, mold from the genus *Aspergillus* can cause serious respiratory infections (Dicus 2000). It is also important to remember that molds present a constant threat to other collections in the same storage facility. At any point during the cleaning and treatment process, the mold spores from the infested objects can become airborne and contaminate other organic artifacts. Because of the potential threat to both humans and other objects, conservators and museum professionals need to follow health and safety standards when dealing with these biohazardous collections. The most important precaution is to wear a HEPA regulation filter respirator that protects against MVOCs (microbial volatile organic compounds) (Dicus 2000; Guild and MacDonald 2004; NPS 2000). These N100 particulate respirators filter out all environmental particulates, and they come in both disposable and reusable models; for my experiment, I decided to use disposable respirators since reusable models can be difficult to clean properly. While I worked individually in an isolated room, anyone else working in the same area as the cleaning and treatment of moldy materials should take similar preventive measures.

Another fundamental precaution is the use of disposable nitrile gloves when handling the remains to prevent any contact with the mold, as well as to prevent any DNA contamination that could negatively affect future analysis (Dicus 2000). I wore a lab coat throughout the entire process, as well as non-ventilated safety goggles for the cleaning process; after each day, I washed the lab coat with bleach and the glasses with 70% isopropyl alcohol (Guild and MacDonald 2004). I also took several preventive measures to maintain as clean and aseptic environment as possible. The moldy remains were isolated from other objects in an exhausting fume hood, where they remained throughout the entire experiment to ensure that any airborne spores were properly filtered (Florian 2000). All of the work surfaces and tools, such as the camera, were wiped down with a 70% isopropyl alcohol to kill any contaminants. Used protective equipment and other trash were disposed of immediately in double-bagged trash bags in an outside dumpster (Guild and MacDonald 2004).

1. "Defrosting" the Remains

After defining my safety procedures, the next step was to bring the frozen Senegalese remains to ambient temperature. As previously mentioned, the collection had been frozen for the past five years as an interim measure to prevent continued mold growth until a treatment plan could be devised. The freezing of moldy materials is often recommended to save time in preparation for treatment, since freezing slows down metabolic activity and kills active, germinating spores (Guild and MacDonald 2004; Florian 1997; Florian 2000). However, fungal spores can remain dormant in frozen contexts, with some strains still reproducing and other species able to remain active or viable after extreme cold storage for up to 22 years (Dersarkissian and Goodberry 1980; Florian 1997). While determining how best to "defrost" the remains, I could not ascertain whether the bones had been frozen while moist. This added an element of difficulty; if the bones retained moisture, then the "defrosting" process would release this moisture in the bones and possibly create a suitable microclimate for any remaining fungal spores to activate (Chemello personal communication 2012). The moisture in the bones could also crack and warp the already fragile human remains during this process. Therefore, it was important to slowly and carefully bring the remains back to ambient temperature (50-60 degrees Fahrenheit) (Florian 1997).

I removed a sample of eight bags of bones from the Museum of Anthropology's freezer. The bones were difficult to identify due to the extent of the mold growth and toilet paper wrappings, but I tried to choose long bones to ensure as much homogeneity for my comparative tests as possible. After removing the bags from the freezer, they were placed immediately in the fume hood, which provided a stable environment with low relative humidity and constantly circulating air to inhibit mold growth (Guild and MacDonald 2004). All of the individual fragments were removed from the bags, and the moldy toilet paper wrappings and tags were immediately removed. After making new labels, the moldy excavation materials were discarded according to safety procedures, and the bones were placed in fresh polyethylene bags. After transferring each set of bone fragments to a new bag, the bags were weighed individually to determine a starting weight (Chemello personal communication 2012). Over the next four hours, I carefully monitored the bags.

Each bag was left slightly open to let air out slowly so the bones would not warp or crack with rapid changes in temperature. Florian (1997) has also found that the slower the thawing process, the fewer dormant fungal spores will remain. I also made sure to check for any condensation forming on the inside of the bags, indicating the bones had been wet when frozen and were therefore more fragile. I was prepared to change the bags if condensation occurred to prevent an increase in relative humidity that might activate remaining fungal spores (Chemello personal communication 2012). Every hour, I weighed each individual bone bag to determine if the bones were losing weight, which would also indicate that the bones had been wet when frozen and would require an even slower defrosting process to ensure ice crystal retraction did not damage the skeletal remains (Florian 1997). After four hours, the bones did not sustain any damage from the defrosting process; they were mostly likely moist but not saturated when put into the freezer, preventing any serious damage from occurring. I transferred the bones to fresh bags once more, still partially closed to allow any humidity to escape, and then left the remains in the fume hood for 48 hours to completely dry and acclimate to room temperature.

Figure 2. Bone #21, femur. Pre-cleaning

2. Cleaning the Remains

Once the remains reached ambient temperature (50-60 degrees Fahrenheit and a relative humidity below 60%), I cleaned the bone fragments in each bag. I decided against wet-cleaning methods to preserve important archaeological evidence, such as attached soil deposits, and avoid interfering with future scientific analysis (Dicus 2000; NPS 1996-2012). The bones were hundreds of years old and very fragile, and their submersion in water might have further damaged them (Griset et al. 2004; Janaway et al. 2001). Most conservators recommend a dry cleaning method, such as vacuuming or electrostatic dusting to remove the negatively charged conidia (Florian 2000; Griset et al. 2004). A vacuum outfitted with a HEPA filter to prevent exhausting particles back into the room is the environmentally safest option, and vacuums can easily dislodge debris without damaging the surface of the bones (Florian 2000; Guild and MacDonald 2004; NPS 2000). However, the Museum of Anthropology does not have a specially outfitted vacuum for filtered fine cleaning, so each bone fragment was dry-brushed instead. Using a soft-bristled painter's brush, I was able to remove loose soils, mold growths, and accretions of toilet paper with minimal damage to the skeletal remains (Chemello personal communication 2012; Griset et al. 2004; Janaway et al. 2001). When necessary, I also used a wooden toothpick to gently dislodge soil accretions that had mold growth on their surfaces (Brothwell 1981).

In most cases, mold grows in the dust and deterioration products on the surface of materials. For the Senegalese remains, the moist toilet paper provided the greatest sustenance for the mold, as indicated by the concentration of mold colonization on it, and led to the growth of fungal spores on the dirty surface of the bones. Although the mold growth could be removed entirely, spots of discoloration remained on the bone surface, due to the presence of colored conidia, hyphae, sclerotia or pigments in the substrate of the bone that could not be removed (Florian 1997). Though the bones are not entirely cleaned, this initial cleaning was an important step in removing viable nutrients from the bones' substrate to prohibit the growth of future mold. Further, these stains do not negatively affect the research potential of the bones. Nawrocki (2003) argues that bones will continue to attract mold in curatorial settings if they have not been properly cleaned of organic residues. The condition of the bones was recorded both before and after the cleaning process with photographs, illustrations, and written descriptions to give a thorough account of their condition (Cassman and Odegaard 2007:29-47). After brushing off the surface debris, the bones were placed in fresh polyethylene bags and kept in the fume hood until they could be treated.

3. Treatment

The Senegalese human remains needed treatment; the bones were more fragile after the freezing process; the mold continued to damage the bones' surfaces; dormant fungal spores continued to survive the freezing temperatures, etc. All of these factors diminished their value, preventing them from functioning as scientific, cultural, or educational resources, so conservation treatment was justified (Florian 1997; NPS 1996-2012).

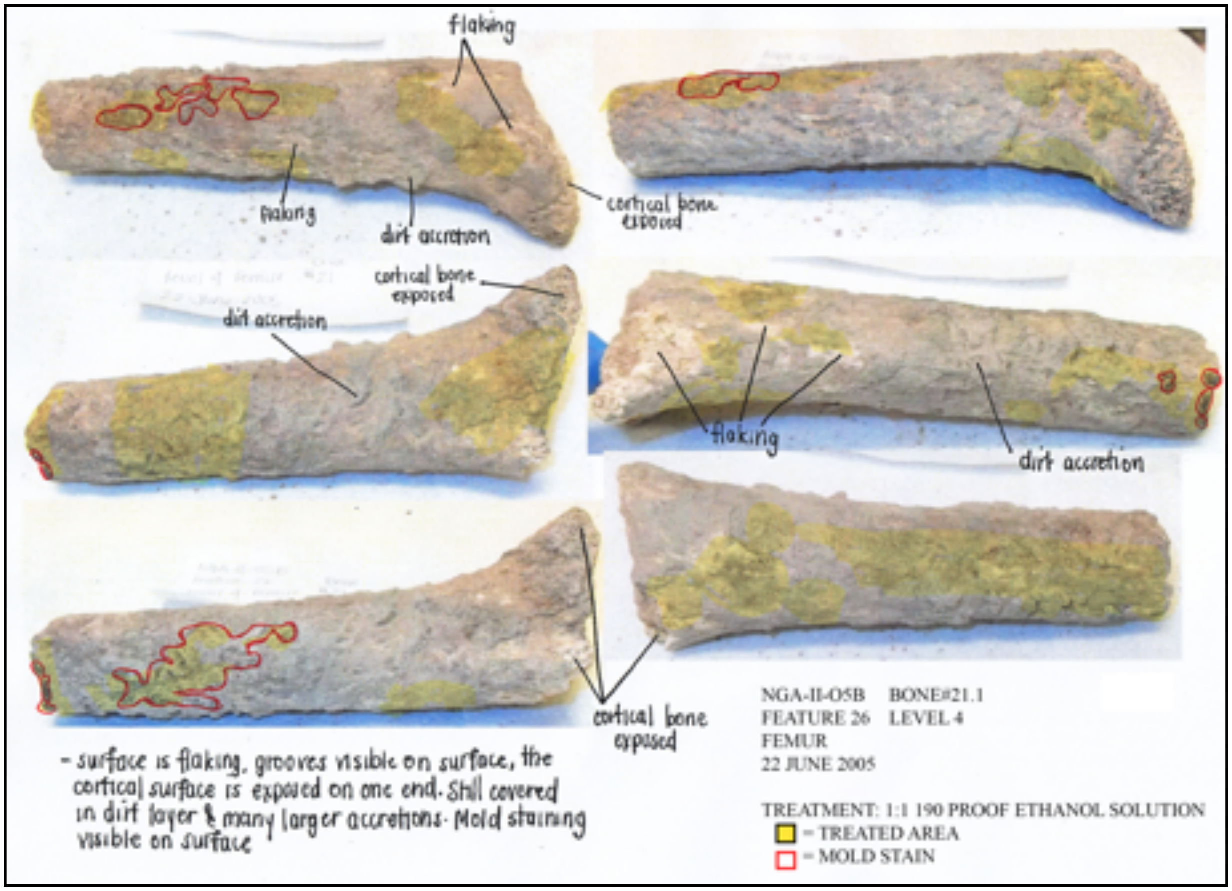
As previously discussed, I decided to test five different solutions, recommended by forensic anthropologists and conservators, to determine which was most effective at killing mold on the infested human remains. The treatments are: 70% ethanol, an ethanol solution, a detergent solution, a Borax solution, and an ammonia solution (See Table 2). I choose five bags with bones in the worst condition, and within each bag I selected the three largest elements to treat. To illustrate, I used 70% ethanol to treat bone elements 2.1, 2.2., and 2.3 from the bag containing Bone #2. The different solutions were applied using cotton swabs to provide controlled spot cleaning to the affected areas, and each cotton swab was disposed of after one application to prevent the contamination of the solution (Cassman and Odegaard 2007:77-92; Florian 1997). The application of each spot of treatment was carefully documented to provide a detailed record for future researchers, indicating the portions of the bones that had received treatment and could potentially compromise analysis (NPS 1996-2012) (See Figure 5).

Table 2. Tested Treatments

Treatment	Bone Number	Bone Elements
70% ethanol	Bone #2	Bone 2.1, 2.2, 2.3
1:1 ethanol and distilled water solution (190 proof)	Bone #21	Bone 21.1, 21.2, 21.3
20 mL powdered Tide detergent: 2L distilled water	Bone #21	Bone 21.4, 21.5, 21.6
150 mL Parsons sudsy ammonia: 2L distilled water	Bone #23	Bone 23.1, 23.2, 23.3
20 mL powdered Borax: 2L distilled water	Bone #19	Bone 19.1, 19.2, 19.3

Experiments have shown that certain species of mold spores are activated by chemicals including detergents and organic solvents, although this process is not well understood (Griffin 1981; Guild and MacDonald 2004). One way to combat the activation of fungal spores while cleaning is to use sparing amounts of solution to prevent dousing the bone in liquid that would take time to dry, leaving the bone moist and vulnerable to re-activation of the mold (Florian 1997). Most conservators also recommend removing remnants of detergents or surfactants used for cleaning, either through rinsing or flushing, to prevent activation (Cassman, Odegaard, and Powell 2007; Florian 1997). Therefore, I used moistened cotton swabs to remove the detergent cleaners (Tide solution, Borax Solution, ammonia solution) from Bones 21, 23, and 19. For Bones 2 and 21, I used high concentrations of lab grade quality ethanol to ensure that the ethanol acted as a biocide instead of an activator (Florian 1997). Fortunately, ethanol does not leave behind a surface residue, so the bones treated with the different ethanol solutions did not have to be carefully rinsed.

Figure 3. Example Object Treatment Form



4. Storage

Storage is especially important in conservation and collections care management since it provides a preventive measure to help avoid potentially harmful conservation treatments. Cassman and Odegaard (2007:103-123) refer to storage as the most common line of defense in the care and preservation of objects. Since storage materials have the most intimate contact with objects, conservators and collections care managers should use the highest quality materials when possible, although they can be quite expensive (Cassman and Odegaard 2007:103-123; Griset et al. 2004). Fortunately, the most important storage item is both accessible and affordable. Polyethylene bags protect objects from sudden increases in relative humidity and contact with water, prohibiting the growth of biological contaminants. Snugly fit polyethylene bags also prevent deterioration through minimized handling (since the interior of the bag is readily visible) and minimal dislodging of flakes or soil (Cassman and Odegaard 2007:103-123; Guild and MacDonald 2004). However, conservators and collections managers need to make sure that bones are completely dry when placed inside the bag to prevent the elevation of relative humidity within the bag (Guild and MacDonald 2004; Janaway et al. 2001).

After treating the Senegalese bones, they were dried in the fume hood, outside of plastic bags, for 48 hours to allow for the total evaporation of all moisture so they could be housed safely without creating a moist microclimate. The bones were placed in snug fitting polyethylene bags, which were then placed on top of an archival tissue paper cushion inside a lidded, acid-free cardboard box. I left the remains in the closed box in a room with temperature and relative humidity control for six weeks so that I could assess the effectiveness of the five different treatments.

6. Results and Analysis

After six weeks, I inspected the five different bags of human remains for any mold re-growth or damage. None of the treated remains showed any sign of mold re-growth upon close analysis, as well as any residues or adverse effects from the conservation treatments. There are several factors contributed to these results: the freezing of the remains; the environmental stabilization; and the treatments. All three of these components need to be discussed in order to further understand the results of this experiment and to make future recommendations.

6.1 The Freezing Period

When the Museum of Anthropology consulted with a private conservator, they recommended putting the bags of bones directly into the freezer until someone could properly treat the remains. With the transfer of the curator and the lack of a conservator, the Senegal collection remained frozen in the Museum of Anthropology's freezer for five years (O'Brien personal communication 2013). This long freezing period provided some important benefits, such as killing any active fungal spores. Freezing the bones removed any of the bound water in the substrate of the human remains, which slowed down the metabolic activity of the fungus and prevented further growth. Since the fungus remained in a freezing environment for an extended period, the metabolic activity slowed down enough to kill large amounts of the population, including all active spores or hyphae (Guild and MacDonald 2004; Florian 1997). Therefore, a large majority of the fungus infesting the Senegalese human remains was killed during the freezing process.

Freezing infested artifacts, especially when there is a significant number of affected objects, is a smart, time-saving solution. It can quickly slow down fungal growth and kill many of the active spores with minimal manual effort; however, long-term storage, as in the case of the Senegalese remains, is not advised. Long-term freezing greatly increases the chance of damage to human remains, as ice crystals formed in the freezing process can damage cell walls and structure (Florian 1997). These damages drastically impair the regain ability of the material, meaning the original shape and physical appearance of the object can be compromised. Freezing is not a 100% effective solution either; freezing does not always stop fungal activity, and if the object is wet when placed in the freezer, the fungus can continue to grow and produce black hyphae that are especially resistant to removal (Florian 1997).

Although freezing can kill active mold, it does not eliminate the problem of dormant or dry spores (Guild and MacDonald 2004). Resistant to freezing, dry spores can survive and have the potential to reactivate, as long as the moisture in the frozen materials remains elevated and provides a suitable microclimate for mold reactivation after thawing (Florian 1997). Dormant conidial spores can also survive freezing; studies have shown that most common species of mold can survive up to 22 years in a dormant state, while other species can continue to grow at freezing temperatures (Dersarkissian and Goodberry 1980; Guild and MacDonald 2004). While freezing infested materials is an excellent first step in treatment, it cannot be the sole preservation measure attempted since it is not completely effective and has the potential to damage human remains over an extended period.

6.2 A Regulated Environment

Environmental control also played a role in preventing mold regrowth. Mold grows fastest at warm temperatures that exceed 75 degrees Fahrenheit and in moist environments with a relative humidity higher than 65% at any given temperature (meaning the air cannot hold more than 65% of its total water-carrying capacity) (NPS 2000). By keeping the Senegalese remains in the fume hood, I was able to maintain an environment that prohibited fungal growth. The continual movement of air generated by the fume hood fan system ensured that hot or moist air did not settle, maintaining a temperature below 75 degrees Fahrenheit and a relative humidity below 60% (Guild and

MacDonald 2004; Thacker et al. 2008). Although mold species can continue to grow outside optimal conditions, a controlled environment with lower temperatures and relative humidity provided was essential to preventing a mold outbreak or regrowth on the Senegalese remains. Environmental control is an important element of preventive conservation that allows collections care managers and conservators to "prevent" the deterioration of objects, and the resulting necessity to intervene with treatment (NPS 1996-2012).

However, museums and institutions cannot always provide a properly regulated environment for their collections. As discovered by the Heritage Health Index (Heritage Preservation 2005), a quarter of collecting institutions have no environmental controls, and moisture has damaged over half of the collections in American institutions. This harsh reality is especially problematic for biologically infested artifacts like the Senegalese remains; as previously discussed, freezing does not kill dry or dormant fungal spores. These spores could easily activate and infest the Senegalese remains again if they are not kept in a controlled environment, which is not a guarantee in today's complicated, under-funded world of collections management and museum storage (Guild and MacDonald 2004). Environmental control can prevent dormant or dry fungal spores from reactivating, but these spores can still pose health risks to humans. While dormant mold spores do not pose an immediate threat to the skeletal remains, they retain their allergenic and toxigenic properties dangerous to humans (Guild and MacDonald 2004). Since the Senegalese remains were infested with an unidentified mold from Africa, it is safest to kill all remaining spores for future professionals or interested parties interacting with the bones. Therefore, treatment was necessitated despite the additional attempts to prevent mold regrowth.

6.3 The Treatment

While the freezing killed the active mold and the prohibitive environment prevented the dormant and dry spores from reactivating, the major focus of my experimental research involved the third component of the conservation process: the five treatment discussed in detail below. Although culturing a surface swab from the remains is the only way to tell if the mold had been completely killed, I did not have the resources to confirm the success of the treatments in this manner. Using a microscope, I tried to determine if the treatments successfully killed the remaining mold spores by examining the bones six weeks after application, a typical time frame used in other mold studies. Ideally, the remains should then be examined every three months for the first year, and then once a year afterward, to ensure the treatments were preventing mold regrowth.

All five treatments were successful in killing the mold: I observed no mycelium, furry growth, or fresh discoloration indicative of mold activation and colonization. The detergent treatments (Tide, Borax, and Ammonia) worked by interfering with the metabolic processes responsible for fungal growth and spore production, killing the spores and inhibiting future mold growth (Dersarkissian and Goodberry 1980). The two ethanol treatments (70% ethanol, 190 proof ethanol) killed the spores through dehydration and the destruction of fungal proteins (Florian 1997). With the reductions in viable spores due to the freezing and environmental control, it is likely that one application of the treatment was sufficient to kill the mold and protect the remains throughout their lifetime (Dersarkissian and Goodberry 1980).

While all the treatments were successful, I recommend the 70% ethanol as the best treatment for future use for several reasons (see Table 3 for reviews of all five solutions). First, the solution penetrates the cell walls of the spores, dehydrating and destroying the proteins, effectively killing the spores on contact (Dersarkissian and Goodberry 1980). The high concentration of the ethanol helps ensure the solution acts as a biocide and not an activator, a danger with the detergent solutions (Tide, borax, and ammonia) if not properly rinsed (Cassman, Odegaard, and Powell 2007; Florian 1997). Second, ethanol is also safe for the bones and does not leave behind a residue, preserving the physical integrity of the objects. Third, the 70% ethanol treatment does not need to be mixed with distilled water and does not require a second application step, such as flushing with water, which reduces the difficulty of implementing the treatment. Fourth and finally, even though this experiment was completed in a lab setting with easy access to materials and storage, the 70% ethanol treatment can be used at other institutions or even in the field. 70% ethanol, commonly known as rubbing alcohol, is inexpensive and available at most pharmacies, including those in rural areas and in developing countries. It also does not require special storage, lending itself to use in a variety of settings. In Table 3 below, I evaluate the other treatment methods along with all of the criteria discussed above. While the 1:1 solution of 190 proof ethanol and distilled water also has more pros than cons, its high cost, special storage needs, and the necessity of mixing it with a second liquid makes the treatment less accessible in field situations or developing countries. The problems with the detergent solutions easily outweigh the benefits.

Table 3. Treatment Rankings based on Pros and Cons of Each Method.

Treatment (ranked)	Pros	Cons
1. 70% ethanol	- Kills spores on contact - High concentration to prevent activation - Does not require a second application step - Does not require mixing with a second liquid - Does not leave a residue - Cheap and widely available - Easily stored	- Does not evaporate
2. 1:1 solution of 190 proof ethanol and distilled water	- Can kill spores on contact - High concentration to prevent activation - Does not require a second application step - Does not leave a residue - Evaporates, preventing activation	- Can cause proteins to coagulate, preventing cell from being destroyed (goes back to dormancy) - Does require mixing with a second liquid - Expensive and needs to specially ordered - Requires special storage

Treatment (ranked)	Pros	Cons
3. 20 mL Tide and 2 L distilled water	- Can kill spores on contact - Cheap and widely available - Does not require special storage	- Can just return spores to dormancy - Can activate spores - Does require a second application step - Does require mixing with a second liquid - Does leave a residue without rinsing - Does not evaporate
4. 20 mL Borax and 2 L distilled water	- Can kill spores on contact - Cheap and widely available - Does not require special storage	- Can just return spores to dormancy - Can activate spores - Does require a second application step - Does require mixing with a second liquid - Does leave a residue without rinsing - Does not evaporate
5. 150 mL Parson's sudsy ammonia and 2 L distilled water	- Can kill spores on contact - Cheap and widely available - Does not require special storage	- Can just return spores to dormancy - Can activate spores - Does require a second application step - Does require mixing with a second liquid - Does leave a residue without rinsing - Does not evaporate

7. A Multi-faceted Approach to Mold Infested Remains: Concluding

With the Museum of Anthropology case study, I tested a variety of methods, and the resulting recommendations represent a multi-faceted, comprehensive approach to treating human remains that aims to eradicate infestation at every available step (See Figure 6). Once the infested human remains have been isolated, freezing should be the first step in treatment, since it effectively inhibits mold growth and kills active spores. However, the bones should be completely dry (which helps to kill spores through dehydration) before entering the freezer to prevent damage to the human remains and prevent a high moisture content from reactivating spores upon thawing (Florian 1997). Dry human remains also should not remain in the freezer for longer than six months to prevent structural damage (Florian 1997; Guild and MacDonald 2004). After freezing, a slow thawing process will also kill many of the remaining active spores while decreasing dormant spore viability for future reactivation (Florian 1997). Since it is a more gradual change in temperature, slow thawing is also safer for the bones as long as the collections staff constantly checks for possible condensation.

Table 4.

Recommended Procedure for Mold Infested Archaeological Human Remains	
1. Freezing	- stop growth, kill active spores
2. Slow Thawing	- kills active spores, decreases remaining spore viability, safe for human remains (no drastic temperature changes)
3. Environmental Control	- prevents the activation of dormant or dry spores
4. Treatment	- apply 70% alcohol treatment to affected areas of bone; allow for 48 hours of drying
5. Storage	- snug polyethylene bags are resistant to mold, maintain proper microenvironment, prevent physical damage

Once the remains have been brought up to ambient temperature, they should be kept in an environmentally controlled area with a temperature lower than 75 degrees Fahrenheit and a relative humidity lower than 60% to prevent the activation of surviving dormant or dry spores. The infested remains should then be treated with 70% ethanol, applied only to affected areas and precisely documented on photograph forms, and left to dry for 48 hours to ensure the bones retain no moisture. Treated remains should then be placed in polyethylene bags, which are resistant to biological activity, to provide a stable, secure microenvironment while allowing for easy accessibility. Every step of the treatment should be properly documented, and these records also need proper curation so they can inform any future analysis or treatment of the remains.

While the Museum of Anthropology case study focused on developing the best treatment plan for conservators and collection managers to follow when dealing with mold-infested human remains, this thesis research can also suggest a number of simple preventive measures that can be applied to any archaeological setting involving human remains excavation, since the best treatment is to *prevent* mold from developing in the first place. Excavators should brush bones clean to help minimize the organic debris left on the remains that could potentially support fungal infestation. Bones should be completely dry before packing; excavators can achieve this with fans or by placing the materials in an area with good air flow to ensure evaporation and prevent the retention of any moisture that would create a suitable climate for biological activity. As an extra precaution or to mitigate any moisture content remaining in the bones, excavators should pack silica gel in with the human remains to regulate the microenvironment and maintain a low relative humidity. Although archaeological field work is a complex endeavor, these are simple, low-cost and minimal effort steps that can be taken to prevent the infestation of human remains and conservation treatment.

Though the Senegalese human remains became infested during field work and transport to the Museum of Anthropology, their infestation was also the result of a breakdown in communication. This case study demonstrates how important it is for curators, collections professionals, and archaeologists to improve communication. Archaeologists should consult collections managers and conservators at the institutions where the collections will be curated for proper collections care advice for excavation and transport. If collections professionals are not present at their institution, archaeologists can consult a variety of resources like the American Institute for Conservators website (http://www.conservation-us.org) that offer advice and tips, and large archaeology museums such as Arizone State Museum have published guidelines for preparing materials to be stored by the museum (Griset et al. 2004). Once objects have been transported to the collecting institutions, collections professionals and archaeologists need to prioritize the inventorying and documentation of the objects, taking care to treat artifacts that require immediate attention. An open dialogue between archaeologists and collections care professionals will ensure that collections receive timely, appropriate attention and are preserved for future needs.

Although the United States museums and collection institutions house over 4.8 billion artifacts in storage, millions of these artifacts are deteriorating from inadequate collections care and conservation attention. A number of obstacles prevent the fields of archaeology and conservation from providing the highest quality of preservation for these collections. Despite these difficulties, many professionals continue to strive to prioritize conservation in both the archaeological and museum worlds. One important way archaeologists and conservators meet these goals of preservation is through the development of collections care standards that are accessible, effective, and easy to implement in a variety of settings. These standards need to be scientifically tested for accuracy and safety to ensure the integrity of these priceless objects, but also be flexible enough to deal with the realities of archaeological and conservatorial work which entails vagaries such as minimal funding and staffing.

The UMMA case study was designed to fill a void of collections care standards for mold-infested archaeological human remains, and after rigorous testing, I have developed a set of recommended guidelines for any institution facing a similar problem with their collections. Mold is a reality of museum storage; objects in every collection in every museum in the world are covered with a variety of mold spores, and only a few easily disrupted environmental conditions prevent these spores from activating. Mold infestation threatens all of the organic collections in museums, since spores can easily become airborne and colonize other nearby artifacts. While these standards apply only to a specific subset of archaeological artifacts, it is a small but important step towards a more unified, informed field of collections care management that prioritizes the preservation of these valuable resources.

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Submission information

Form: Undergraduate Research Award Faculty Support Letter
Submitted by lcyoung
May 1, 2013 - 11:46am
99.9.114.148

MENTOR INFORMATION

Information about you, the faculty/mentor/supervisor.

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PROGRAM AFFILIATION

Your program affiliation.

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Student Applicant's UMich Email address

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Student's Project Title

Treating Bones: The Intersection of Archaeology And Conservation

Student Project Type

Multi-Term Project

Course Name/Number (if applicable)

Anthrarc 398 and 399

LETTER OF SUPPORT

Letter

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April 30, 2013

Dear MLibrary Undergraduate Student Research Award Selection Committee,

I am very pleased to nominate Stephanie Berger's honors thesis for MLibrary Undergraduate Student Research Award. The UM library system was a valuable resource for Stephanie's research. She used technical journals articles, edited volumes, and international publications that discussed a broad range of topics, such as archaeology, forensics, museums, conservation, and the biology of mold. Her thesis also intertwines traditional publications with on-line resources in a masterful way. I was very impressed the sophistication of Stephanie's argument, especially her applications of methods developed in other fields in her case study.

In the Department of Anthropology, we encourage students to build on their experiences and interests to develop their own research topic. Stephanie's research explores the interface between the field of archaeology and museums by looking at ethical issues pertaining to the conservation of human skeletal remains. Stephanie's thesis builds on her experience working with the Museum of Anthropology NAGPRA collections staff and integrates information from her minor in Classical Archaeology, where conservators are regular members of excavations crews, and her other minor in Museum Studies.

Stephanie's thesis focused on a common problem in museums: mold. She designed an experiment to test different ways of removing mold from human skeletal remains. Although her research centers around this straight forward methodological question, Stephanie's thesis goes beyond methods by contextualizing this experiment in larger ethical issues about the treatment of museum collections and the responsibilities of researchers (in this case archaeologists) and museum professional (collections staff and conservators). She explores the historical development of museum and archaeology to identify sources of friction and communication breakdown between these two fields, which share a common goal of preserving information and objects. Stephanie presents a thoughtful, balanced, and well-written discussion of the different perspectives and priorities of archaeologists and conservators. Her argument is incredibly well organized, and she did an excellent job of framing it in the larger context of research and the preservation of objects.

Stephanie told me that one very important factor in choosing her research topic was that she wanted her research to be helpful to others. She has successed in meeting this goal. Her thesis research will be used by the Collections Manager at the Museum of Anthropology to make decisions not only about the care and treatment of human skeletal remains but also about other organic materials that become infested with mold. I am also recommending that Stephanie revise the case study section of her thesis for publication to make her results accessible to archaeologists and museum conservators.

Thank you for considering Stephanie Berger's thesis for a MLibrary Undergraduate Student Research Award. I highly recommend it. Please feel free to contact me if you have any questions about Stephanie or her thesis.

Sincerely,

Lisa C. Young
Honors and undergraduate advisor for anthropological archaeology