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Crafting Nature: An Ethnography of Natural History Collecting in an Age of Genomics

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Crafting Nature:
An Ethnography of Natural History Collecting in an Age of Genomics

By

Adrian Van Allen

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Committee in charge:

Professor Mariane Ferme, Co-chair
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Professor Mia Fuller
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Abstract

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A specific understanding of "nature" has been crafted through centuries of assembling, examining and preserving selected parts of the world, now recast yet again through genomics. In the face of increasing extinction rates, with an estimated 50% of all species potentially heading towards extinction by mid-century, the ethical imperative to preserve biodiversity before it vanishes has taken on multiple forms. Nature conservation efforts have traditionally focused on stabilizing dwindling populations of endangered species and their habitats. In contrast, museum projects have emerged in the last few decades that focus on preserving vanishing biodiversity through genetic collecting for an uncertain future. In engaging the different practices of "crafting nature" in the distinct disciplinary "cultures" of one museum—the Smithsonian National Museum of Natural History (NMNH) in Washington D.C.—I examine how biodiversity is being collected, preserved and constructed in the contemporary age of genomics.

My ethnography focuses on the Global Genome Initiative (GGI) at the Smithsonian NMNH, tasked with "preserving and understanding the genomic biodiversity of life on Earth." The GGI seeks to sample and cryo-preserve half of the families of life in the next six years, gathering "genome-quality" tissue samples from newly collected specimens in an effort to biobank the planet's swiftly vanishing biodiversity. I follow specimens, tissues and data to different parts of the museum, examining the details of crafting specimens for the collections—both morphological (a bird skin in a drawer) and molecular (a tissue tube frozen in liquid nitrogen)—attending to how specimens are assembled, how they circulate and how their use and perceived value shift at boundary crossings. Natural history museums have historically been apparatuses for articulating knowledges, power, and natures into an ordered whole. I argue that these

articulations that have extended through to contemporary museums and their genetic collecting programs.

Throughout this research, I came to see how *(bio)materials matter*. Focused on objects and their significance in networks of social and cultural significance, scholarship on material culture has attended to the relationships of objects to each other and to the history and geography of the object. My research focuses on the material culture of genetic collecting within the museum, another form of replication and conservation which shifts current understandings of the relationships between originals and copies, specimens and samples, collectors and collected. As biotechnological tools and practices have migrated into the museum, corresponding analyses and theoretical debates have emerged in anthropology. These fields intersect in museum genomics, where I take up contemporary biotechnology and the history of the museum, attending to their intersection in current collecting and replication practices and embedding them in a longer history of scientific collecting and the reproduction of knowledge. I examine how biotechnology is redefining and preserving life through specimen preparation methods—using craft as my method to gain a first-hand understanding of how "nature" is made and remade in the back rooms of the Smithsonian National Museum of Natural History. Through being taught how to make specimens—to prepare a bird study skin, take tissue samples, sort and scan tissue tubes, pin beetles and pull insect legs for DNA analysis, run electrophoresis gels, press and mount plants, sample leaves into liquid nitrogen tanks, label bones and map genomic workflows from field to lab to freezer—I track the forms of value created through these multiple hand-crafted transformations, and examine how matter comes to matter through the physical and intellectual labor of the museum's invisible technicians.

Collections are *made to matter*—through their preservation, negotiated use and continuing re-evaluation. As specimens' biologies are taken apart into differently valued parts and pieces, spread across the spaces of the museum—from cabinet to liquid nitrogen tank to pinned in a drawer—it is important to remember that specimens remain sites of contested classificatory meanings, objects of shifting value, and (dis)embodiments of particular "natural orders." Through exploring museum objects in biographical terms, as mobile and transformative of a variety of relationships, I reiterate that there is multiplicity not only *between* but also *within* objects. Genomic collections in museums embody multiples kinds of significance, telling complex biographies. Collections are not simply accumulated

objects, but instead can be seen as a continual reassemblage of people, places, and materials and interests—they are a shifting composition of the people who have made, use, and collect the objects, and the biosocial imaginaries they both represent and reproduce. In analyzing the different methods of producing knowledge through producing specimens, I seek to render visible the ways collections are made, how they are valued and how they articulate the conditions of possibility for multispecies futures.

This work is dedicated

To my husband, Will
To my parents
And to the staff of the Smithsonian National Museum of Natural History

This would not have been possible without you

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List of Abbreviations

Barcode of Life Database	BOLD
Biodiversity Information Standards	TDWG
formerly the Taxonomic Databases Working Group	
Center for Conservation and Evolutionary Genetics	CCEG
Consortium for the Barcode of Life	CBOL
Convention on Biological Diversity	CBD
Darwin Core	DwC
Encyclopedia of Life	EOL
Global Biodiversity Information Facility	GBIF
Global Genome Biodiversity Network	GGBN
Global Genome Initiative	GGI
Herpetology Collections Network	HerpNET
Ichthyology Collections Network	FishNet2
Mammal Networked Information System	MaNIS
National Anthropological Archives	NAA
National Science Foundation	NSF
National Zoological Park	NZP
Natural History Building	NHB
Ocean Biogeographic Information System	OBIS
Ornithological Information System	ORNIS
Smithsonian Collections Database	Emu
Smithsonian Environmental Research Center	SERC
Smithsonian Field Information Management System	FIMS
Smithsonian Institute for Biodiversity Genomics	SIBG
Smithsonian Institutional Archives	SIA
Smithsonian Lab Information Management System	LIMS
Smithsonian Laboratories for Analytical Biology	LAB
Smithsonian Museum Support Center	MSC
Smithsonian National Air and Space Museum	NASM
Smithsonian National Museum of American History	NMAH
Smithsonian National Museum of Natural History	NMNH
Smithsonian National Museum of the American Indian	NMAI
Smithsonian Tropical Research Institute	STRI
United States Botanical Garden	USBG
United States Department Of Agriculture	USDA
United States Geological Survey	USGS
United States National Museum	USNM
Vertebrate Zoology Collections Network	VertNet

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Chapter 1
INTRODUCTION

(Re)Valuing Collections in the Anthropocene

Objects are not innocent, but fraught with significance for the relations they materialize.
— Lucy Suchman (2005:279)

Specific understandings of "nature" have been crafted through centuries of assembling, examining and preserving selected parts of the world, now recast yet again through genomics. Through crafting "natural" objects—from preparing study skins, to pinning insects, to taking tissues samples—natural history museums have been apparatuses for articulating knowledges, power, and natures into an ordered whole. These articulations have extended through to contemporary natural history museums and their genetic collecting programs. Thinking through natural history collections, both morphological and molecular, as transformed life raises many questions as well as offering up opportunities for thinking through how, why and by whom life is being archived. In engaging the different practices of "crafting nature" in the distinct disciplinary "cultures" of one museum—the Smithsonian Institution National Museum of Natural History (NMNH) in Washington D.C—I examine how biodiversity is being collected, preserved, constructed and standardized in the contemporary age of genomics.

In the face of increasing extinction rates, with an estimated 50% of all species potentially heading towards extinction by mid-century (Barrow 2009; IUCN Red List 2015), the ethical imperative to preserve biodiversity before it vanishes has taken on multiple forms. While nature conservation efforts have traditionally focused on stabilizing dwindling populations of endangered species and their habitats, citing the interdependence of ecosystems, projects have emerged in the last few decades that focus on preserving vanishing biodiversity through genetic collecting for an uncertain future. Natural history museums have also shifted to echo this perspective, moving from diorama-based exhibits as "windows on nature" to emphasizing biodiversity, networks of all living things, and the genome as a "library of life's code" (Encyclopedia of Life 2014) that can be gathered and

preserved in their collections. As life is increasingly understood as a network of living things, systems, and processes—not just as biodiverse, but also as biocomplex (Biodiversity Information Standards 2015; Hanner et al. 2009; Peterson et al. 1998)—natural history collections have also been transformed into networks of increasing complexity, with vouchers (the reference specimen), tissues and data dispersed across museum departments as well as across the globe at different museums, research centers, zoos, botanical gardens and biorepositories. The larger cultural shift towards reducing life to the biological (Franklin and Lock 2003; Landecker 2007; Radin 2013; Rose 2007; Sunder Rajan 2006) forms the condition of possibility for genomic collecting projects that concentrate the dwindling diversity of life into museum-based assemblages of vouchers, tissues and data. Examining one instance of how genomic collections are made and remade, standards are developed and shared, and values are produced forms the core of this dissertation.

My study focuses on the Global Genome Initiative (GGI) at the National Museum of Natural History (NMNH), tasked with "preserving and understanding the genomic biodiversity of life on Earth" (GGI 2013). The GGI seeks to sample and cryo-preserve half of the families of life in the next six years, gathering "genome-quality" tissue samples from newly collected specimens in an effort to biobank the planet's swiftly vanishing biodiversity. My research examines the GGI's research strategies, funded expeditions and genomic collecting protocols, tracking specimens, tissues and data to different parts of the museum, from Botany to Birds, from the Laboratories of Analytical Biology (L.A.B.) to the Biorepository. I explore the details of making specimens for the GGI collections—both morphological (a bird skin in a drawer) and molecular (a tissue tube frozen in liquid nitrogen) —attending to how specimens are assembled, how their use and perceived value shift, and how they circulate. My ethnography is based on fourteen months of fieldwork between 2013 to 2016 at the Smithsonian National Museum of Natural History (NMNH), a site where collecting practices are changing rapidly with the integration of genomic technologies as a response to increasing extinction rates.

I examine three main threads in this dissertation, focused on the material practices of crafting natural history collections in an age of genomics. I attend to the assemblage of specimens in different disciplinary histories and "cultures" in the museum that combine materials, people, places and interests; I examine the negotiations at disciplinary borders as genomic collecting standards are created

and integrated into existing practices; And I explore the various kinds of value produced as specimens are assembled and circulated across these borders. Across these three threads, I think through the different kinds of “nature” and “natural order” that result from these practices and the visions for the future embedded in the creation of a genomic archive of all life.

The kinds of questions I ask in this dissertation range from those concerning the smallest details of changes in knowledge production and practice within specimen preparation (such as types of steel pins used for mounting insects, the size of fonts on specimen labels, how to label cryovials and how much tissue to put in them, kinds of cotton to stuff specimens) to broader ranging questions about biology, “life” and the human position within this more comprehensive ontological frame. What does "life” become as it is collected, classified, selectively disassembled, manipulated and mobilized within the context of contemporary genomic museum science? What reciprocities are crafted to maintain relationships between the innovation of biodiversity biobanking and long-established continuing taxonomic methodologies for ordering life? In what ways are human subjectivities—ways of being human—imagined and woven together with hopes of biodiversity protection? What deep intuitions around the protection of species, but also their loss and destruction, inform the urge to archive all families of life on earth, frozen for posterity? Asking these questions required that I zoom into the micro-scale of the process and production of making genomic tissue samples, their vouchers and their data sets within multiple organism-specific disciplines—and out again to a global scale to understand their expanding context as collections are distributed across multi-institutional coalitions. In these new global frameworks tissues can be biobanked separately from the voucher specimen (the referent for all pieces derived from it), the genomic data stretched across open-source databases worldwide, and amplified DNA taken from the tissues circulating to museums and institutions in yet other locales—after obtaining the appropriate permits and permissions for third-party access.

Throughout this research, I came to see how (bio)materials matter. Focused on objects and their significance in networks of social and cultural significance, material culture studies attend to the relationships of objects to each other and to the history and geography of the object (Appadurai 1986; Bleichmar and Mancall 2011; Comaroff and Comaroff 1992; Ferme 2001; Gosden and Marshall 1999; Joyce and Gillespie 2015; Kopytoff 1986). My research takes up the material

culture of genetic collecting within the museum, another form of replication and conservation which shifts current understandings of the relationships between originals and copies, specimens and samples, collectors and collected (Bell 2012; Hayden 2010; Moutu 2006). As biotechnological tools and practices have migrated into the museum, corresponding analyses and theoretical debates have emerged in anthropology (Bamford 2007; Franklin 2007; Haraway 1991; Hayden 2003b; Helmreich 2009; Rabinow 1997; Sunder Rajan 2005, 2006; Twine 2010). These fields intersect in museum genomics, where I take up contemporary biotechnology and the history of the museum, attending to their intersection in current collecting and replication practices and embedding them in a longer history of scientific collecting and the reproduction of knowledge. I examine how biotechnology is redefining and preserving life through specimen preparation methods—using craft as my method to gain a hands-on understanding of how "nature" is made and remade in the back rooms of the Smithsonian National Museum of Natural History. In other words, I examine how matter comes to matter (Barad 2003) through the physical and intellectual labor of the museum's invisible technicians (Shapin 1989).

In order to explore the creation, stabilization and circulation of museum specimens, I describe what I believe are the most illustrative moments in the creation of genomic collections and their voucher specimens, examining what work is required to sustain their value as useful objects with which to document and know the natural world. To do so, I define the object under analysis as the whole specimen, its tissue parts and its digital representation (as genomic data). By incorporating insights from scholars who have explored what it means to unravel the multiple biographical trajectories of objects and their roles in the production of knowledge (Alberti 2011; Bell 2012; Gosden and Marshall 1999; Ingold 2012; Joyce and Gillespie 2015), I demonstrate that biological specimens and their digital representations are scientific-epistemic objects (Knorr-Cetina 1997, 1999, 2013; Rheinberger 1997, 2000). Further, they are constitutive of lively and ever emerging forms of material culture in the contemporary natural history museum, articulating my encounters with the visions, practices, and imagined futures of global biodiversity biobanking.

Through my fieldwork in the museum, I saw genomic collecting at the Smithsonian NMNH mainly follow two paths–articulated by members of the museum community as either "*mining"* the historic collections for ancient DNA or

"*extending*" the collections with new specimens and fresh tissue samples.[1] These categories emerged from my observations, my participation in taking tissue samples and tracking their movements, and in interviews I conducted with museum staff, as well as in various articles and reports about the continuing relevance of the museum's collections and the need for continued support for their maintenance and utilization (DiEuliis 2016; Kress 2014; Lyman 2010; Rocha et al. 2014; Yong 2016). In "mining" the collections, specimens preserved over a century ago are now being re-evaluated for use in projects such as mapping historical climate change, reorganizing branches of the tree of life, and potentially resurrecting extinct species (Church and Regis 2012; W. Miller et al. 2008; Revive and Restore 2013). Further uses for collections include tracking invasive species and mapping the influx of disease vectors through birds and mammals in the name of national security (Heraty et al. 2007; Horváth et al. 2005; Strasser and Fantini 1998). At the same time the collections are being "extended" with tissues, DNA extracts, and environmental samples to name but a few of the parts and pieces being extracted and preserved in freezers and liquid nitrogen tanks.

My method for understanding these artifacts was to learn to make them (Dewey 1938; Harris 2007; Ingold 2013; Wilkinson-Weber and DeNicola 2016). I chose a view from below (Harding 2008), that is, an approach that positioned me as one of the specimen preparators or lab technicians—where I could learn to craft specimens and see first hand the differences between what was said, what was done, and what was made. This perspective, of *learning-through-making* (Dewey 1938; Dudley 2014; Lave 2011; Ingold 2013; Sennett 2008), gave me access to those negotiations at the disciplinary borders, and I conducted interviews with preparators and technicians across the museum. Through being taught how to make specimens—how to prepare a bird study skin, take tissue samples, sort and scan tissue tubes, pin beetles and pull insect legs for DNA

[1] Although genetic sampling has been practiced at the Smithsonian NMNH for the past thirty years, the increasing accessibility of biotechnological tools has brought new attention and corresponding pressures to collections, as I outline in this chapter. The two main areas of concern for curators, data and collection managers, specimen preparators and the Registrar were how to deal with the rapidly increasing requests to sample existing collections (*mining*) and how to adequately bind together genetic samples to their vouchers via data (*extending*). While other modes of genetic collecting certainly exist in the museum—such as collecting genetic samples but keeping them separated out for research, a practice characterized by some as "hoarding" —these are not my specific focus. In this dissertation I examine the two main modes by which *the collections are expanding*—either through mining genetic samples that then circulate out to other institutions, producing more data and more samples, or extending the collections through adding new genetic material and associated voucher specimens.

analysis, run electrophoresis gels, press and mount plants, sample leaves into liquid nitrogen tanks, label bones and map genomic workflows from field to lab to freezer—I tracked the forms of value created through these multiple hand-crafted transformations, divisions, and boundary crossings (Appadurai 1986; Graeber 2001; Kopytoff 1986; Moeran 2010; Munn 1986; Star and Griesemer 1989). Understanding the social lives of objects—as living things were transformed into specimens and then into data, accruing different kinds of value as they circulated within and outside of the museum—forms a central thread in this dissertation.

During my fieldwork I participated in developing the Global Genome Initiative's first version of a genomic collecting protocol, a process that required negotiating the different ways of organizing the natural world, preparing specimens and doing genetic research in the distinct "cultures" of the museum's Divisions and Departments. The urgency of creating these comprehensive cryocollections has catalyzed debates at the National Museum of Natural History (NMNH) over the standardization and efficiency of workflows in the different disciplines, such as the Division of Birds versus the Department of Entomology versus Botany—highlighting the different disciplinary practices involving birds, worms and plants. Another source of debate was the value of tracking the "life histories" of genetic samples as they travel through and between museums, with the amount of detail in the data trail seen as either "vital" or "wasted labor" by different museum staff. The very purpose of a collection was also a recurring source of friction—be it pinned beetles in a drawer or vials of frozen tissue—questions were raised repeatedly over how they should be conserved or used, shared or secured.

My research has taken me from the Division of Birds to the National Parasite Collection, from "Beetle Heaven" in Entomology to the Vertebrate Zoology Preparation Lab, from the US Botanical Garden to the Biorepository. At each site I learned the local "culture," the specific craft practices and the different customs around specimens and collections. Through extended conversations during participant observation, as well as through more formal interviews, I sought to draw out the different narratives about nature and its preservation in each site—from conserving the collection as intact objects in the face of increasing genetic sampling requests, to larger controversies concerning biodiversity conservation of endangered species or ecosystems through the addition of newly collected specimens.

In learning how to "craft nature," I followed the operational sequences[2] of specimen preparation, looking to the "stickiness of practical encounter" (Tsing 2005) and the folding of time as techniques dating back to the 1860's are being modified to incorporate genome-quality tissue collection protocols. Examining how natural history collections are being both reassessed as resources for mining genetic material and extended with "genome-quality" tissue samples, I chart the processes of "biology unbound'" (Helmreich 2009:280) in specimen preparation practices. Specimens collected recently – as well as those preserved over a century ago—are now being re-evaluated for use in projects such as mapping historical climate change (Ostrom et al. 2014; Suarez and Tsutsui 2004), potentially resurrecting extinct species (Church and Regis 2012; Poinar et al. 2006; Revive and Restore 2013; Shapiro 2015; Seddon et al. 2014; Zimov 2005), and creating genetic databanks such as the Smithsonian's Global Genome Initiative (GGI 2013).

An attention to the specific qualities of the materials in play—the ways they are either pliant or resistant to transformation—gives insight into the different disciplinary histories that shape the collections, as well as their imagined future uses. For instance, a small chunk of muscle tissue cut from a bird or a reptile slides easily into a 2ml cryotube with the help of forceps, whereas a large butterfly has to be crumpled into the tube, body folded, with the wings occasionally removed beforehand and mounted on a sliver of cardstock. Much of the technology for biobanking originated within the human biomedical science community, which is reflected in the way vertebrates (birds, mammals, reptiles, fish—anything with a backbone and significant muscle groups to sample) fit into the workflows, whereas the rest of the planet's biodiversity has to be compressed and folded (sometimes quite literally) into the standardized spaces. The move towards standardizing genomic samples and data from the different disciplines within the museum—in an effort to make them legible across disciplines and institutions and meet the goals of the GGI—has deep implications for the disciplines in question. Each Department and Division has their own history of collecting and an existing set of standards that value particular parts of an organism, distinct ways to preserve it based on those evaluations, and specific kinds of data relationships that are deemed vital. Genomic collecting protocols,

[2] Though I reference *chaine operatorire* ("operational sequence"), I do not follow the traditional model in this dissertation; instead I use an interpretation of following the technical, social and material "coming-into-being" (Coupaye 2009: 433) of specimen assemblages, which I detail in the next chapter in *Methods, Part II: A Visual Anthropology of Specimen Preparation.*

such as the GGI's, call many of these practices into question and are in the process of reshaping how, what and why biodiversity is biobanked across the disciplines.

Materials matter, and my focus on the ways materials are transformed, becoming part of different assemblages of people, places, interests and concepts, seeks to bring the (bio)materials of the museum into productive conversation with the ongoing discourses in science and technology studies (STS) and anthropologies of science around the rhetorics of genomics, public policy, colonial histories of collecting, bioprospecting, and the reproduction of knowledge. Using craft-as-method I analyze not only my experiences of making specimens, but also my own craft practices as a visual maker within museum culture. My own history has shaped my interactions in the museum, from what I focus on to what I discard. I have chosen to focus on how "nature" is crafted in the museum, not only through the different rhetorics being produced, but also how those rhetorics are shaped and oriented through the biomaterials of specimens.

In attending to the details of material practices, and putting them in contrast to their long histories within the museum, I can bring into focus various continuities and ruptures in those practices. A striking example was when I was learning to prepare a bird study skin, following procedures that were almost identical to those from an 1856 manual written by the second Secretary of the Smithsonian, the ornithologist Fullerton Spencer Baird (1856). Semi-frozen duck on the table in front of me, I measured the distance up from the cloaca (anus) a thumb-width, and then made a long incision up across the belly to the throat using short, delicate strokes so as not to cut through the intestines beneath. After much work peeling the skin from the body and then measuring internal organs we catapulted from the nineteenth century to the twenty-first century, taking tissue samples from the heart, liver and muscle. After pushing the red globs into a 2ml plastic tube, we dutifully labeled each one and put them in the preparation lab's freezer. We then returned to our bird skin to stuff it with cotton wool, the same process from Baird's 1856 protocol—even using the same kind of upholstery thread he recommended. *The heart of the matter, in this particular study, may be an actual heart.* As I trace the path of sampled heart tissue frozen in a cryovial, its circulation to the lab and then the biorepository, I can see what different materials and concepts are variously broken apart, brought together and how they change as they move across borders. Donna Haraway's concept of a ventriloquist for "nature" (1997:24), helps to illuminate how genetic samples in the biorepository

function to negotiate value within larger cultural and scientific networks, "speaking" for their species, genus or family.

Throughout this dissertation I look to the contemporary fusions of nature, culture and capital created within museum collecting and preparation practices. In the context of genomics in the museum, specific ethical choices are being made and "natural" truths (re)made according to shifting ideals of value and use. Attending to the biomaterials of museum specimens and their makers leads to a fuller understanding of how life is being redefined by biotechnology, both within the museum and beyond. Following scholarship that examines assemblages I suggest that collections – be they frozen genetic samples or bird skins in a drawer – are not simply accumulated objects, but instead can be seen as a continual reassemblage of people, places, materials and interests, a shifting composition of the people who have made, used, and collected the objects, and the biosocial imaginaries they both represent and reproduce (Bell 2012, 2013; Bell et al. 2013; Deleuze and Guattari 1987; Gosden et al. 2007; Hayden 2003b; Pearce 1995; 2010; N. Thomas 2010; Rabinow 1996).

Examining how museum nature is crafted—pulled apart, reassembled, pinned, pressed, stuffed, pickled or frozen—provides insight into how one view of the natural world is created and maintained, driven by an ethical imperative to collect and preserve dwindling biodiversity for an unknown future. Embedded within that worldview is a perspective on our own species' role in a shared human and multispecies ecological future, providing either potential salvation (through genomics) or continuing destruction. The museum as a sociocultural apparatus creates *a natural order of things*, naturalizing power relations, and replicates these relations in its research platforms, collection strategies, and conservation narratives. These reconfigurations of natural order are not happening in a uniform top-down mode, but in small on-going negotiations at the borders of disciplines and domains—for example, what counts as "genome quality tissue" for vertebrates such as bison and birds may not hold true for insects or for plants. Each discipline has its own version of "nature" and "natural order" that is legible in the particular ways it crafts specimens, organizes its collections and allows access and use of those collections. In analyzing these different modes of "crafting nature" in the museum, I attend to the implications of these histories and the ways they structure emerging definitions of life and the conditions of possibility for a shared ecological future in an era that has been characterized as the Anthropocene, or "Age of Humans"—a concept I engage with later in this

chapter in a discussion of the "vital inherent value" of natural history collections as they are used to mark time in the Anthropocene. "Objects are not innocent," as Lucy Suchman reminds us, "but fraught with significance for the relations they materialize" (2005:279). The next sections examine in greater detail the re-evaluation of natural history collections as genetic resources, followed by an outline of the shape of the dissertation.

Histories of Nature and Natural History: The Smithsonian

August 2014. Stepping into the central rotunda of the Natural Museum of Natural History in Washington D.C., I face a taxidermy mount of a charging young male elephant that dominates the columned marble space [Figure 1-1]. His name is "Henry," renamed as part of a marketing campaign to refurbish him, which was completed in 2015 and included a cleaning, repairs to the cracked hide with colored wax, and a new minimalist marble pedestal to replace the naturalistic base he used to share with birds in an acacia tree, snakes, dung beetles and a rusted tin can (supposedly to represent each of the museum's departments—the tin can being Anthropology's somewhat abject representative). Through monumental openings surrounding the elephant I can see into three sections of the museum. To the left are modernized dioramas of African mammals, with a male lion on a central white pier. Straight ahead a life-size model of an Atlantic right whale[3] competes for attention with a preserved Coelacanth and glass cases offering glimpses into the creatures of the deep sea. To the right the opening is blocked by a plywood wall. Fragile sections of the Burgess shale, the earliest known fossils of complex life, are usually displayed beneath articulated dinosaur skeletons, but these have been crated and put into storage while the hall of "Deep Time" undergoes restoration through 2017.

[3] A cast made of a blue whale (*Balaenoptera musculus*) was taken from the remains of a specimen capture at a whaling station in Hermitage Bay, Newfoundland by Smithsonian staff in 1903. Made with shredded bills from the nearby U.S. Mint (an option that was cheaper than paper at the turn of the nineteenth century), it was exhibited in 1904 at the St. Louis Exposition and then displayed in the United States National Museum (Smithsonian Institution, A Century of Whales 2016). The current model of a Atlantic right whale (*Eubalaena glacialis*) that hangs in the Sant Ocean Hall was modeled instead of cast, based on an actual living whale named "Phoenix" and constructed of foam and papier-mâché on an aluminum frame (Smithsonian Institution, Sant Ocean Hall 2016). Each of these models replicates not only a specific whale, but also specific relationships between materials, (human and nonhuman) animals and interests—such as a whale "embodied" in 1903 shredded currency or molded foam in 2000, the material processes articulating the shifting relationship between scientists and specimens in whaling stations or in the wild ocean.

Figure 1-1. The Smithsonian National Museum of Natural History rotunda, with the elephant “Henry” before (top photo, August 2014) and after restoration (bottom photo, February 2016).
(Photos: Smithsonian Institution)

Figure 1-2. Specimen of Smithsonite from Namibia in the Mineral Hall at NMNH (USNM 121794) (August 2015).

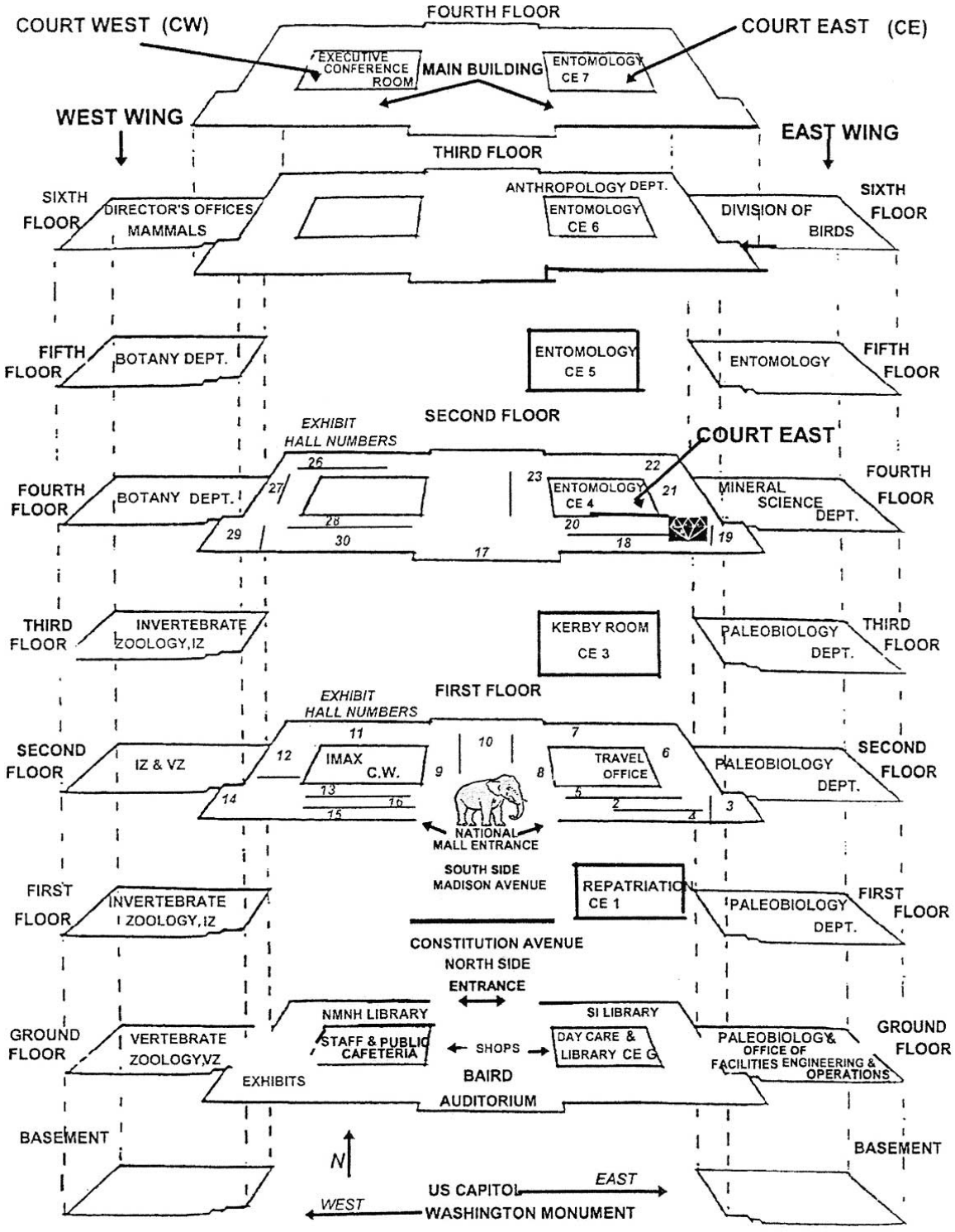

Figure 1-3. Map of the National Museum of Natural History, Washington DC. (August 2014)
(Source: Smithsonian Institution)

Looking up, several floors are visible through the marble columns ringing the mezzanines, including the Mineral Hall on the second floor which includes specimens of "Smithsonite," or zinc carbonate ($ZnCO_3$), a mineral ore of zinc collected and named by James Smithson, the original benefactor of the Smithsonian Institution (Smithson 1802) [Figure 1-2]. Unseen from these public spaces are the labyrinthine corridors lined with white metal specimen cases and old exhibits, rows of offices, laboratories, and equipment rooms behind the scenes [Figure 1-3]. The collection extends even further, with the majority of the 138-million object collection of the different parts of the Smithsonian Institution stored at the Museum Support Center in Suitland Maryland, with 435,000 square feet of catacombing collections storage (Smithsonian Institution, Museum Support Center 2016).

These behind-the-scenes spaces are the setting for a hive of social, scientific and taxonomic activity. The taxonomists working at the museum—scientists who devote their activities to identifying organisms and tracing the evolutionary and bio-geographical relationships between them—draw upon the vast collections of specimens, pinned, stuffed, pickled and frozen. The remains of lost species and their thriving relatives are ordered, preserved and classified in every comer of this vast museum, an index to at least part of the planet's biodiversity [Figure 1-4, Figure 1-5, Figure 1-6, Figure 1-7, Figure 1-8, Figure 1-9, Figure 1-10]. The National Museum of Natural History's specimen collections consist of organisms in whole and in parts, of fragments segmented, preserved and extracted, in DNA cryogenically stored at -310°F (-190°C). Each discipline specializes in a particular group of organisms, and each labors towards a collective goal with the knowledge that their specific expertise contributes to the greater understanding of relations between living (and extinct) organisms—a collective effort to refine the twigs and branches of the Tree of Life.

The Smithsonian Institution is often conflated with the group of eleven museums[4] that ring the National Mall in D.C., a strip of rectangular parkland that runs

[4] Besides the National Museum of Natural History (NMNH), museums include the Smithsonian Institution Building (The "Castle"), the Arthur M. Sackler Gallery and Freer Gallery of Art, the Arts and Industries Building (under restoration), the Hirshhorn Museum and Sculpture Garden, the National Air and Space Museum, the National Museum of African Art, the National Museum of American History, the National Museum of the American Indian, the National Portrait Gallery and the Smithsonian American Art Museum. Scheduled to open in September 2016, the National Museum of African American History and Culture will be the latest addition to the museums around the National Mall.

Figure 1-4. Botany collection, Smithsonian NMNH (Photo: Smithsonian Institution)

Figure 1-5. Fish collection, Smithsonian NMNH (Photo: Smithsonian Institution). The flammable “wet” (alcohol preserved) collections were moved from the Natural History building out to special-built sections of the Museum Support Center. (Photo: Smithsonian Institution)

Figure 1-6. Anthropology collections, Museum Support Center (Photo: Smithsonian Institution)

Figure 1-7. Invertebrate Zoology collections, Smithsonian NMNH (Photo: Smithsonian Institution)

Figure 1-8. Mice study skins, Mammals collection, Smithsonian NMNH (Photo: Smithsonian Institution)

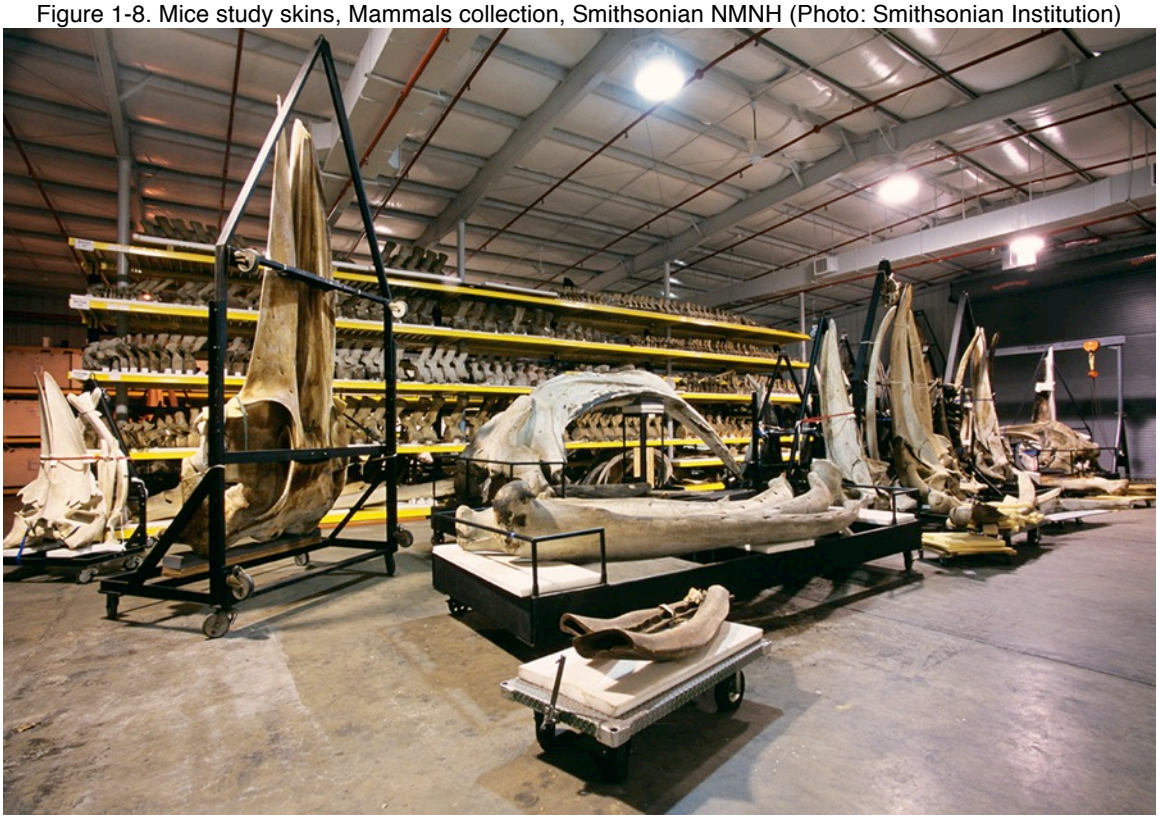

Figure 1-9. Whale skulls, Mammals collections, Museum Support Center (Photo: Smithsonian Institution)

Figure 1-10. Entomology collection, Smithsonian NMNH (Photo: Smithsonian Institution)

between the Lincoln Memorial and the United States Capitol Building. However, the Smithsonian Institution claims status as one of the world's largest museum and research complex, consisting of nineteen museums and galleries, the National Zoological Park, and nine research facilities ranging from sites in Virginia to New York to Panama [Figure 1-11] (Smithsonian Institution 2016). As of 2016, the National Museum of Natural History (NMNH) collections of specimens and objects count for 129-million of the Smithsonian's 138-million holdings (Smithsonian Institution 2016). During my fieldwork as I looked through cabinets filled with thousands of pinned insects, birds and mammals, bones and biological fragments in endless rows of alcohol-filled jars, or in racks of frozen cryovials, I was not at all surprised that the natural history collections dwarfed the rest of the Smithsonian's holdings. This amassed biodiversity was, I came to understand, the basis for the Smithsonian's "power to convene," a phrase voiced by various curators and administrators, signaling the institution's ability to bring together and leverage its social capital in multiple ways, including the creation of the Global Genome Initiative (GGI). The specimen collections are not merely a *resource*, I came to understand, but are also finely crafted *tools* for scientific inquiry, as delicately made as pieces of laboratory glass while also capable of yielding new kinds of information to new audiences.

Established in 1846, the Smithsonian Institution had a circuitous path to its foundation. British scientist James Smithson left his estate to "the United States of America, to found at Washington, under the name of the Smithsonian Institution, an "establishment for the increase & diffusion of knowledge among men" (Ewing 2008). In August 1846, legislation was finally signed establishing the Smithsonian Institution, to be administered by a Board of Regents and a Secretary of the Smithsonian. Though originally designed as a center for scientific research, the Smithsonian also became the depository for various U.S. Government collections. These included collections made by the United States Exploring Expedition between 1838 and 1842 as they circumnavigated the globe, amassing thousands of stuffed and alcohol-preserved animal specimens, tropical birds, an herbarium of 50,000 plants, crates of shells, minerals samples, jars of seawater, and ethnographic artifacts (Goode 1897; Dougal et al. 1844; Philbrick 2004; Viola and Margolis 1985). These specimens and objects became part of the Smithsonian collections, along with collections made by several military and civilian surveys of the American West, notably the Mexican Boundary Survey and Pacific Railroad Surveys, which collected Native American artifacts along with natural history specimens (Baird and Emory 1857).

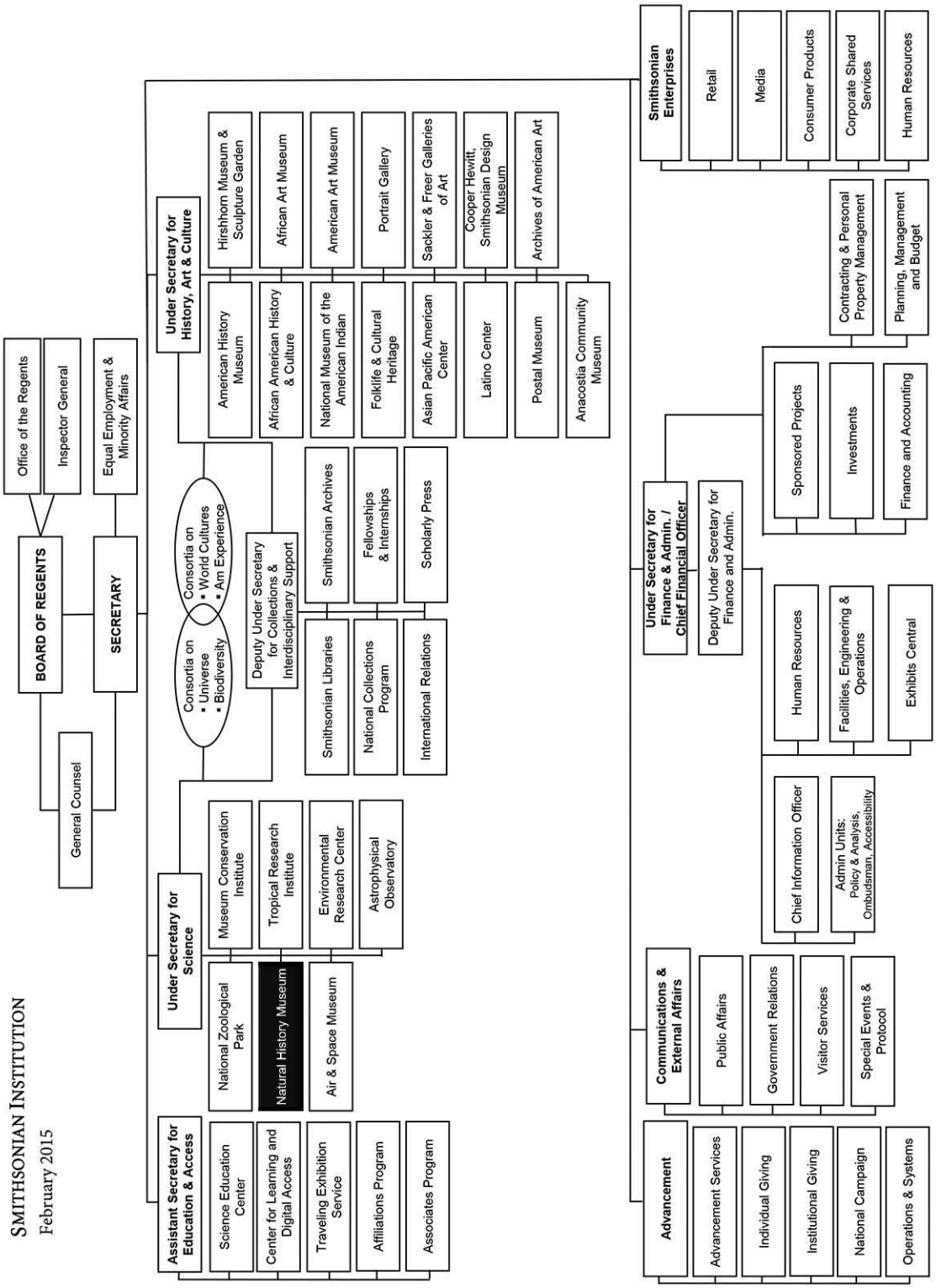

Figure 1-11. Smithsonian Institution organizational chart (February 2015) (Source: Smithsonian Institution)

Many specimens collected in the early nineteenth century were preserved in ethanol before formalin (a derivative of formaldehyde) came into common use as a preservation method, with the consequence that many historical pre-formalin specimens may actually be better sources for extracting "high-quality" ancient DNA.[5] These early Smithsonian collections—as maps of historical biodiversity and vanished ecologies—are now being reconsidered by scientists as "untapped resources" for genetic sampling, a move towards revaluing collections that is underway on a global scale. The Smithsonian is but one site where such revaluations of natural history collections are taking place, and as extinction rates increase the pressure on collections to preserve the natural world for posterity will correspondingly increase.[6]

From the beginnings of the Smithsonian and its collections in the mid-nineteenth century, to the proliferation of buildings, museums, and the interests housed in each I now move forward to the beginning of the twenty-first century, stepping forward approximately one hundred and sixty years to focus on the emergence of genetic collecting in one particular museum—the National Museum of Natural History.

"Preserving and Understanding the Genomic Biodiversity of Life on Earth:" The Global Genome Initiative

Life is increasingly understood as a network of living things, systems, and processes—not just as biodiverse, but also as biocomplex (Bowker 2005b; Gaston 2000; Kohler 2013; UNEP 2010). Natural history collections have also transformed into networks, with vouchers (the reference specimen), tissues, and

[5] One area of debate in current museum genomics concerns the quantity and quality of potential information in historic specimens, as this "storehouse of biodata" is limited by the ancient DNA that can be extracted from the materials—from dried muscle and fur, fragments of bone, fish and reptiles pickled in alcohol and formalin and crumbling mercury-treated leaves. The length of the base pairs needed for contemporary genomic work far exceeds what can be extracted from ancient DNA—the process of pickling a specimen in formalin (a derivative of formaldehyde) essentially cuts up the lengths of DNA into short fragments. So-called "high-quality" DNA provides longer strands of protein sequences that are more readily assembled into reliable genomic data. What has been preserved in museum collections has great value, and much utility—but in specific ways, and as stated, in specific ways of knowing the natural world. Projects such as the GGI seek to "know the world" in a slightly different way, to capture genomes in their entirety. Or as close to entirety as timing, technology, funding and access will allow as biodiversity dwindles daily.

[6] "High-quality" DNA is a subject I discuss in greater detail in the section on creating a "genome-quality" tissue standard in Chapter 3: Standards/Data. In the context of ancient DNA extracted from historic alcohol-fixed specimens, this means longer chains of unbroken DNA protein sequences. The longer the sequences, the easier it is to put it back together—at least theoretically.

data dispersed across museum departments as well as across the globe at different museums, research centers, zoos, botanical gardens, and biorepositories (GGI 2013; GGBN 2015; Lavoie 2013; Prendini et al. 2002; Pyke and Ehrlich 2010). The Smithsonian Natural Museum of Natural History is not only one of the world's largest museums, but through its extension through these global networks of collaborating institutions has expanded its collections and the power it can leverage for genetic collecting projects.

One such project is the Smithsonian's Global Genome Initiative (GGI). Begun in 2010 as part of a five-year Strategic Plan at NMNH, is a project tasked with "preserving and understanding the genomic biodiversity of all life on earth" (GGI 2013) within the next six years. The GGI has positioned itself both within the museum and within a growing global network of collaborating institutions (including museums, zoos, herbaria, research centers), as the central authority that will collect and synthesize existing collecting protocols and preservation workflows into one standardized document. With the stated goal of creating an open-source genome databank to be utilized for nature conservation and biodiversity research, the GGI has situated itself as a natural progression in collections-based research—a move from studying anatomical to genomic similarities in order to expand taxonomic knowledge. While the GGI seeks to map and genetically barcode a synoptic sample of the "Tree of Life," importantly it will also train the next generation of genomics researchers in biodiversity science, contouring the shape of future conservation genetics (GGI 2013). The expanding technological and computational capacity to sequence genomes has facilitated the increasingly central role of DNA sequences in both evolutionary theory and ecological investigations, and created the capacity for making a genomic archive of life.

The Global Genome Initiative (GGI) began with a six million dollar gift from a private donor.[7] This has provided the means to fund genomic collecting on a large scale at the NMNH, through creating infrastructure in the form of freezers, liquid nitrogen tanks and salaries for technicians and administrators, as well as

[7] As of June 2016, the total estimated budget for the Global Genome Initiative was fifteen million dollars to complete its goal of preserving genome-quality tissue of each family of eukaryotic (multi-cellular organisms, characteristic of all life forms except bacteria and other primitive microorganisms) life on earth.life on earth. Various fundraising strategies were underway during my fieldwork, seeking funding from a variety of sources including private donors (such as I witnessed on the tour of the Smithsonian Biorepository, detailed later in this chapter) to working with other institutions both nationally and internationally that were potentially interested in collaboratively funding biodiversity biobanking projects.

much-needed funding for Smithsonian scientists to go on collecting expeditions, provided that the GGI's protocol is followed. The protocol includes everything from obtaining collecting permits to assessing the genomic quality of the samples to making a certain number of those samples "discoverable" on their partner website, the Global Genome Biodiversity Network (GGBN). The GGI is in effect setting out to standardize collecting methods, and in that process they are also standardizing biodiversity into comparable and computable units. This can be understood in a long history of specimens-as-data within museums dating back to Renaissance cabinets of curiosity (Findlen 2002; Shelton 1994; Strasser 2012b), as well as in the molecularization of life in a modern era of genetics and biotechnology (Haraway 1997; Rose 2007; Sunder Rajan 2012). These two threads—museums and biotechnology—converge in the project of the GGI and the genomic collecting expeditions it funds,[8] marking a return to encyclopedic natural history collecting now utilizing biotechnological tools.

Genetic databanks—and the power relations embedded in the conceptual frameworks which drive them—have implications which reach far beyond the museum, into research fields as diverse as agriculture, pharmaceuticals, medicine, energy production, security and potentially de-extinctioning species (Bowker 2005b; Church and Regis 2012; Franklin and Lock 2003; Haraway 1991; Ong and Collier 2005; Rader 2004; Radin 2013). In invoking the conceptual category of "value" in a context of taxonomic classification, my analysis is informed (and further complicated) by a consideration of research into biological value that has proliferated during the last decade, mainly by anthropologists and sociologists with an interest in biotechnology and biomedicine. This research has tended to define biological value as the potential for the commercialization of biological material (and knowledge).

"Biodiversity biobanking" is characterized by its advocates as a branch of "pure" science with no (explicit) commercial future. Yet, as earlier and ongoing research has demonstrated, the commercial potential of nature is itself shaped and unleashed by its prior classification and the corresponding identification and description of species, genera and the relationships between these "natural" groupings. "Specimen collections on the one hand thus present a solid and tangible arrangement of artifacts speaking for possible natural orders," the

[8] The GGI funded eighteen expeditions during my fieldwork, which included collecting insects from Argentina and North Carolina, mammals from Kenya, and birds and parasites from French Guiana.

anthropologist Rebecca Ellis has written, “on the other hand, collections—and the nature(s) they both embody and represent—are valued in multiple and constantly (re)emerging ways, even if this variety of meanings is not always explicitly in view” (2008:32). Theorization of the relationship between the classification of nature and the instrumental uses to which it is put (commercial or otherwise) has emphasized the co-production of classificatory systems with broader political, economic, social and ethical frameworks. One method for keeping these re-emergent properties in view, I argue, is through attending to the *(bio)materials themselves* and the ways in which they are transformed by the social, political and conceptual fields at work in the museum.

The GGI currently promotes biodiversity biobanking as being associated purely with academic rather than commercial ends. This suggests that the genomic collections wouldn’t achieve an exchange value as part of a commercial “regime of value.” The insistence upon such a division of “regimes of value” could appear too restrictive, however, as Arjun Appadurai (1986a) points out, most objects can circulate within and between a multiplicity of these domains. Bronwyn Parry (2004:34–5) in her informative account of the bioprospecting of museum botanical collections—a phenomenon she characterizes as “micro-sourcing”—makes what may be the most literal links between two “regimes of value” and in so doing evokes Cori Hayden’s (2003b) distinction between a nature that *is* and a nature that *does*:

> “The collections of biochemical compounds, living or cryogenically stored materials, and even herbarium specimens that have been created by systematists … are more likely to have been accurately identified and classified. They are also less likely to have been patented, as they have been investigated for purely academic purposes in publicly funded institutions.” (Parry 2004:34)

The distance created by taxonomists between their interest in natural order and the possible uses to which this knowledge might eventually be put could be subject to more complex entanglements than first meets the eye. To reiterate, I am arguing that it is the genomic collection’s ability to extend the traditional collection and yet also move between different disciplinary boundaries (as an extension of a specimen, but also as a lab sample, and as a disembodied genomic data set) that both reifies a certain natural order and potentially troubles it. The shifting biological value of specimens entangles what biology *does* with what biology *is*. In following specimens, tissues and data across these borders, I argue that classificatory value becomes active rather than passive. In a contemporary cultural climate that places such a high emphasis on productive

use, or what has been called the instrumentality of the beginnings and ends of life (Kaufman and Morgan 2005), genomic museum collections are a potential resource for uses never imagined during their collection. Perhaps in the context of specimens and their pieces, this should instead be thought of as the *instrumentality of their afterlives*.

Transforming Specimens into Data

January 2015. On a snowy morning I stood in a large room reminiscent of a chapel, with red brick walls and a high arched ceiling [Figure 1-12]. The glass cases lining the walls were filled with representative treasures from the nineteen different Smithsonian museums and galleries—a taxidermy bear perched above an astronaut's helmet and a set of vintage lunch boxes—totems for the museums of National Museum of Natural History (NMNH), National Air and Space Museum (NASM), and National Museum of American History respectively (NMAH) [Figure 1-13]. I was in the Commons of the Smithsonian "Castle," a structure dating from 1886 which served as the first Smithsonian Institution building, now housing the administrative hub of the Smithsonian's expanded research and museum network that reaches from the Mall of Washington DC to observatories and research stations around the world [Figure 1-14].

On this cold morning bright light filtered in through the gothic windows, highlighting the different displays that were being set up for a special event in the room: the launch of the Smithsonian Institute for Biodiversity Genomics (SIBG), a project that is tasked with "characterizing and interpreting … genomes in order to gain a greater understanding of the natural world and the complex interconnectedness of its species and ecosystems, provid[ing] scientists around the world with novel tools and insights that will help solve the problems that threaten our planet's diversity of life" (SIBG 2015). As one curator said, "It's the Smithsonian using its power to convene, leveraging its position . . . and also, of course, the collections." The collections, in this case, were not simply the 138 million objects and organisms (living and dead) within the Smithsonian's museums, archives, biorepository and zoo, but also the collection of scientists working to "characterize and interpret" those collections. "The power to convene" was a recurring phrase over the course of my fieldwork in the museum.

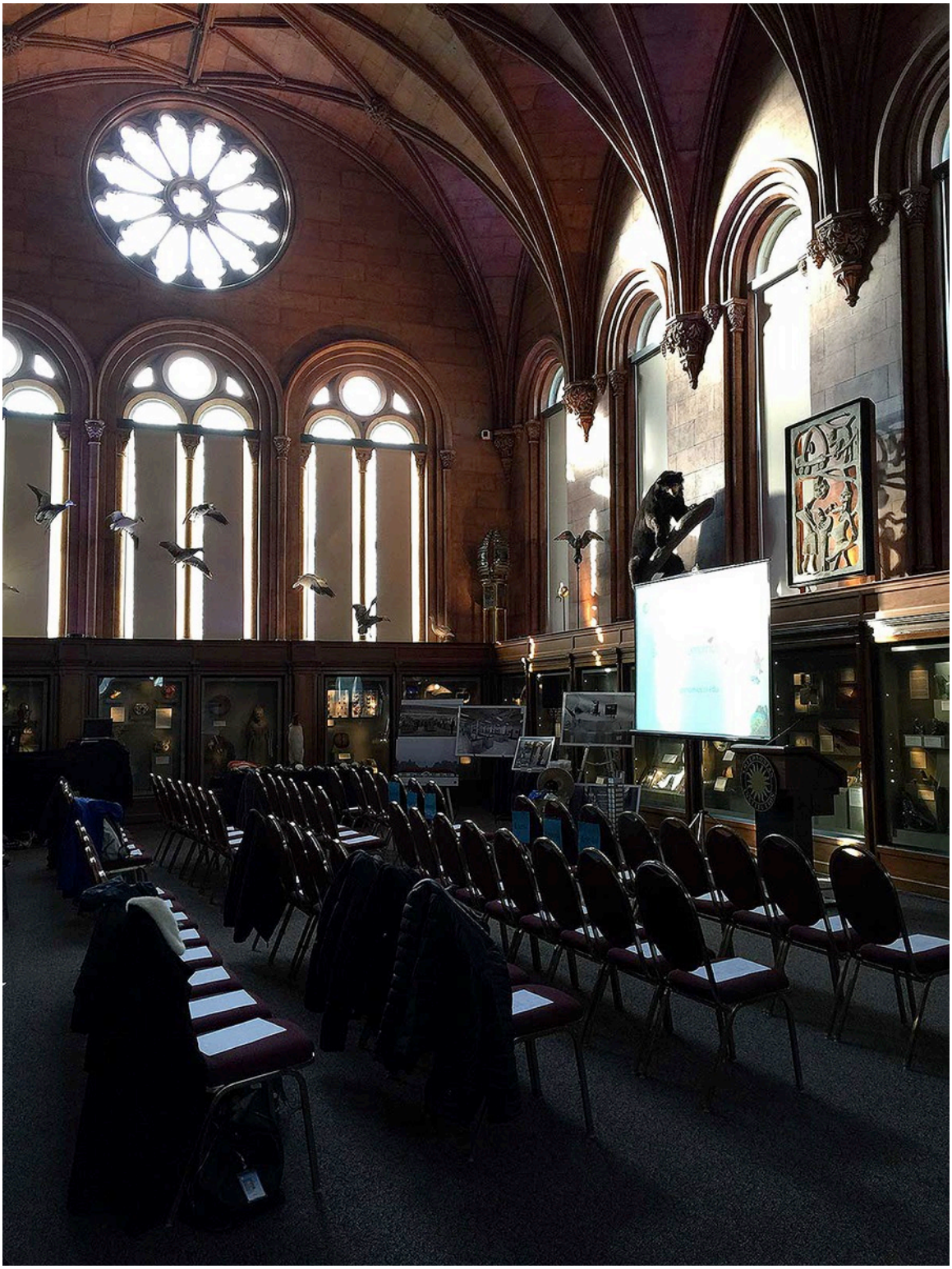

Figure 1-12. The Smithsonian Castle Commons (January 2015).

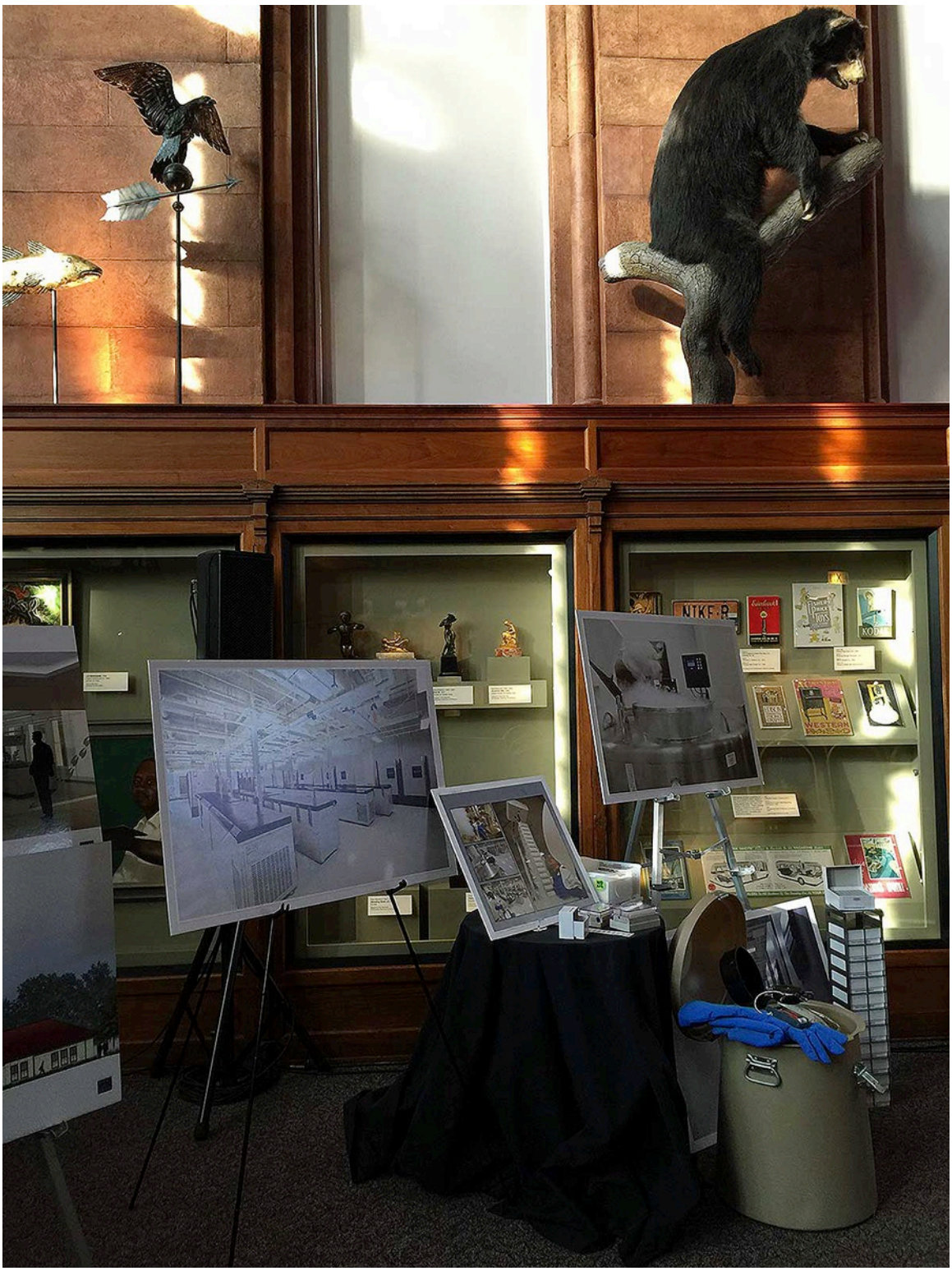

Figure 1-13. Iconic objects from various Smithsonian museums in the Castle Commons (January 2015).

Figure 1-14. The Smithsonian Castle in September 2014 (top) and in (1889).
(Photos: Smithsonian Institution)

To my left, staff from the NMNH's Division of Birds were draping a table in black velvet on which they carefully laid out bird study skins [Figure 1-15]. These were not the lifelike taxidermy mounts of museum dioramas but a scientific preparation for research collections, dating back to the eighteenth century and designed to highlight the diagnostic aspects of a skin for study, such as the beak, plumage, or wing and leg bone lengths, while maximizing storage space. Wings were tucked down along the sides, to make the bird as compact as possible, a "round skin" as it was sometimes called (Poliquin 2012; Wonders 1993a, 1993b), with birds lined up in drawers "like little soldiers in a row" as one curator put it [Figure 1-16].

In contrast, a taxidermy mount of an emperor penguin stood upright in the midst of the elongated bodies, glass eyes keeping watch over the room—a reject from the Hall of Birds many years earlier I learned ("His feet didn't come out right, - paint peeling off the epoxy according to the taxidermist, so we got him") [Figure 1-17]. I caught the eye of one of Bird people organizing the table, Jacob Saucier. He gestured down at the table. "It's the new phylogenetic tree," he told me, "based on the papers that just came out . . . We're rearranging the birds to match it." He was referring to the centerpiece of the SBGI program that day, a special issue of *Science* (Zhang et al. 2014) that "shook up the tree of life" and reorganized it based on 147 recently sequenced bird genomes [Figure 1-18, Figure 1-19].

"We did a honeycreeper genome," a man with a soft voice said as he reached down and plucked a small yellow bird from the tabletop. The bird had a long curved beak, its feet tied together and festooned with a bundle of tags, some with beautiful nineteenth century cursive script [Figure 1-20]. The DNA sample for the genome hadn't come from this historic specimen, he explained, but from a live one he had sampled in the wild. He paused and held out the bird skin. "Smell it! It smells like an old canvas tent." I bent my head down and indeed it had a musty, canvas-y quality to it. He introduced himself as Rob Fleischer, Head of the Center for Conservation Genomics at the National Zoo. Later during the summer I would visit Rob and his labs at the Zoo, talking over the history of genetic collecting at the museum while we looked over his collection of samples, tiny plastic vials bound with rubber bands or lined up in boxes, all carefully labeled. "I've been collecting these things for so long, some of these honeycreepers aren't around anymore. But at least I have these," he said while placing a hand on the vials.

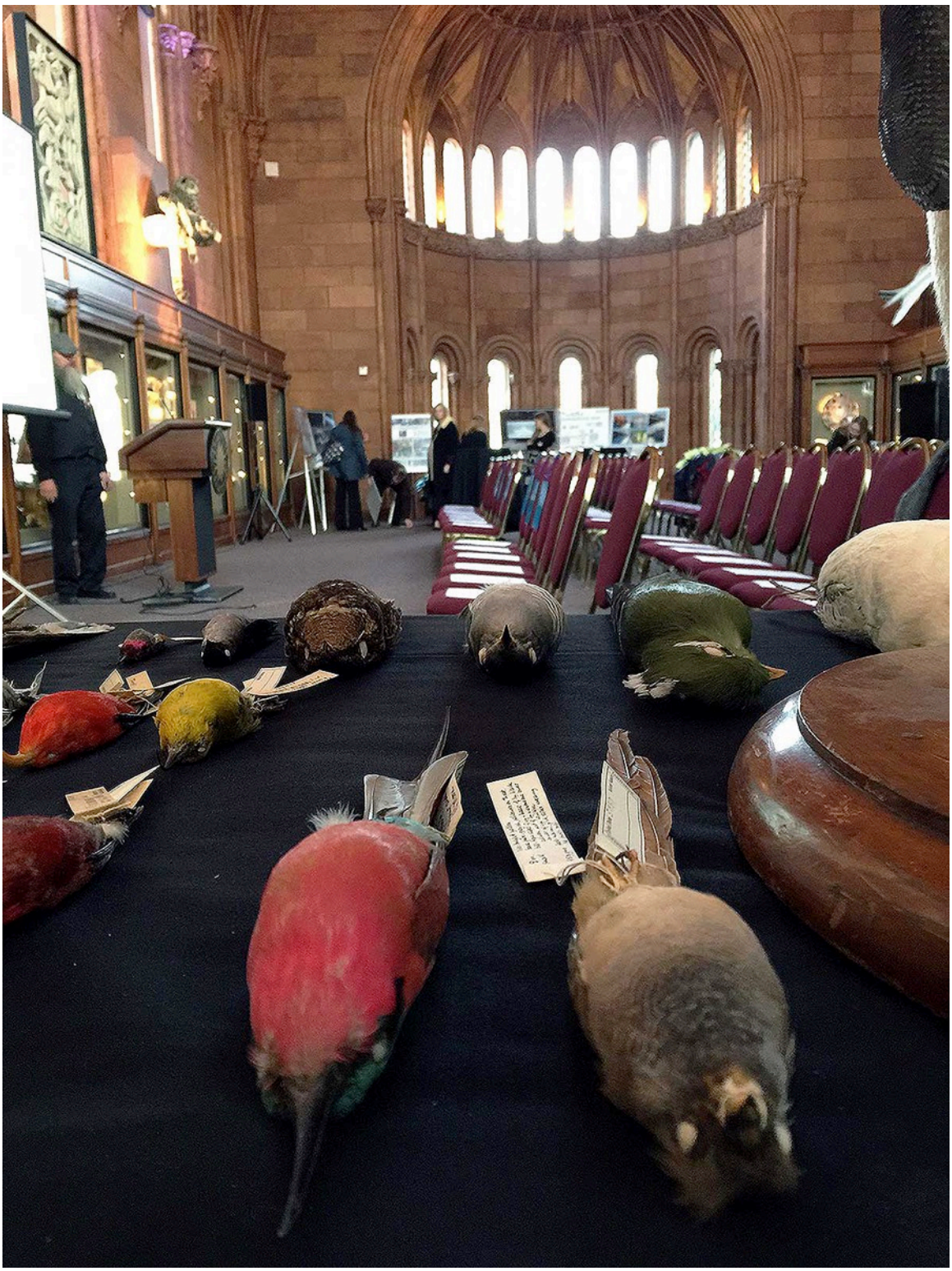

Figure 1-15. A phylogenetic tree of bird study skins (Smithsonian Castle Commons, January 2015).

Figure 1-16. Detail of a study skin of a hoatzin (*Opisthocomus hoazin*, USNM 351845). Collected by Alexander Wetmore, a curator in the Division of Birds in 1937.
(Smithsonian Castle Commons, January 2015).

Figure 1-17. A phylogenetic tree of bird study skins, with watchful penguin (Smithsonian Castle Commons, January 2015).

Figure 1-18. Science 2014: A Flock of Genomes.

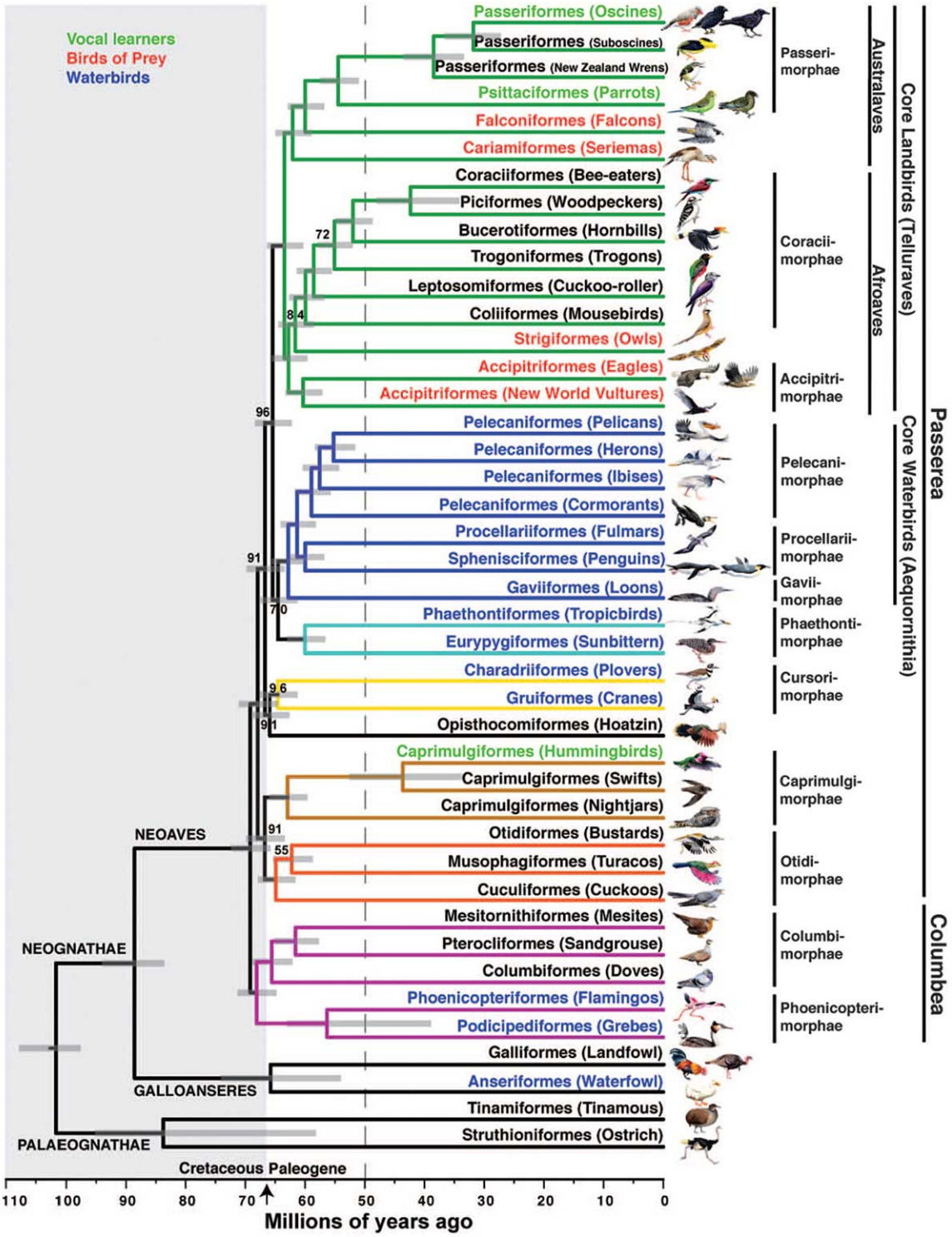

Figure 1-19. A new avian phylogenetoc tree. (Source: Science 2014, A Flock of Genomes).

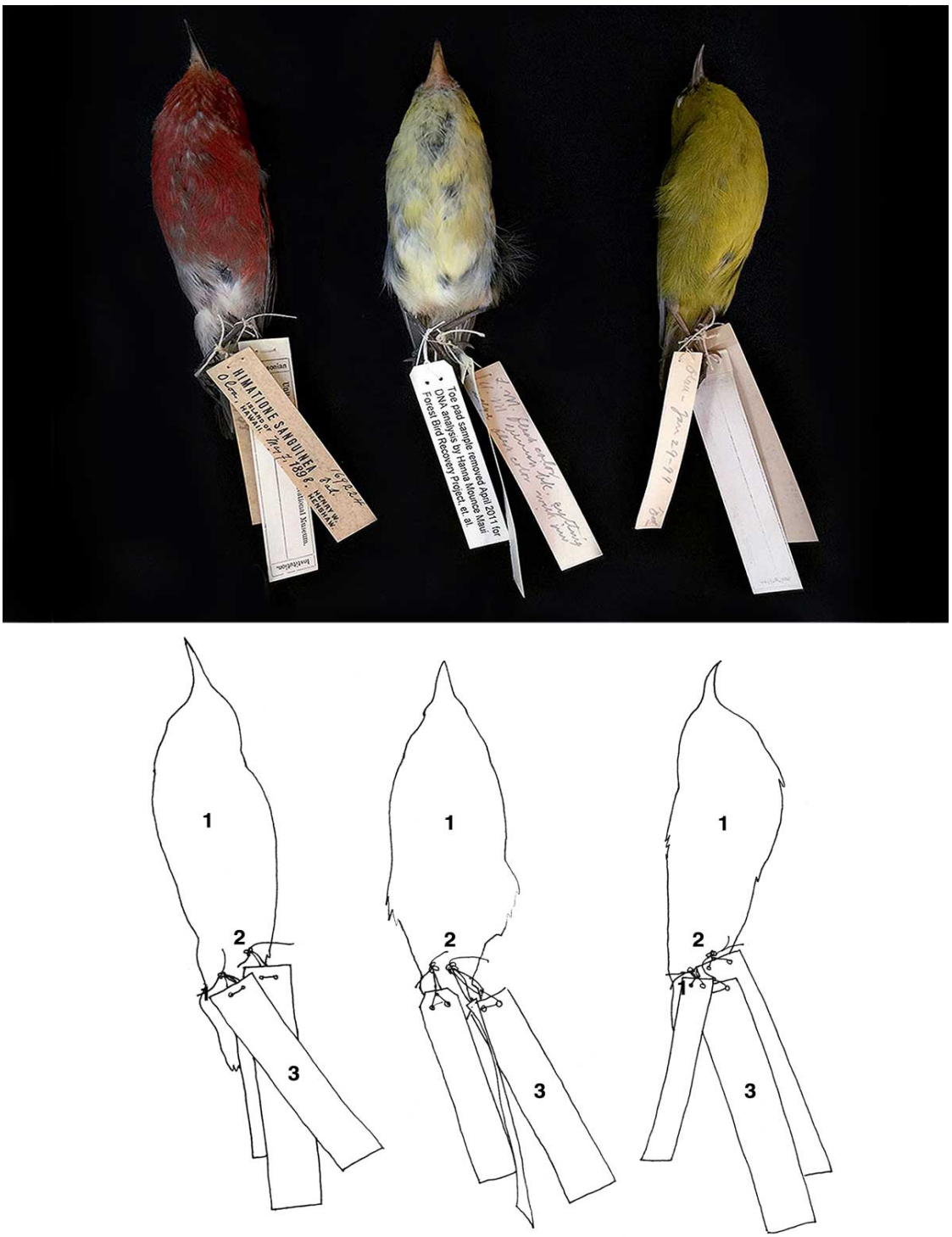

Figure 1-20. Anatomy of a Bird Study Skin: [1] study skin of bird, filled with cotton;[2] upholstery thread is carefully tied between feet and labels – literally the thread holding the data in place; [3] the labels, each representing an event in the afterlife of the specimen. Left to right, three species of honeycreeper: *Himatione sanguinea sanguinea* (USNM 169224), *Pseudonestor xanthophrys* (USNM 607975), and *Chlorodrepanis virens* (USNM 128418). (Smithsonian Castle Commons, January 2015).

To the right of the table of birds I saw a poster displaying the proposed Biodiversity Genomics Lab at the Zoo, and another smaller poster documenting the extraction and sequencing of the honeycreeper genome. Next to these was a tableau of Biorepository paraphernalia—several posters showing staff loading vials into the liquid nitrogen tanks, a steel rack with tubes, and a dewer (a travel-sized tank) of liquid nitrogen with a temperature probe snaking out of it to show that indeed, it was full of the real thing [Figure 1-21]. I ambled over and chatted with Chris Huddleston, the Biorepository manager who was checking the temperature gauge. I had carried this dewer back from the storage facility with the Director of the Global Genome Initiative, Jonathan Coddington, the day before, and I wanted to check my handiwork had been successful. It had all worked out Chris assured me, but there were no specimens in the dewer. If there were, we couldn't have a temperature probe showing it was full of liquid nitrogen—it would just be a big beige plastic tub.

During our dewer-carrying, Jonathan had pointed out how difficult it was to make the biorepository materials compelling to people, that the concept of "all life on ice" was engaging but that a tray of tubes ("abstracted biodiversity") was a far more difficult thing to capture imaginations with. As a curator later told me offhand, "If it's got eyes that can look back at you, you're set," or in the succinct words of one of the preparators in the Division of Mammals, "A tissue tube just doesn't have much, well … *personality*." After spending a year among the collections (full of cotton-filled eyes that did indeed seem to look back at me) versus the racks of tubes, I was inclined to agree.

Holding a box of frozen tissues tubes for a tour with a VIP donor at the Biorepository some months later, Jonathan had said "You like cats? Ok, so this is about two dozen different species of felines, the family *Felidae*." The donor blinked, looking down at the box and then up at him "In your hand?" "Yep," he replied, "I'm holding in my hand about a dozen species of cats from several continents." He rattled the tubes slightly, imparting a tiny *frisson* of liveliness to the frozen cylinders. A moment later they were carefully placed back in the super-cold -80 degree freezer—"Don't want them to thaw, degrades the DNA." We all craned our heads in unison to peer inside the freezer as the door was briefly opened. More rows upon rows of frozen boxes [Figure 1-22].

Figure 1-21. Biorepository display, including a liquid nitrogen dewer
(Smithsonian Castle Commons, January 2015).

The tissue tubes, as I had just witnessed, needed a narrative to make them compelling, to "enliven" them. A miniature frozen zoo to hold in one's hand, saving biodiversity for posterity—that was the conservation narrative of the Biorepository. This narrative was particularly important in the context of giving a tour to a potential donor, a necessary move to bring the vital charisma of the specimens to the forefront and emotionally engage them in the narrative of preservation. However the stillness of the place, from the rows of stainless steel tanks and freezers in the white florescent rooms to the static frozen tubes, all worked against these "enlivenings."

In contrast, one of the other stops on the donor tour was the Mammals Pod to see the preserved skin of Ling-Ling the giant panda [Figure 1-23]. A gift from China to President Nixon in 1972, she had passed from the National Zoological Park (NZP) to the NMNH for preservation in 1992—The hollow-eyed panda skin, oddly flattened, with yellowed fur, was deeply narrative all on its own. Laid out on a shelf at eye-level, Ling-Ling's path through life seemed imminently present as we gazed at her, visible in traces such as the dirt in the underside of her claws or the delicate broken hairs around her snout, brittle with age. The narratives the museum scientists created and maintained for their own purposes were aligned with the narrative of "saving biodiversity for posterity," but differed between individuals and between disciplines in the amount of morphological detail they required to engage with the collections.[9] Invoking these different narratives in front of specimen cabinets or lab benches functions to make the assembled properties of the object, from one perspective, *legible* (Keane 2003).

Back in the Smithsonian Castle, I turned from the Biorepository display to the other side of the room. All of the Smithsonian data processing is represented by an array of posters, with bioinformatics staff loitering nearby ready to offer up interpretations of the diagrams and photos. The NMNH's Laboratories for Analytical Biology (L.A.B.) had photos of its long lab benches, autoclaves and sequencers being used by staff in their labeled lab coats and

[9] For instance Freya Goetz, a member of the Invertebrate Zoology Department, moved from being a molecular technician to a museum technician (a title that covers multiple kinds of work and workers). She made the move to doing scientific illustration and preparing histology slides because she wanted to "see the creatures" she was working with (I explore making slides and specimens with Freya in Chapter 5 on the boundary crossing of birds and their parasites). On the other hand a number of curators and lab techs who focused on molecular work—and who came from backgrounds in bioinformatics—found the "narratives" they needed to connect with collections in the data itself, "seeing the creatures" in the arrays of genomic sequences.

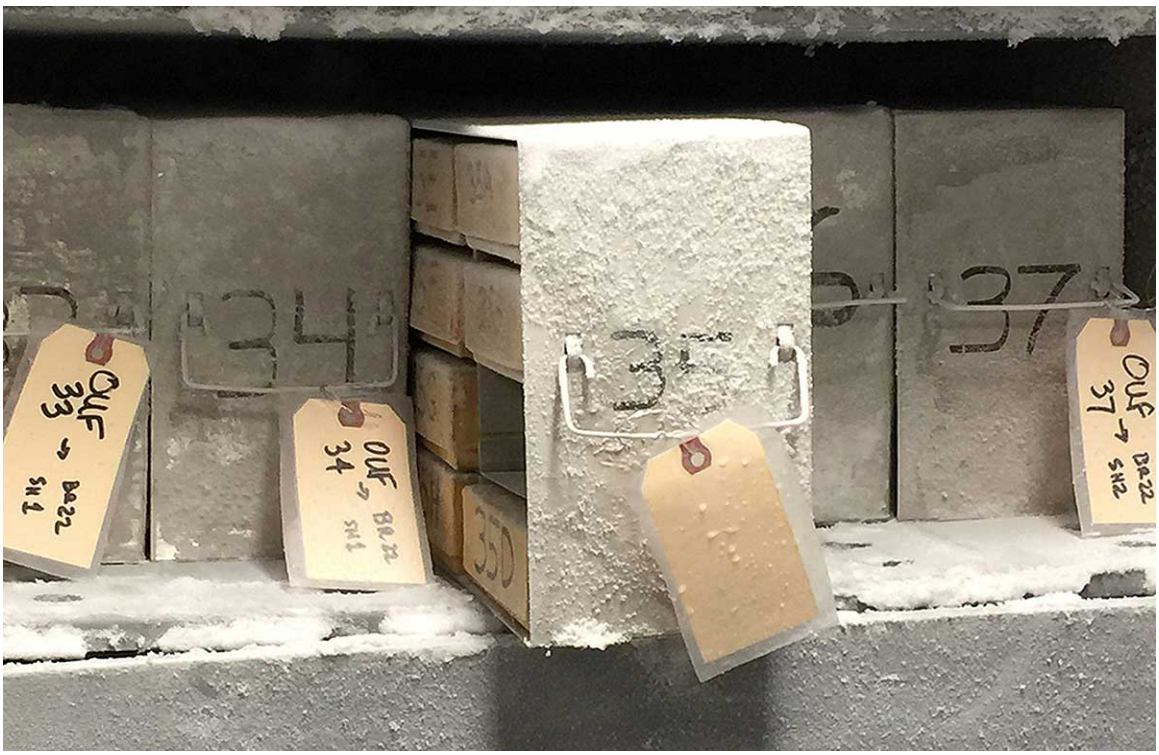

Figure 1-22. Inside a freezer in the NMNH Biorepository (November 2014).


Figure 1-23. Ling-Ling looks back (*Ailuropoda melanoleuca*, USNM 579891)
(Smithsonian Museum Support Center, Mammal Collections, November 2014)

safety glasses. The data-processing facilities had several posters, including a workflow diagram showing the step-by-step process from DNA extraction to uploading the data to Darwin-CORE, a processing mainframe. The posters on their stands clustered together in the apse-like space of the room [Figure 1-24], and peering behind them I caught a glimpse of what was currently occupying the center of the "apse": the 3D printed portrait bust of President Obama, recently completed by a Smithsonian team for the National Portrait Gallery [Figure 1-25]. This struck me as serendipitously appropriate to the context at hand, with representational data manifested in many forms on this side of the room, from genomes to portraits.

The room had become crowded with people, various young-faced post-docs, fellows and assistants circulating around the clustered groups of scientists and curators (jackets thrown over their fleece vests) and administrators (recognizable in their pressed suits). We filled the chairs and more people stood along the back walls—genomics, it would seem, was relevant to the interests of many across the Smithsonian. "Doing genomics will keep natural history museums relevant . . . and funded," one curator told me, "It's that simple." The SIBG Initiative, according to the glossy brochure that featured color photos of animals and Trees of Life intertwined would " . . . help train future generations of researchers, inspire citizen scientists, enable new technologies, and promote new approaches for the study and protection of our environment and ecosystems" (SIBG 2015). The series of talks that followed "shook up the tree of life" in various ways, from talks which covered the collecting, processing and analysis of the avian genomes, to an overview of the GGI project and its funding for genomic collecting expeditions, to the increasing capacity of genomic data sequencing. Listening to these conceptualizations of how to preserve and understand biodiversity on a genomic level I began to think about what was represented in that room. Represented not only by the rhetorics at work (an area covered by much STS scholarship on genetics)[10], but more pointedly by the physical objects themselves and the way they were arranged in the space: a flow from bird study skin to biorepository tissue tube to data workflow.

[10] STS scholarship on genetics has covered areas ranging from the rhetorics of synthetic biology (Rabinow and Bennett 2012), to the interaction of publics and their genomes (Fujimura 2003; Fortun 2008; Rabinow 2002; 2005), to the policy debates surrounding bioprospecting (Ellis et al. 2009; Hayden 2003a; 2003b; 2007b; Parry 2004; Waterton et al. 2013).

Figure 1-24. Data display, with Obama portrait in background (Smithsonian Castle Commons, January 2015).

Figure 1-25. 3D printed portrait bust of President Obama (Smithsonian Castle Commons, January 2015).

What I saw in the assemblage of objects arcing across the room was a series of transformations laid out in stages: the transformation of living things into museum specimens, and those museum specimens then refigured as data. This thought stuck with me over the next year as I interviewed specimen preparators, curators, collection managers and administrators across the museum—*how do living things become specimens, and how do specimens become data?*

The Shifting Value of Natural History Collections: Assemblages and Circulations

As I learned to prepare bird, mammal, insect and botany specimens I paid close attention to these transformations of living things into specimens and into data, and also to the different patterns of assemblage and circulation (as detailed in the following chapters on different types of museum objects: *Data, Tissues, Birds, Beetles* and *Trees*). The "flow" of specimens-as-data was not unidirectional nor was it singular—I followed the disarticulation of (formerly) living things as they became specimens and were broken up into different parts and pieces—a bird divvied up into a stuffed skin, tissues tubes, loose feathers in baggies, a skeleton bundled and tied with string. I then tracked the movement of these different parts to different sites in the museum and their continuing transformations, for example into DNA extracts and protein sequences in the Laboratories of Analytical Biology (L.A.B.), or into cleaned and labeled bones in the Osteology Prep Lab, or into feathers sorted into the library of the Feather Identification Lab.

Each piece was its own assemblage that included the selected biomaterials, the people who collected and selected them, and the conceptual frameworks guiding those choices. As each assemblage circulated from site to site it gained different types of value and meaning as it negotiated boundaries—the feathers scattered on the lab table after preparing a study skin becoming, for example: a precious source for destructive sampling for isotope mapping for ornithologists, a resource for finding ectoparasites[11] by holding the feather up to the light to reveal the telltale black dots of mites for parasitologists; or material for making microscope slides revealing a species' unique feather microstructures, used by the Feather

[11] Parasites that live on the outside of the host are called *ectoparasites* (e.g. lice, fleas, and some mites). Those that live inside the host are called *endoparasites* (including all parasitic worms—more on this in Chapter 6 regarding the boundary crossings of birds and their parasites).

Lab for identifying the remains from bird strikes reported by the US Navy, the US Air Force the Federal Aviation Administration (FAA 2015).

These are but a few examples of the kinds of shifting value of specimens I encountered in the museum, but they serve to illustrate how something as simple as a feather that falls out during the process of skinning a bird can shift radically in value and meaning (or potential meaning) as it moves from the table or floor of the Vertebrate Zoology Prep Lab to either the trash bin or to a labeled zip lock baggie in the collections. As Christina Gebhard (a Museum Specialist in the Division of Birds and the woman who taught me to make a bird study skin) said to me one day while she pinned out a gull wing, "This feather," holding up a fallen feather with her forceps, "if it falls out here then it might be trash, but once it's in the collections, that's it. You have to go through the whole Department-reviewed destructive sampling request process and you better hope we have a lot of them [the species], you have a good record of getting results and publishing . . . and you haven't been caught trying to pluck your feathers out of our collections when we weren't looking." She has a very dark look on her face, and I ask if that's happened frequently. "More than you'd think, which sucks . . . We went to the trouble and expense to collect these birds, getting permits, funding expeditions, you know all of that—and we want them to be used the right way. They're a precious resource. You can't just go out and get more—sometimes countries have changed policies, don't let things out-of-country anymore—we have to use what we have as best we can."

The use (and abuse) of these "precious resources" was a primary concern for many of the museum staff I spoke with during my fieldwork in the museum. Though each department and division had its own version of what was key to save and what could be thrown away—what precisely was precious and what was expendable—the narrative of preserving the precious, and making sure the uses those resources were put to were valid was repeated over and over. "Valid uses," in most cases, meant that the sample from the collection led to the publication of an article in a peer-reviewed journal with a data-set that was also published and accessible, or "discoverable." The key concern was that the data extracted from the collection be circulated to a scientific public, and further, that the Smithsonian get credit for being the source, a key part of demonstrating the continuing relevance and validity of the museum and its collections.

For a national museum that relies partially on Congressional funding decisions each year—combined with the internal struggles within the museum hierarchy for relevance—the museum staff described these public demonstrations of relevance as *vital*.

"Vital inherent Value"—Marking Time in the Anthropocene

The "rediscovery" of natural history collections by conservation biologists as sites for gaining new types of data—data types that were unthinkable when the collections were originally made 150, or even 50, years ago—is rapidly shifting the value of collections in the face of these new demands, in ways and directions that seem beyond the valuations given by museum biologists. Valued now as sources of potential insight into historic climate change, population bottlenecks and extinction events, these natural history collections become "windows into the past" that will potentially provide for our own species' future needs, according to Kress and the assembled taxonomists who spoke at the Smithsonian Institute on Biodiversity Genomics (SIBG) launch in the Castle on that snowy January morning. Mining collections will help us *curate* the global environment we have formed, I would argue, but not restore it to some version of "natural." The collections are not just a way of marking time in the "Anthropocene," of measuring human impact and configuring pieces to fill gaps humans have made in the fabric of biodiversity. Natural history collections are also cultural artifacts of our species' multiple and on-going redefinitions of what constitutes the "natural world"—as defined in the Global north. As such they serve as a conduit for voicing what place in that (Euro-American) iteration of "nature" human beings could, or should, occupy.

A deeply motivating factor for conservation of biodiversity stems from the destruction of "natural" habitats. Though a deeper analysis of the "naturalness" of many of these environments is warranted, it is perhaps also productive to examine this move as articulating a perspective of the "natural" world as merely a resource—one which has flowed from the Global south into the collections and laboratories of the Global north.[12] Within the context of "salvage" operations such as the Smithsonian's Global Genome Initiative (GGI), mass biodiversity loss is framed as result of human intervention into a "pristine" nature, with a moral

[12] As scholarship on bioprospecting has detailed (Ellis et al. 2009; Hayden 2003a; 2003b; 2007b; Parry 2004; Waterton et al. 2013).

imperative to gather and preserve it before it disappears. The Smithsonian's recent announcement in September 2014 of another Initiative, "Living in the Anthropocene," organizes the weight of the scientific community as conservators of nature in opposition to the (economic) interests of destruction (Smithsonian Institution 2016; Wilson 1988).[13] Various narratives of human-modified worlds emerged from the events around the Initiative launch, and during a speech by the NMNH Director Kirk Johnson, he categorized human intervention into the natural world into eras, discussing the different points of reference for when and how we as a species should think about the "traces" we have left in the world. "Understanding the nature of that human footprint," writes Rick Potts, a Smithsonian curator of physical anthropology, ". . . the ways in which we as human beings are engaged in altering the Earth on a truly planetary scale . . . has enormous implications for the way we think about our own future and the future of the planet" (Smithsonian Institution, Living in the Anthropocene Consortia 2015). The argument continues to revolve around where to place the golden spike that marks the beginning of the Anthropocene epoch—when early modern humans caused the extinction of most large mammals (the "charismatic megafauna")—in the early ice age, at the beginning of the industrial revolution, at the atomic age?

I follow the argument made by Donna Haraway (2015) that issues of naming the era variously referred to as the "Anthropocene, Plantationocene, or Capitalocene" (2015:159) have to do with "scale, rate/speed, synchronicity, and complexity" (Ibid.) more than the simple acknowledgment that human beings have radically reshaped the natural world over differently defined epochs of time. The recurring question in considering such systemic phenomena must be an attention to "when *changes in degree become changes in kind*, and what are the effects of bioculturally, biotechnically, biopolitically, historically situated people (not Man) relative to, and combined with, the effects of other species assemblages and other biotic/abiotic forces?" (2015:159 emphasis added). In Haraway's interwoven multispecies world no one species acts alone; instead "assemblages of organic species and of abiotic actors make history . . . the evolutionary kind and the other kinds" (2015:159). This brings to the forefront not simply ecological

[13] The Living in the Anthropocene is "designed to help connect people across the Smithsonian who are working on projects related to the Anthropocene, and to share and promote these efforts" in the context of "planetary-scale human alteration of the environment that has led many scholars to recognize a new geological epoch, the 'Anthropocene,' or Age of Humans. Living with our environmental effects over the long term requires not just a better understanding of ecology and Earth systems, but also of our history, our cultures, and ourselves." (Smithsonian Institution, Living in the Anthropocene Consortia 2015).

devastation brought about by human forces—a dominating version of the Anthropocene cast as the "Age of Humans"—but instead shifts the focus down to specific assemblages of historically situated *people*, *places* and *things* and the effects of their interactions. This resonates with my own focus in this dissertation on the details of interaction, practice and the flow of knowledge in making genomic collections at the Smithsonian NMNH.

Thus the question of naming our current anthroposcenic epoch becomes a question of when "changes in degree become changes in kind" (Haraway 2015:159). Within the context of the scientific community's debates on how and where to "appropriately"—which I read as ethically—mark the boundary line, is at its core a debate about how to acknowledge of our own species' role in shaping and reshaping global environments, as articulated by the Smithsonian "Living in the Anthropocene" consortia members. However, following Haraway, I would argue that no one species acts alone (2015:159). The discussions within the scientific culture of the Global north over where to place the golden spike marking out the boundary of the Anthropocene, I would argue, are actually marking out *other kinds* of boundaries—those between "our" own species and everything else that lives, breathes and moves in our shared and interconnected world, even *within* and *on* our own (multispecies) bodies. For instance, the tool crafted by a curator in Invertebrate Zoology for making histology slides in Chapter 5 (utilizing one of his eyelashes, a bit of glue and a stick) is not only a convenient *bricolage* (Levi-Strauss 1966:22) of materials at hand; a closer look at the eyelash and the microorganisms thriving on it speaks to the kinds of *bricolage* that constitute all living things. We are all multispecies assemblages and the futility of drawing definitive boundaries between "individuals" becomes clear—as assemblages of "biotic/abiotic forces" we make history together, as Haraway suggests, of "evolutionary kinds and other kinds too" (2015:159). What *kinds* of histories are made—or acknowledged—depends on how boundaries are drawn, by whom, and driven by what interests. Through following the crafting of genomic collections at the Smithsonian NMNH, I offer one view into the how some of these histories are built and how they shape possible futures.

In "Feral Biologies" (Tsing 2015; cited in Haraway 2015:160), Anna Tsing suggests that the inflection point between the Holocene and the "Anthropocene" might be the wiping out of most of the spaces for refuge (what she calls "refugia") where diverse "species assemblages" (Ibid.) can be reconstituted after major cataclysmic events such as massive loss of habitat, epidemics, or an influx of

invasive species that shift local ecologies. From one perspective the Global Genome Initiative's gathering of "all species of life"—albeit of eukaryotic life (no bacteria or viruses) at the family level—can be seen as a replica of a "refugia," a constructed site of refuge from which to reconstitute the "natural" world after a potential cataclysmic event in the future. As the material world of Anthropocenic "*nature*" becomes a site of contesting interests and values, however it is also the material *culture* of nature that is called into question, as embodied in the practices for collecting and preserving natural history collections. "Species diversities that had taken millions of years to assemble," writes Tsing of the disappearing Indonesian rainforests, "were cleared, burned, and sacrificed to erosion" (2005:2). In the face of this devastation she asks, "Who speaks for nature?" (2005:2), a question that echoes the parallel questions of how nature speaks (Haila and Dyke 2006), and with what voices (Kohn 2013).

Through asking who speaks for nature in the friction for environmental control, we can also ask how does nature speak through the collections made from those disappearing environments? What voices come through the collections, and whom are they speaking for? Environmental destruction as well as its conservation are symptoms of the complex power relations entangled in the making of natural order—of nature as a resource in multiple registers: for economic interests, biomedical research, national security, agriculture, and as a resource for understanding nature itself as small genomic parts of it are sorted, valued, collected, and stored for future analysis and replication. I claim that these actions become understandable only if one considers them in view of the entangled processes of producing scientific knowledge through the *crafting* of morphological and molecular specimens. Part of crafting specimens is crafting the data with which they are inextricably entwined. *Databases are artifacts*, part of the web of knowledge production within the museum, forms of archives that bind up the different kinds of biomatter in chains of relation—voucher specimen to tissue sample to extracted DNA to genetic data (Derrida 1996; Leonelli 2012b; Mohns and Geismar 2010; Salmond 2012; Strasser 2012b).

As scholarship in both the biological sciences (Pyke and Ehrlich 2010; Suarez and Tsutsui 2004; Winker 2004), history of science (Daston 2000b; Strasser 2010) and in science studies (Fujimura 1996; Kohlstedt 2005) have shown, many scientists continue to use collections to discover, describe, and document plants and animals with traditional methods—such as the bird skins, pinned insects, mounted slides, and pressed plants I learned to produce at the Smithsonian

(more on these processes and practices in the following chapters). However, the application of new technologies to study specimens is expanding, becoming integrated into the traditional practices, or in some cases disrupting them. Much of the current scientific understanding of several recently extinct species – such as the Tasmanian tiger or Thylacine (*Thylacinus cynocephalus*), the Caribbean monk seal (*Neomonachus tropicalis*) and the passenger pigeon (*Ectopistes migratorius*), to name but a few – have directly resulted from genomic information extracted from museum collections (W. Miller et al. 2008; Rocha et al. 2014; Schipper et al. 2008). This includes not only genomics but other kinds of extractions and abstractions of biomatter: "combining DNA–, amino acid– and isotope-based analyses of a few grams of bone from a historical specimen of an endangered Pacific seabird, the Hawaiian petrel, has illuminated aspects of the bird's diet, past population demographics, food chain dynamics, and the deleterious impacts of industrial fishing on this oceanic predator" (Rocha et al. 2014:814). From this perspective, museums are being recast as unparalleled – and largely untapped – resources for creating tissue collections of extinct species, part of large-scale genomic studies of animals and plants (Casas-Marce et al. 2010; Godoy et al. 2004; Horváth et al. 2005; Rohland et al. 2010; Rohland and Hofreiter 2007; Nachman 2013; Wandeler et al. 2007).

“In this era of deteriorating natural environments,” writes John Kress, former Smithsonian Secretary for Science, “a pressing challenge is to continue to build scientific collections for future needs. Museum collections, and the species they represent, provide windows into the past, inform about the present, and help predict the future of natural habitats and human-altered environments. They are the common language of the biological sciences.” (Kress 2014:3010). The world’s bird populations have dwindled by the hundreds of millions within the past few decades, particularly the most common species, and the urgency of such assessments, according to Smithsonian scientists, should focus attention on determining causes for these declines—knowledge which can be gained from phylogenetic projects coupled with ecological and population analyses (A. Baker 2005; Kress 2014; Ye et al. 2014). The Avian Phylogenomics Project, for example, has selected 45 avian species for whole genome sequencing and assembly, and will—when complete—have derived over 60% of its tissue samples from archived museum collections (Avian Phylogenomics Project 2016).

Framed as yet another source now available for big data science, natural history collections, specimens and associated data have been accumulating for

hundreds of years. The amount of "untapped biodiversity resources" compressed into museum collections, botanical gardens, and university collections is not precisely known, however estimates are as high as three billion specimens (Bi et al. 2013; Hykin et al. 2015; Janecka et al. 2015; Nachman 2013)—which "suggest the magnitude of this storehouse of information about the natural world" (Kress 2014:3010). However, I would argue that this "storehouse of information" has been configured in a specific way, based on the specific cultural histories that formed it, which in turn have shaped the kinds of information it can then offer up. Or, more precisely, that it can be *conceived* of offering up. The conceptualization of the collection as a resource that can inform us about the natural world is based on a desire to *know* the natural world in particular ways, and to re-inscribe those ways of knowing through the practices of creating specimens—through collecting, processing and circulating specimens, their parts and their data.

"Our predecessors in [the Division of] Birds collected these specimens, they had a very specific idea of what they were going to be used for," Helen James (a curator in the Division of Birds) told me several months after the SIBG launch as we went through several locked doors into the type specimen collection. I was going to photograph a Hudsonian godwit (*Limosa haemastica*, USNM A8074) collected and prepared (not very well, it turns out) by Charles Darwin in March 1833 [Figure 1-17]. "Now we use them for things they never could have imagined." When I ask her what future uses she can imagine the collection being put to, she pauses, tilting her head slightly. "We can't know, of course, what direction technology will go. But we can prepare things in different ways—like pickling the specimen so the entire organism stays intact, making sure we don't lose anything. Or lose less anyway. We're doing that with some birds now, taking tissue samples and then pickling, then doing microCT scans . . . I got some amazingly detailed scans of the structures inside a beak recently, from a pickled bird . . . For the future, we just have to be very detailed in the data, make sure we keep it all connected, record everything. You never know what might end up being relevant."

Future needs, it would seem, compel museums to continue collecting and preserving for as-yet-unknown uses. As the "common language of the biological sciences" (Kress 2014:3010), collections not only speak for the past, but must be maintained and added to with new biodiversity surveys to speak for the *future* as well. Although most museum specimens were not originally collected for the purposes for which they are now used, new technologies will "continue to reveal

new information previously unanticipated in scientific specimens" (Hykin et al. 2015:e0141579). According to many at the Smithsonian (Rocha et al. 2014) and beyond (Droege et al. 2013; GGBN 2015) the collections need to be added to—"extended" with genomic samples—to maintain their value and "keep in time" with the time series already marked out by the existing collections. The toe pad from a bird skin collected in 1910 can be sequenced and compared with one collected last year, or one living in a zoo. An outmoded view of collections, according to museum geneticists, suggests "drawers of bird skins, empty shells, and dried plants . . . However, current collections also include living specimens, spirit-preserved samples, deep-frozen tissues, and DNA" (Kress 2014:3010). These different domains—of public exhibition or private research—each define the value or use of a specimen according to the needs at hand. Many of these needs require large data sets derived from the collections: a thousand primates from over a 100 year period were used to determine the emergence of the HIV virus (Suarez and Tsutsui 2004). Further, it is the pairing of this collected and collated "irreplaceable biodiversity" and its associated metadata that combine to define its (potential) value.

The collections continue to expand, and the various uses to which they are put also expand. Each new use adds to their value and is a reconfiguration of the "values" bound up in each specimen, which in turn are contingent on the ways they can be utilized in each new context. More utility equals more value in this particular equation of life, and further (or greater) utility may equal a set of values that may not be visible to us at the present moment.

While museums are being reconsidered by new "users" (including conservation biologists and geneticists) as valuable sites for mining genetic samples, this is but one of their many uses according to the recent turn in revaluing collections (Bell 2013; Bennett and Joyce 2010; Harrison et al. 2013; Pearce 1994a). Human impacts have caused widespread extinctions which are already being studied through the historical records enmeshed in scientific collections, charting the dwindling ranges of species, their decline in numbers and finally as the last site where they exist—as their last numbers die in zoos they become preserved specimens and collection data. These historical records can "reveal former patterns of geographic distributions and population abundances of species that today are threatened or extinct" (Rohland et al. 2010:677). The valuation of these last remains of species can have very different priorities depending on context.

During the summer of 2015 the last white rhino at the National Zoo took ill and died, its body drenched in ("DNA-shredding" according to a lab tech) chemical disinfectant and then subjected to a ("non-aesthetic" said a specimen preparator) necropsy by the veterinarians at the zoo. Tissue samples weren't taken and the skeleton had been "chopped up," according to one preparator, "with something so precious, you think they'd be more . . . thoughtful. You never know, this might be our museum's last chance for a [rhino] skeleton." The skull, with incredibly valuable horn attached, had been carried off to the Osteology Preparation Lab at the Museum Support Center in Suitland Maryland, much to the consternation of various staff. The horn, according to many voices at the museum, should be removed from the skull and locked up, secured against theft. Others found it abhorrent to further mangle the skeleton, wanting to leave it intact while it sat in its tank of circulating water, being cleaned and degreased over several months. "I'm documenting absolutely everything either way," the head of the Osteology Preparation Lab, John Ososky, told me.

Cast in this light, one of the key challenges for museums is to find ways to sustain themselves as repositories for a long future with uncertain requirements, while making the museum's resources available, "maximizing access and benefit-sharing"—a nod to the Convention on Biological Diversity and the Nagoya protocol which followed it, locating the project of contemporary museums within a global network of value and exchange. Convened in 1992 under the auspices of the United Nations, the Convention on Biological Diversity (CBD) is currently in the process of being endorsed by most countries (the United States, notably, has not yet signed). Among other issues, such as technology transfer and patent rights on biotechnological products, the CBD binds the signing parties to undertake a survey of the species of plants and animals living within the political boundaries of the country as well as setting aside enough protected areas to allow the preservation and "sustainable use" of their national flora and fauna. The necessity to know "what we have" to be able to "assess what we are missing" is the underlying logic of this re-evaluation of natural resources, and by extension, the natural history collections which have been documenting biodiversity over time.[14]

[14] Digitizing collections has been another form of making the collections available, and I would argue an interesting form of making a museum "replica." However, an accurate computerized inventory of the existing collections (much less a digitized version of them) has only just begun, with the majority of museum collections still largely inaccessible to wider publics.

Evoking the massive and continuing losses in biodiversity—the number of individuals of all wild animals on Earth has decreased by 50% since the 1970s—"underscores the *vital inherent value* of museum collections today, tomorrow, and into the future" (Kress 2014:3010 emphasis added). The logic of the argument here is that if we do not value the collections of life we have, we will be unable as a species to impede the rate of loss. Museums are situated as a key component in configuring our understanding, and preservation, of life itself. However, this raises several questions. What forms of life are being conserved or preserved? Further, how do the evolving museum practices of mining and extending the collections shape these forms of life, and our species relationship to the rest of the global assemblage of non-human species? Further, what cultural orientations are embedded (and naturalized) within these taxonomic classifications and divisions of the "natural" world?

Crafting "Natural Orders"

At this point in my examination of the shifting value of natural history collections as biobanked "natural order," it is useful to point out that so-called "natural order(s)" have historically been perceived and generated through different conventions, reflecting different combinations of interests, with implications for collective meaning (Dean 1979; Foucault 1966; Hull 1988; Stemerding 1991). Scholars have demonstrated, for example, that the portrayal of natural order(s) by taxonomists depends very much upon what properties of organisms are considered to be indicative of order (Fontaine et al. 2012; Helmreich 2008; Hesse 1974; Levi-Strauss 1966; Waterton 2010). As Foucault's (1966) work on the history of natural historical pursuits demonstrates, the classification system developed in the seventeenth and eighteenth centuries known as the Linnaean hierarchy essentially operated—and continues to do so today—as a linguistic device equipped to lay out a grid of the observable (morphological) physical qualities of organisms, organized according to the measurements of similarities and differences between them, such as the color of feathers or fur, lengths of leg or wing bones, number of spines or toes, or the shape of an insect's genitalia. It is this visually perceived ordering of similarity and difference that Foucault sees as exemplary of the "classical episteme" of the time. An organism's place in the world became defined in that it "exists in itself only in so far as it is bounded by *what is distinguishable from it*" (Foucault 1966:158 cited in Waterton et al. 2013:7, emphasis added).

From the beginning of the nineteenth century, a growing sense of dissatisfaction with the limits of Linnaean linguistic naming and classificatory tools encouraged natural historians to explore the temporal complexities of the relationships between organisms, and they began to present natural orders as evolving states, thus with an inherent propensity for further change. After Darwin's 1859 evolutionary theory became established in the late nineteenth century, an interest in inheritance and common lines of reproductive descent became relevant, and complemented the visual detection and analysis of morphological characters in the labor of classificatory organization. As Foucault notes, these shifts, together with Cuvier's focus on the vital processes or functions of parts of organisms as integral to their classification, propelled the life sciences to develop from their practices of naming and differentiation, towards temporal dimensions of descent and inheritance, and functional qualities which might influence evolutionary "fitness."

From the nineteenth century onwards, as the standard narrative goes, natural historians sought to uncover the large-scale patterns of living nature through collecting in the field and classifying in the museum, in contrast to "modern" biologists in their laboratories uncovering the fundamental workings of the living organism. Gradually, the emerging disciplines such as biology, zoology, ecology and genetics came to dismiss the outdated methods of taxonomy as "unscientific," involving, so it was perceived, mere description. "Museum work," I was told by one curator, gesturing towards the Capitol building at the end of the Mall "is all too easily dismissed as just . . . 'stamp collecting,' not doing serious science." "To be competitive," I was told by another, "you do genomics, you do it well or you'll go extinct [He pauses with a slight smile] . . . The older generation [of curators] get in post-docs and think up projects . . . and even if they don't have the skills to do it themselves they know how to ask the right questions." The right questions may be the same questions that have been asked for over a hundred years about the relationships between species, but now using biotechnology. "We're essentially asking the same questions as [Charles] Darwin did," as one of the museum geneticists told me, " . . . but with new tools."

From the mid-twentieth century onwards, a continuing dependency on the visible morphological characteristics of specimens was complemented by the use of DNA sequences as a new form of classificatory currency (Avise 1994; Hull 1988). Indeed, genetic collections have been created and used by scientists at NMNH

for at least thirty years, though they have seen a shift (according to some) from being expendable “research materials” to being proper parts of the collection due their share of conservation, cataloging and care. New biotechnologies migrated into the museum and introduced powerful molecular and computing methods for indicating common ancestry and species histories. This shift was hailed as harboring great potential in terms of its ability to reconfigure species boundaries and bring a “higher resolution” approach to understanding the descent of species – the capacity to build Trees of Life based on phylogenetics, and now, phylogenomics.

By the end of the twentieth century, taxonomy, like most areas of the life sciences, was being reframed by state-of-the-art genomic approaches, increasingly relying on DNA and molecular techniques and powerful computer technologies to “split” or “lump” the natural world. Taxonomists themselves were classified as either “splitters” or “lumpers,” depending on their propensity to either divide species into ever-more finely grained sub-species or to mass them together into one species “lump.” These methods of analysis built on the 1990s “genome revolution,” reifying an underlying assumption that molecular genetic sequences were the code of life, deterministic of all that was thought to follow (Fujimura 2003; Margulis and Sagan 2002; Murray et al. 2011; Parry 2004; Wandeler et al. 2007). This genomic reframing enabled an acceleration of taxonomic practice and allowed the discipline to expand its scale and speed of knowledge production. The consequences of integrating these genomic practices into the life of museum collecting, specimen preparation, sample and data sharing are examined in the cluster of ethnographic case studies at the center of this dissertation.

An example of bio-political configurations in a taxonomic context is evident in the (neo)colonial practices of collecting and mobilizing natural specimens, often in the form of genetic material (Hayden 2003b; Parry 2004). The museum staff I engaged with over the course of my fieldwork were generally very cognizant and reflective about the potentially neocolonial aspects of their collecting activities, caught between the desire to create collections they saw as vitally important to a shared ecological future that would be informed, and secured, by scientific research, in tension with the knowledge that previous methods of obtaining specimens from exotic locales were no longer viable either practically, politically or ethically.

Tensions arose when these interests collided. On the one hand, the desire to collect to complete a time series of specimens (that is, the same species collected in the same place over years, decades or even over a century) with the intent to chart species decline and in turn provide leverage for ecological protection. On the other hand, a swiftly changing field of international, national, federal and local permits to navigate with seemingly illogical or contradictory aims driving them. “If I go get a hunting permit I can shoot a hundred ducks in the state of Virginia, no problem,” one museum specialist told me, “but try to get a permit to collect just a fraction of that for a scientific collection—good luck.”

In the following sections, I ask how crafting (genomic) specimen assemblages in the museum can be seen as a form of the “molecularization” of life (Rose, 2009), and within the context of taxonomy, how these assemblages have intensified and transformed the distribution of practices between field, lab and database. How has museum genomics (or “museomics,” as the Mammal curator Jesus Maldenado calls it) introduced a further concentration to practices of collecting and curation inherited from earlier centuries of taxonomic knowledge and artifact production? How has the Global Genome Initiative produced new regimes of labor and distribution? How has the valorization of the power of DNA—in this case a move from “mere” genetics to entire genomes captured for future use—been utilized to determine and represent “life” itself?

Biodiversity Inventories as Data Collections

Non-human life has been a focus of renewed concern for nations and their natural history museums in the last twenty years in response to shifting ideas of value and use. Advances in biotechnology have rearranged “nature” biotechnologically—striving towards a standardization of genetic uniformity for biomedical concerns on the one hand and the creation of genomic protocols for collecting exotic biodiversity on the other. Collecting genetic materials requires stabilized, standardized “ontologies” (within taxonomic communities, a stable sets of terms) to allow their circulation and flow between nations, institutions and databases. Entangled with these processes are increased control over the ways and means of capitalizing nonhuman life, which has been examined ethnographically from the perspectives of bioprospecting (Hayden 2003b; Tsing 2005), biodiversity conservation (Lowe 2006), markets for genomes (Helmreich

2008; Fortun 2008; Rabinow 1997; Sunder Rajan 2012) and recreating life itself (Franklin 2007; Franklin and Lock 2003).

The control of disease vectors, including charting the various life histories of environmental contaminants, invasive species and other related research has increasingly come under the purview of national security through biological means. Collections are increasingly used to discern levels of threat and possible responses, such as deploying a parasitic wasp to combat invasive species of crop pests (Heraty et al. 2007). In contrast, new scientific disciplines such as biodiversity biobanking aimed at the conservation of biodiversity—the difference found within nonhuman life—have emerged. A somewhat paradoxical scientific relation to nonhuman life has been re-articulated in recent decades, between its genetic destruction on the one hand and its preservation on the other. Life—in every form from networked ecosystem to tissue sample to genomic database—is currently undergoing re-evaluation by multiple interests for multiple uses, and will continue to do so with emerging biotechnological tools and their embedded conceptual frameworks. However, it is worth examining what precisely is being preserved (or crafted), by whom and for what purpose(s). Further, I suggest that a method for examining these preservation practices is to look at the *ways* things are preserved (or discarded), and through this to unearth the rationales motivating the collectors and their collections, through their practices of nature-making in the museum.

An orienting concern within data-driven sciences has been—and continues to be— *the production, negotiation and maintenance of standards* (Bowker and Star 1999; Lampland and Star 2009; Leonelli 2012b, 2013b; Leonelli et al. 2011; Sunder Rajan 2012). To be able to make comparisons between "like" things, they must be produced in the same manner, and refer to the same property in all the samples or objects within a category. This friction—between the standardization introduced by integrating genomics into centuries-old collecting practices in different disciples—was nowhere more apparent than in the negotiations on the lab benches as specimens were being prepared for GGI-funded projects. It is precisely in these moments where I saw how time "folded" to accommodate these new practices and materials, where concepts of *what was being preserved, and why it was being preserved*, were being rewritten, reworded and collectively constructed into a narrative of purpose by the preparators, collection managers and lab technicians making the specimens. Taxonomic systems in the natural

sciences derive from very specific sets of morphological characteristics, which in turn define strategies for collecting and preservation techniques.

These sets of practices—collecting, preserving, categorizing— have evolved historically as different characteristics became valuable at different times. The standardization of ontologies reaches back to Linneaus, where "one had to adopt his definition of sexual characters, or the data produced by the observation of specimens would not be comparable to those of other observers" (Strasser 2012b:86). Curators of contemporary biodiversity biobanks and their databases face even larger challenges, as the objects in question continue to push the boundaries of what *kinds* of things exist in the world, and the proper way to organize them. These databases contain not only a wealth of experimental data, but also links to mutant organisms held in genetic stock centers, cell lines, DNA extracts and clones, as well as links to voucher specimens (Leonelli et al. 2011; Soulé and Wilcox 1980; Strasser 2008). These physical objects are also part of today's data, which is no less diverse than the data of naturalist collections (Strasser 2012a).

The tension between making specimens and their parts legible across boundaries via standardized collecting protocols and standardized naming systems for data ("ontologies"), versus the desires of different Divisions and Departments (Botany, Entomology, or the Division of Birds, for example) to maintain continuity with their disciplinary histories is a central struggle in contemporary museum genomics. This is a struggle for what is preserved, and therefore deemed valuable, and how it is preserved or discarded. The implications of these decisions determine what kinds of uses can and will be made of these "vital resources" in the future.

Materials matter, and each of the object types I have chosen to examine in the following chapters—Data/Standards (Ch.3), Tissues/Networks (Ch.4), Birds/Boundaries (Ch.5), Beetles/Articulations (Ch.6), Trees/Time (Ch.7)— offers a distinct view into these specific disciplinary histories and how they each form a different view of what constitutes a proper natural order. These unique versions of "nature" in each discipline determine what is preserved for posterity, and therefore available for future use (or abuse). I now outline in greater detail the shape of the dissertation.

The Shape of the Dissertation: Data, Tissues, Beetles, Birds and Trees

The chapters in this dissertation emphasize a disciplinary assemblage of objects, practices, and discourses and the way those assemblages materialize specimens, genomics, and specific iterations of nature. Some technologies and practices, such as specimen preparation, tissue collections and data tracking, reappear in different chapters so that in reading through the research project as a whole one might see how these technologies and practices shift in various contexts. As I began to code my field notes and transcripts of interviews (by underlining key words and phrases, and then clustering these into groupings), distinct patterns quickly emerged.[15] From these I selected five concepts for the core chapters of this dissertation (STANDARDS, NETWORKS, ARTICULATIONS, BOUNDARIES, TIME) and to ground them in the material practices of genomic collecting, I chose five very different types of museum objects to pair them with, each with distinct disciplinary histories and material properties (DATA, TISSUES, BIRDS, BEETLES, TREES).

Each chapter combines ethnographic episodes, which are then read through theoretical texts and framed by historical accounts of museum collecting and specimen preparation. These three threads—ethnographic encounter, theory and history—are woven together in each chapter. My goal is twofold: first to subject the core arguments of this dissertation to the varied tools of anthropological analysis, theoretical criticism and historical context; and second to show that the concepts and methods of "crafted nature" have manifested in the museum as objects (i.e. specimens as "natural artifacts") and been tested in these roles in numerous ways. I argue that specimens have functioned and continue to function

[15] Throughout my fieldwork I scanned my handwritten notes (creating annotated pdfs), typed up my fieldnotes, and transcribed interviews—making documents that were both searchable and codeable. I used a modified version of grounded theory (Martin and Turner 1986) for coding that included selecting "in vivo" terms (key phrases chosen from interviews) combined with a more heuristic approach to distilling themes and concepts from the interviews and fieldnotes. Several passes through the material generated a substantial set of interrelated concepts: ACCESS, ARCHIVING, ARTICULATIONS, ASSEMBLAGE, AUTHENTICITY, AUTHORITY, BORDERS, BOUNDARIES, CATEGORIZATION, CRISIS, CIRCULATION, CLASSIFICATION, CONNECTIONS, CONSERVATION, DESTRUCTION, DURABILITY, FUTURES, HISTORIES, INSTITUTIONAL STATUS, KNOWLEDGE, NATURE, NETWORKS, ORDER, POWER, PRACTICE, PRESERVATION, PROBLEM SOLVING, PROCESS, PROGRESS, SALVATION, RESOURCES, SEQUENCE, SKILL, STANDARDS, SYSTEMS, TAXONOMIES, TIME /TIMELINES, TYPES, USE / UTILITY, VALUE. From these I curated a set of five concepts that provided both contrast and cohesion, that is, there was a significant amount of material clustered around these specific concepts, and further when strung together they created a narrative that could be followed through the places and practices of the museum.

as “natural” objects, or proxies for gaining access to truths about “nature.” Further, adding genetic samples to natural history collections continues this orientation towards accessing “natural truth.” However, different ideas about what the proper version of “nature” is, and how to access it, are clearly visible in the on-going frictions between museum communities and different disciplines. The Smithsonian gathers together global genomes within a national museum context, and uses its “power to convene” (SIBG 2015) to organize the accumulated knowledges, natures, and resources into a continually evolving version of the Tree of Life.

Chapter 2, MUSEUMS/GENOMICS - *Changing Cultures of Natural History in Museums, Labs and Biorepositories* situates my project at the intersection of scholarship in STS, museum studies, and material cultures studies. Most scholarship in these areas has focused on public policy and the rhetorics of biotechnology, or at museum visitors and the “nature” of taxidermy dioramas. Instead I take a “view from below” (Harding 2008), looking in the back rooms of the museum to the craft practices of lab technicians and specimen preparators, where natural history specimens are being made and remade, now using genomic techniques. The friction between the Global Genome Initiative’s standardized genomic collecting protocols against the distinct “cultures” of the museum’s disciplinary histories (for instance Botany, Birds, Mammals, or Entomology) can be seen most clearly in the *material details* of producing specimens both morphological and molecular—what is valued and saved, what is discarded, how this changes in different contexts, and how changing practices become naturalized. I describe my methods for engaging these “communities of practice” (Lave and Wenger 2002) within the museum through learning to make specimens, and the following chapters examine these issues by taking up a set of different types of museum objects and related concepts: data/standards, tissues/networks, birds/boundaries, beetles/articulations, and trees/time.

Chapter 3, DATA/STANDARDS - *Crafting Data, Standardizing Biodiversity* explores the emergence of “biodiversity biobanking” in the context of longer histories of specimen-as-data within the museum. By tracing this history forward from seventeenth century cabinets of curiosity, I examine how every age has been one of “data deluge,” faced with the challenge of incorporating new categories of “life” into existing classification systems. This leads me to the contemporary standardization of biodiversity, which is framed as a process of rendering it “knowable,” computable and sharable, examining the Global Genome

Initiative's creation of a "genome-quality" tissue standard. Data is crafted as much as the specimens they are linked to, and the respective value of specimens and data are interdependent—one becomes "orphaned," and useless, without the other.

Chapter 4, TISSUES/NETWORKS - *The Social Lives of Voucher Specimens*, explores the networks between objects, people and interests. I examine the expanding global networks of tissue collections, following the "life histories" of tissue tubes and debates over whether genetic samples can serve as voucher specimens. Maintaining the "analytical chain" between voucher specimen, tissue and data is crucial for a functional database that combines traditional collections and new genetic collections, one which can leverage collections across institutional and international borders (as discussed in the Introduction). However this single standard begins to break down as "collecting scenarios" in different disciplines push at the boundaries of what constitutes an "individual," a "sample," or a proper "voucher specimen." I focus on the means and methods for collecting and preserving these different forms of life, one discipline, specimen and genome at a time.

Chapter 5, BIRDS/BOUNDARIES - *Flight Paths Through the Museum* examines the value produced by boundary crossings, following the parts and pieces of birds as I learn to prepare a study skin and take tissue samples. I follow the discarded bird carcass as it becomes a "fieldsite" for the extraction of parasites for Invertebrate Zoology, with the different values assigned to materials based on different uses in distinct disciplinary histories. What is biohazard for one Department or Division becomes instead a source for valuable specimens in another, each group creating their own tools and narratives for preservation, oriented towards a horizonless future time (discussed further in Chapter 7).

Chapter 6, BEETLES/ARTICULATIONS – *Sharing Techniques and the Value of Parts* investigates how new practices become naturalized, looking to the ways techniques are developed, "articulated," shared and then integrated into regular routines. From the body of a bird (a vertebrate), I move into the bodies of beetles (invertebrates), which offer different challenges for genetic collecting. As beetles are disassembled they articulate different purposes with different pieces—as I learn through pin-mounting beetles, a technique little-changed for several hundred years in the Department of Entomology, to sharing methods for pulling legs off beetles for DNA analysis, to assessing that extracted beetle DNA to see

if it meets the Global Genome Initiative's "genome-quality" standards (as discussed in Chapter 2).

Chapter 7, TREES/TIME - ***Types of Time in the Museum***, from birds and beetles (*Animalia*), I move to a different branch of the tree of life with very different genetics—plants. Examining the types of time in different types of "trees" in the museum, I contrast the frozen time of the Biorepository with the shrinking time of increasing extinction rates. Through collecting genomic samples at the U.S. Botanical Garden I examine the collecting cycles for gathering specimens when they are pollinating, migrating, or swarming. Each of these types of time is embedded in specific relationships to the past in different disciplines, but all are oriented towards a unified future of a complete inventory of "life on ice," where genomic collections are preserved for imagined future uses. The moral imperative to collect biodiversity before it disappears drives collecting efforts such as the Global Genome Initiative, situating collections in the future and also as maps to the deep time of the (genomic) Tree of Life.

Chapter 8, CONCLUSION - ***The Instrumentality of Afterlives*** brings together the central concepts from each chapter—creating data standards, networks between objects, people and interests in tissue collections, the value produced by boundary crossings of birds and their parasites, naturalizing new practices in beetle pinning and DNA extraction, and the types of museum time in trees—and examines them in the context of the instrumentality of afterlives. By this, I mean how the collected dead of biodiversity in museum collections are being used to "preserve and understand" their living kin beyond the museum. It is through examining the *material practices* of how specimens are taken apart and put back together—as parts of "unbound biology" assembled with the interests of their makers, circulated within and beyond the museum—that the construction of "natural order" and the value of different forms of life become legible.

Narratives of natural order and the habits of making combine, and can then be read in the biomaterials and the uses made from them. I ask: How are nature and natural order crafted in the museum? How we can think through "practices of all kinds" (Adamson 2007:7) by attending to the ways these versions of "typical" nature (Haraway 1989) are made and remade? I engage with the communities of practice in the museum that are creating these collections and in doing so analyze what uses they are put to—both in documented use cases and in their imagined future potential as described by their makers. In matters of materiality,

as in all things, I hope to open up future discussion about how and why we build collections, and how we understand ourselves and our (continually shifting) relationship to various natural worlds through their assemblage and circulation.

The particular themes I have chosen to pursue are meant to be suggestive of the larger whole, not comprehensive. My study of crafting specimens in the museum—from pinning a beetle to assessing the "genomic quality" of a beetle leg, from pressing plants to dropping their leaves into liquid nitrogen—uses craft as a *method* of understanding both the production process and future limitations of making scientific knowledge. Throughout these chapters, the themes of order and nature, craft and value and multispecies relations—both implicit and explicit—are interwoven with scholarship from the four main fields of scholarship I engage with including Science and Technology Studies, Material Culture Studies (including ethnographies of craft), Museum Studies and Enviornmental Anthropology.

I now turn to examining my main conceptual threads—how genomic natural history collections are crafted, the value produced through their assemblages and circulations, and the different versions of nature and natural order that emerge from these practices—in the context of scholarship on objects, natures, museums, and biotechnologies.

Chapter 2
MUSEUMS/GENOMICS

Cultures of Natural History in Museums, Labs and Biorepositories

Many Species of Animals have been lost out of the World, which Philosophers and Divines are unwilling to admit, esteeming the Destruction of any one Species a Dismembering of the Universe, rendering the World imperfect.
— John Ray (1713:172)

Existence is no more than the precarious attainment of relevance in an intensely mobile flux of past, present, and future.
— Susan Sontag (1966:74–5)

The three main lines of inquiry for this dissertation examine how natural history collections are crafted in a genomic age, the kinds of value these assemblages and circulations produce, and the different versions of nature and natural order that are correspondingly made and remade in the museum.

This first section of this chapter takes up each of these themes within the context of different bodies of scholarship on objects, natures, museums, and biotechnologies in Science and Technology Studies, Museum Studies, Material Culture Studies, and Environmental Anthropology. First I examine *Craft as Practice, Process and Method*, locating this dissertation at the intersection of scholarship by social scientists and historians on the life sciences and museums. This project looks closely at the processes, practices, and material culture of museum genomics in the "back of the house," drawing on concepts of *learning-through-making, thinking through things, ways of knowing* and *how matter comes to matter*. Next I explore the *Value in Assemblage and Circulation*, engaging relevant literature on the shifting value of biotechnology, both (human) biomedical and multispecies. From the assemblage of life to the circulation of biocapital, I look at how value is created through the division and reassessment of living things, tracking the lives and afterlives of biological collections. This leads to *Versions of Nature and Natural Order*, where I take up research on the various cultures of natural history in the (genomic) museum, locating them in longer

histories of collecting, classification, and the production of different iterations of what constitutes "nature" and how natural orders are correspondingly produced. Framed within these bodies of scholarship in the second part of this chapter I lay out my methods for my data collection and analysis, examining how to become part of a "community of practice," learning through making specimens and photographing operational sequences.

To begin I locate the area carved out by this dissertation—a craft ethnography of making specimens both molecular and morphological—at the intersection of scholarship that analyzes the life sciences and biotechnology on the one hand and museums and material culture on the other.

Craft as Practice, Process and Method

Fieldwork / Labwork / Museumwork

Social scientists and historians have identified the museum as an important site of technical and social innovation (Bell 2012; Foucault 1966; Gosden et al. 2007; Gosden and Marshall 1999; Haraway 1985; Jubien 2001; Pearce 1993; Stocking 1985; N. Thomas 2010), where cultural concepts of natural order have been shaped through collection, curation, and display (Alberti et al. 2014; Bennett 1995; Bleichmar and Mancall 2011; Findlen 1994; Greenblatt 1992; Pyke and Ehrlich 2010; Stewart 1992; Smith and Findlen 2002; N. Thomas 1991), where negotiations for authority and representation are on-going (Bell 2010; Clifford 1997, 2004; Issac 2011; Karp and Lavine 1991), and where the political nature of constructing archives and historical imaginaries isare empowered or eroded (Arnoldi 1999; Comaroff and Comaroff 1992; Daston 2000a; Gordon et al. 2013; Ferme 2001; Stoler 2010).

Museum studies scholarship has focused on the public and narrative displays in the "front of the house," with a substantial literature on reading the cultural "text" of exhibits and the shifting narratives of power, place and natural order on display. In examining the constructions of nature in the museum, work has primarily centered on taxidermy and the "windows into nature" of dioramas. These range from Donna Haraway's critical analysis of the American Museum of Natural History and its trifecta of virile male nature, colonialism, and the

transformative power from “upholstery to epiphany” in taxidermy (1985); to Susan Leigh Star’s examination of the craft versus commodity in making wax leaves or preparing an elephant hide as scientific practices shifted from museum to laboratory (2014); to looking at “life on display” in twentieth century science museums and laboratories in the U.S. (Rader and Cain 2014); to the “cultures of longing” embodied in taxidermy (Poliquin 2012); and the display of animals in museums, zoos and natural history as proxies for inaccessible “wild nature” (Thorsen et al. 2013); to a menagerie of stuffed museum animals, following their “afterlives” through their display, disassembly and recontextualization (Alberti 2011).

Ethnographic work within museums has echoed this orientation towards the civic and civilizing effect of museums. These include examinations of how producing exhibits produces knowledge for different audiences, such as mediating what kinds of sacred cultural knowledge is displayed or hidden (Isaac 2007; Lonetree and Cobb 2008; Shannon 2014), negotiations between different stakeholders over exhibit designs (Macdonald 2002; Marsh 2014), and exhibitionary complexes that discipline visitors into civilized viewers (Abt 2011; Alberti et al. 2014; Bennett 1995; Price 2007). More importantly for thinking through this dissertation’s research questions I follow Gosden and Larson (2007a) in their examination of *how objects collect people,* that is, how “museum objects to some degree conceal the mass of relations that lie behind them, ranging from the people who originally made and used the objects . . . to their trade and transfer and ending, for now at least, with the curators, conservators and visitors who make up the museum community in the present” (Haidy Geismar 2009). This work brings to the foreground the web of relations within and between objects ——providing a framework for exploring genomic collections as circulating assemblages of materials, people, places and interests.

Shifting from the non-human animal to the human one, scholarship examining the life sciences has examined (human) genetic collections as contested sites for repatriation and the politics of indigeneity (Fortun 2008; Haussler et al. 2009; “Human Genome Diversity Project, Workshop 1” 1992; “Human Genome Diversity Project, Workshop 2” 1992; Jasanoff 2011; Kowal et al. 2013; Radin 2013; Sunder Rajan 2012), problematized biological reductionism (Haraway 1976, 1997; Rose 2007; Sahlins 1976), and explored how social life is enacted through scientific objects and protocols (Barad 1996; Daston and Galison 2007;

Franklin 2007; Latour 1988; Latour and Woolgar 1979; Mol and Law 2002; Knorr-Cetina 1999, 2013; Rabinow 1997; Traweek 2009).

Ethnographies of genetic labwork have for the most part been human-centered, radiating out from human interest into model organisms used for biomedical research. [16] Within the small body of scholarship at the intersection of biotechnology and collections the emphasis has been on the rhetoric of policy, publics, and commodification. The insights in this research have for the most part been gleaned from attending conferences and interviewing high-level administrators and managers. For example, in their study of DNA barcoding, Watertown, Ellis and Wynne (Waterton et al. 2013) attended international conferences with taxonomists and toured labs with project directors—never speaking to those at the lab benches in front of them who were actually doing the taxonomic work they were studying (Waterton et al. 2013).[17] Rebecca Ellis (2008) and Bronwyn Parry (2004), respectively, chose to interview upper-level management in government agencies, museums, and biolabs in their studies of biodiversity policy and the public trade in botanical genomes for pharmaceutical research. (respectively). While this work provides valuable perspectives on the shifting value of genetic collections, the lack of an integrated approach that takes into consideration the biomaterial itself, and further, attends to the practices of those who transform the materials into the valued objects under discussion, leads to analyses that perpetuate the power hierarchies of labor and value these authors seek to critique.

At the intersection of these bodies of scholarship the emergence of genetic collecting within the museum has only begun to be addressed. Despite much excellent work on themes such as bioethics and bioprospecting (Tsing 2005; Hayden 2003b; Parry 2004; Lowe 2006), the indigenous repurposing of genetic collections (Radin 2013; Kowal et al., 2013), and the politics of access, authority, and the archive (Bowker 2005a; Derrida 1996; Ellis et al. 2009; Stoler 2010; Waterton 2008), scholars examining the implications for genetic collecting within the museum have not yet fully explored the importance of: How are these genomic archives are made and remade, focused on the details of material

[16] Model organisms include arabidopsis yeast plants, c. elegans worms, drosophila fruit flies, and mice.
[17] It is worth noting that had these social scientists visited the museum biolabs during my fieldwork, I could easily have been one of the bodies seated at the lab bench with the other techs, pulling insect legs or taking tissue samples. The lack of engagement with the practices themselves, I argue, leads to an inadequate analysis of contemporary bioscience, as the chapters of this dissertation seek to demonstrate.

practice; the value of these collections as an integral part of their making, and how values can shift as they move across boundaries; and how specific concepts of nature in different disciplines and contexts affect the ways an archive is made and moved: from field to freezer, from lab to collection, from database to scientific publics.

My approach in this dissertation is to instead to look at the material culture of museum genomics in the "back of the house," a place usually invisible and inaccessible to the public. I look to the making and remaking of genetic and traditional collections in detail, asking what is being made, how is it is being made, and by whom? Models for this kind of analytical engagement come from a variety of sources. Most, most significantly I draw on concepts of *learning-through-making* (Dewey 1938), analyzing materials as a method for *thinking through things* (Henare et al. 2007; Ingold 2013), in *ways of knowing* (Pickstone 2001), how *matter comes to matter* (Barad 2003), and *the sticky materiality of practical encounter* (Tsing 2005).

In Science and Technology Study terms I look at the oscillations and frictions that constitute biodiversity biobanking at the Smithsonian (Ellis 2008; Ellis et al. 2009; Parry 2004; Tsing 2005), exploring the intimate and fluid connections between the minutiae of biological organisms, their tissue samples, their DNA, and embedded within them the vision for a shared human and non-human futures. I observed the ways in which the taxonomic community in the museum, inheritor of several centuries of approaches to natural history classification entangled in histories of colonialism, now finds itself caught up in the changing landscapes of several wider intersecting domains. These include the genomic life sciences, biodiversity policy, and the increasingly fraught activity of collecting and transporting specimens (now categorized as "national biowealth" post-CBD[18]) across international borders.

[18] Convention on Biological Diversity, signed on 1992 (though the United States was not, as of 2016, a signatory.

On Process: Ways of Knowing and Ways of Making

Different styles of scientific reasoning have been used productively by authors as different as Thomas Kuhn ("paradigms"(1962)), Michel Foucault ("episteme"(1966)), and John Pickstone ("ways of knowing"(2001)). These perspectives, given their emphasis on thought processes, have a tendency to separate out material practices, which I argue are an integral part of understanding how science is made, used and conceptualized. Materials matter, as much as the rhetorics of policy and publics thatwhich have thus far been a central focus of scholarship within science and technology studies, particularly in genetics (Fortun 2008; Gibbon and Novas 2008; Jasanoff 2005; Rabinow 2002; 1997; Rabinow and Rose 2006; Rabinow and Bennett 2012; Sunder Rajan 2012).

Bruno Strasser (2012a), a historian of science who pushes the boundaries of this body of "rhetorics of science" scholarship, productively takes up Pickstone's "ways of knowing" (2001) as a way of integrating both the cognitive and the material. "Analysis," one of Pickstone's ways of knowing, for example, is interpreted by Strasser to be both a mental operation of analyzing abstract ideas into more specific components and the material operations of physically dividing scientific objects into their constitutive parts (Strasser 2012a). In the context of making museum specimens, both morphological and molecular, this has great potential for unpacking the assemblage of a specimen. This perspective offers the possibility to recognize the specimen's parts and pieces, their shifting value, and the negotiated terminology used to describe them as a "way of knowing" through both the material and cognitive operations at work. Instead of replacing each other (such as Kuhn's paradigms), Pickstone's "ways of knowing" add new layers to the composition of science and technology as it is made and remade, which allows the examination of scientific practices in terms of elements layered over time. This has been a very productive method for understanding both the biological, social, and material aspects of crafting genomic museum specimens in my research.

The notion of process also offers new ways of thinking about life that avoids articulating it as a unified, universal phenomenon. Georges Canguilhem (2008) has suggested that life should be seen as an "order of properties" to convey the idea that modern science investigates and ultimately seeks to intervene in

biological systems. Scientific practices achieve this through a focus on life processes that are treated as discrete but interrelated phenomena—such as reproduction, growth, generation, and degeneration. One aim of this dissertation is to understand how these vital phenomena become embedded within the specific material practices put in place by biodiversity biobanking. Through my selected frameworks I analyze the redefinitions of life as it is skillfully crafted, as well as the representations (visual, semantic, and material) that are created within the scientific and museum communities around the molecularization of life (Rose 2007), life as "surplus" (Cooper 2008), and life as "unbound biology" (Helmreich 2007; 2009).

Making and Marking Time in the Museum

My method of inquiry is within a framework of "making" (Clarke and Fujimura 1992; Hallam and Ingold 2007; Ingold 2013), looking at collections not as a fixed set of objects, but as being in a continual process of "becoming" or "coming-into-being" (Deleuze and Guattari 1987; Haraway 1989; Ingold 1988; Kirksey and Helmreich 2010). Within the life cycle—and death cycle, or afterlife—of specimens I look to the stickiness of practical encounter (Tsing 2005) in specimen preparation, following how biologies unbind (Helmreich 2009) in the making of genomic collections, becoming an assemblage (Deleuze and Guattari 1987) of biomaterial, data, places, people and interests. I track the circulations of these assemblages (Appadurai 1986; Joyce and Gillespie 2015; Kopytoff 1986; Moeran 2010; Munn 1986; Ong and Collier 2005) through the museum and beyond out to the distributed networks of scientists, museums and laboratories. I look to the way these collections of data, frozen tissues, stuffed bird skins, pinned beetles and pressed tree branches function as ventriloquists (Haraway 1997) for their species, genus or family of life in the collecting schema of the Global Genome Initiative (GGI). Life, as read through the collection, can be understood as reduced and molecularized (Rose 2007) and also as expanding as biological data becomes Big Data (Leonelli 2013a, 2014; Page et al. 2015; Stephens et al. 2015).

Sarah Franklin's (2007) study of Dolly, the first cloned sheep, placed this genetic curiosity in a larger genealogical context of agricultural production, colonialism, and the gender politics of reproduction—examining how life can be copied. Building on her work I examine how an "archive of life" is currently being created

in the museum, locating the Smithsonian's GGI in a long history of museum collecting with origins in colonial expansion and the cultures of crafting specimen collections to recreate idealized versions of natural order (Findlen 1994; Foucault 1966; Jardine et al. 1996; Pearce 1994c). Implicit in crafting a complete archive of all life is a view of the natural world as a malleable resource for constructing an idealized view of "nature," a fixed structure for which parts are created to fill holes in the collection—be it a taxidermy mount in the nineteenth century or a vial of frozen tissue last week (Alberti 2005; Brand 2009; Ferry and Limbert 2008; Findlen 2002; Fujimura 1996; Raffles 2001, 2010; Revive and Restore 2013; Wonders 1993a, 1993b).

Scholarship on the copy has identified the emancipatory potential of the technological reproduction and the aura of the authentic original (Benjamin 1968), and more recently examined the Western-centric notion of the copy as a degradation of the original (Gitelman 2006; Heidy Geismar 2013; Griesemer and Shavit 2011; Hayden 2007a, 2010; Issac 2011). Applying these concepts of an "authentic original" to the genetic collection—specifically to the narratives of salvation employed by conservation projects—raises questions of authenticity, replication and materiality, revealing assumptions about using all available biotechnological tools to create genomic catalogs and even "authentic" copies of extinct species (Church and Regis 2012; Revive and Restore 2013). Joanna Radin (2013) has identified an orientation to the future by cryopreservationists as "predictive hindsight," with the implication that what has been collected and curated is not simply an extinct species, but a recreation of a version of history. From examining scholarship on the processes, practices, and material culture of museum genomics, I now turn to look at the forms of value created as specimens are assembled and circulated.

Value in Assemblage and Circulation

Shifting Values of Biotechnology and Museum Specimens

Literature focusing upon the domains of biotechnology and biomedicine has explored the co-emergence of forms of capitalism with humanity's knowledge and use of biology, in the wake of proliferating (post) genomic developments (Ellis 2008; Fortun 2008; Franklin and Lock 2003; Hayden 2003b; Helmreich 2007,

2008, 2009; Parry 2004; Rabinow 2002; Rabinow and Bennett 2012; Rabinow and Rose 2006; Rose 2007; Sunder Rajan 2005; Mitchell and Waldby 2006). A belief in the irrepressible generative nature of biological life has been called upon to warrant the potential promises of biotechnology, as various scholarship in STS and anthropologies of science have examined (Franklin and Lock 2003; Hayden 2003b; Helmreich 2007; Parry 2004; Rabinow 2002; Rose 2007; Sunder Rajan 2012).

This literature defines biovalue as the actual or hoped-for capital created and circulated by unleashing the potential of genetic function as it is transformed into information. The commodifiable characteristic of biology, following the assertion of Cori Hayden, is active biological function (rather than the revelation of order which is described in more passive ontological terms). For these enterprising practitioners of plant screening, describing new plant compounds have little worth if not accompanied by a description of their efficacy: what a plant has and what a plant does are two different questions. Patent claims on substances derived from nature revolve around a newly vital emphasis not on what life *is*, but on what life *does* (Hayden 2003b).

To understand the significance of specimens requires placing them in specific contexts—contexts that may include multiple ways of defining, manipulating, and assessing value. Examining how value is created through the division of living things for natural history collections, genomic and otherwise, I turn to value as a form of “meaning-making” (Graeber 2001:2), which integrates work on production and exchange (Strathern 1992; Mauss 1954; Marx 1867; Munn 1986), and which I then use to explore the social lives of (museum) objects (Alberti 2011; Appadurai 1986; Joyce and Gillespie 2015; Latour 1999a).

Nancy Munn has suggested that kula exchange in Gawa co-mingles and exchanges qualities between “men” and “things”: "Although men appear to be the agents in defining shell value, in fact, without shells, men cannot define their own value; in this respect, shells and men are reciprocally agents of each other's value definition." (1983:283, cited in Appadurai 1986:20). In this reciprocal construction of “regimes of value” (Appadurai 1986:20) it is not only the paths along which objects travel (in this case kula shells) that play an important role, but diversions from those paths as well. The relations “between paths and diversions” is critical, according to Appadurai, to the politics of value in the kula

system, and he offers up the kula as "the paradigm" of what he calls "tournaments of value" (1985:21):

> "Tournaments of value are complex periodic events that are removed in some culturally well-defined way from the routines of economic life. Participation in them is likely to be both a privilege of those in power and an instrument of status contests between them. The currency of such tournaments is also likely to be set apart through well understood cultural diacritics. Finally, what is at issue in such tournaments is not just status, rank, fame, or reputation of actors, but the disposition of the central tokens of value in the society in question. Finally, though such tournaments of value occur in special times and places, their forms and outcomes are always consequential for the more mundane realities of power and value in ordinary life. As in the kula, so in such tournaments of value generally, strategic skill is culturally measured by the success with which actors attempt diversions or subversions of culturally conventionalized paths for the flow of things" (Appadurai 1986:21)

Within the context of museum genomics the different disciplinary "cultures" of Departments and Divisions form a *background* against which the *figures* (Gell 1998:187) of specimens—and their biotechnological parts—move in various "tournaments of value" (Appadurai 1985:21) as they are assembled, exchanged and circulated. Regimes of value (Appadurai 1986; Myers 2002, 2013) are weighed and compared when scientists actively engage in evaluating potential use or potential preparation techniques, and the ability of the object to move between domains in the future. For example, using a mutually-agreed upon data standard for "genome-quality" tissue samples today makes them valuable to multiple users in multiple contexts in the future (as discussed in Chapter 3: Standards/Data and in Chapter 4: Networks/Tissues). Such regimes of value come into friction with each other in "tournaments of value[s] "(Appadurai 1986:21) as specimen-assemblages are called on to serve multiple interests, where various orders of value are assessed and legitimated (Moeran 2013, 2010). Objects, as Julian Thomas points out, rarely exist as free-standing and isolated, but instead "sit as a node within a complex network of associations and connotation" produced through practice which "embody qualities and influences by virtue of [its] materiality" (1999:73).

As different disciplines create different versions of "nature" they negotiate between those versions, with various kinds of naturalizations and translations happening along the way. I examine these in multiple sites and encounters, from the creation of a "genome-quality" data standard (Chapter 3), to managing "types" in genetic collections (Chapter 4), to pulling beetle legs for DNA assessment (Chapter 5), to taking tissue samples from a bird study skin (Chapter 6), to building a Tree of Life by sampling a cocoa tree (Chapter 7). The salvation

narratives of “preserving and understanding all genomic life on earth” shows in its material practices and rhetorics the redefinition of life itself by the biological sciences (the “life” sciences) as a reduced, essentialized molecular version of nature (Rose 2007). It is a redefinition of life as essentially molecular, reducible to data (BOLD 2015; Leonelli and Ankeny 2012; Strasser and De Chadarevian 2011), or inversely, DNA itself can now be transformed into a medium for data storage (Ingham 2013).

The life sciences are in the business of conscripting and in turn crafting human, animal, and ecological natures, and it is worth noting that even these categories reflect a specific Euro-American genealogy of epistemologies of natural order (Alberti et al. 2014; Daston 2004b, 2004a; Foucault 1966; Daston and Vidal 2004; Galison et al. 2001; Galison and Stump 1996; Kohler 1994, 2002, 2013). The essence of life becomes in effect the genome, or more precisely genomic data—a text to be read and potentially rewritten (Bi et al. 2013; Church and Regis 2012; Haussler et al. 2009; Parry 2004; Ridely 2000). However, the data can be mistaken for the thing itself when the metaphor collapses onto the original and supplants it. The data, and the rhetorics surrounding them, are derived from objects—living things transformed into museum artifacts. These artifacts are an assemblage of people, place, things and data, entangled with the interests of those that assembled them. The process of abstracting the specimen into a data set with a voucher naturalizes this knowledge production process and erases the sociocultural contexts that led to its production. This redefinition of "life" by the life sciences takes on interesting and unexpected forms when the scientific work is in caught up with defining and designing the future of “nature,” and the nature of collections in a genomic age.

At the intersection of collections and genomics, I ask: how is “nature” made in the museum? How are “natural orders” assembled through specimens—both materially and conceptually—and how do they circulate? What kinds of value do specimens and the orders they represent accumulate on these circulation paths? What happens as parts and pieces of specimens are categorized as precious or as waste in these transformations and movements? What versions of time are created and negotiated by the collections, looking both to histories of collecting and their future potential? To answer these questions I look to nature-making in the museum, to natural history collecting practices, and to the material practices of “crafting nature.”

On Assembling and Circulating Specimens

I use the terms of *assemblage* and *circulation* as means of interrogating the problems of crafting genomic collections, using these terms as my conceptual tools to open up the practices and processes by which these collections both continue historical traditions and rupture them. I now turn to defining the scope of my use of these terms in more detail.

When I began to use the concept of an *assemblage*, it became clear to me that objects existed by virtue of their historically specific and yet very tangible and material circumstances. Assemblages, I suggest, are formed of organic and inorganic objects, technologies, bodies, and places, and not just of words. With my fingers numb from separating a half-frozen bird from its skin, or eyes straining while I manipulated tiny beetle legs into position, it became clear that the biomaterials of the museum had their own lives—not in a sense of individual agency, but in terms of the ways the matter lent itself to becoming part of assemblage, or instead resisted it. From this perspective, I use the term assemblage in this research to describe the specific patterns through which specimen collections and genomic technologies were integrated—or assembled—with each other and with the histories and practices around them.

I draw on Deleuze and Guattari's version of an assemblage (1987), but ground it in the (bio)materials being assembled and the practices of making (Gosden and Marshall 1999; Ingold 2012, 2013), taking into consideration how "matter comes to matter" (Barad 2003). An assemblage materializes an object by placing it in a specific social and technical constellation, making it perceptible, outlining forms of making, drawing out possibilities and investing meanings by virtue of its linkages, effects, and relationships. Or conversely, by ordering an object in an assemblage, that object can be disinvested of qualities, capacities, and possibilities—becoming dematerialized, or being consumed (such as genetic samples being completely used up, the only trace of their existence being through the data trail of their consumption). In thinking through these material transformations and erasures, I define "assemblage" as an arrangement of materials, discourses, practices, and subject positions that work together within a particular discipline or knowledge tradition (such as Molecular Biology as distinct from Ornithology or Anthropology). It is not the list of elements that make an

assemblage consequential; instead it is the possibilities opened up through the ways different elements articulate with each other.

In analyzing the assemblages within different traditions of knowledge production in the museum, I have attended to how arrangements of words, things, practices and people have drawn out and made perceptible specific qualities, capacities, and possibilities for crafting (genomic) specimens for museum collections, what the scientists have named "biodiversity biobanking." Further, I argue that the different types of time produced within the museum are integral to both making assemblages—from crafting a bird study skin to editing a protein sequence—and their circulation within and outside of the museum, as scientists follow disciplinary histories of what to keep, what to cut, what the remaining pieces will be used for, and how those fragments will "speak" for their species, genus or family of life (Haraway 1997).

In following the movement of these assemblages, or what has been called the social lives of things (Appadurai 1986; Gosden and Marshall 1999; Kopytoff 1986) or object itineraries (Joyce and Gillespie 2015), I attend to their boundary crossings (Star and Griesemer 1989) and the shifts in value as they move within the museum (Graeber 2001) and then out into global networks (Ong and Collier 2005; Tsing 2005). In other words, the circulations of these assembled specimens speak to the accumulation of value and different meanings as they move across boundaries, both within and outside of the museum. For example, DNAs and tissue move from the field to the lab to the freezers and nitrogen tanks of the Biorepository. The corresponding voucher specimens migrate to the appropriate Division or Department at the Smithsonian (Mammals, Birds, Botany, etc.), or to an outside museum in the country of origin. Whole specimens (and sub-samples of them) also circulate to outside researchers in institutions around the world, with an understanding that the tiny pieces of tissue, bone, or amplified DNA extract will migrate back to the Smithsonian if not consumed in the research. Material, even measured in microliters, matters. New kinds of value and new types of "nature" are created and recreated through these circulations. In sum, this dissertation examines the various ways specific assemblages create regimes of value and natural order through their circulation.

Versions of Nature and Natural Order

Multispecies Ethnographies and Natural Orders

Examining the production of value in mining and extending natural history collections, I locate my research within craft ethnographies, both traditional and multispecies (Hallam and Ingold 2007; Ingold 2006, 2010, 2011a; Kirksey and Helmreich 2010; Kohn 2013; Marchand 2010; Paxson 2010; Sennett 2008), exploring hands-on the crafting of specimens using historic methods (Baird 1856) as well as emerging protocols for genomic collecting (Coddington et al. 2007; GGI 2013). In mapping the transformations of living things into museum specimens and into data, I use Stefan Helmreich's concept of "biology unbound" (2009:280) to track precisely how value, craft, and concepts of nature can be rendered visible through an analysis of the *chaîne opératoire* ("operational sequence") of this multi-threaded path (I outline my interpretative use of *chaîne opératoire* at the end of this chapter in *Methods, Part II: A Visual Anthropology of Specimen Preparation*).

To begin to understand what versions of "nature" are being created in the different disciplinary cultures of collecting and preparation practices, I turn to literature on anthropologies of nature-making and ecology (Hayden 2003b; Foucault 1966; Franklin 2007; Ingold 2000; Lowe 2006; Parry 2004; Rabinow 1997; Rader 2004; Rutherford 2011), contextualizing them in the history of Anglo-European collecting practices (Daston and Park 1998; Impey and MacGregor 1985; Jardine et al. 1996; Kohler 2013; Pearce 2013; Pomian 1990; Smith and Findlen 2002) and the emergence of the national museum as both a civic and civilizing institution (Bennett 1995; Haraway 1985; Karp and Lavine 1991; Stewart 1992), as well as within anthropologies of science and technology (Ellis 2008; Franklin 2007; Haraway 1997; Helmreich 2009, 2008; Latour and Woolgar 1979; Parry 2004; Radin 2012; Star 2014; Waterton et al. 2013).

The research for this dissertation employed multi-sited ethnographic research methods (Marcus 1995), including participant observation, semi-structured interviews, archival research, and hands-on apprenticeship within the Divisions of Mammals, the Division of Birds, the Departments of Entomology and of Botany, the Biorepository and the Laboratories of Analytical Biology. Though each of these exists within the same institutional structure, I argue they each represent a

very distinct “community of practice” within the museum, distinct cultures where I had to learn anew how to gain access and acceptance, navigate the “local” culture and speak the “local” dialect of Birds or Beetles or Genomics with each type of specimen I wanted to learn to make.

“As soon as we let go of the universal as a self-fulfilling abstract truth, we must become embroiled in specific situations,” writes Tsing, “and thus it is necessary to begin again, and again, *in the middle of things*” (2005:11 emphasis added). My experience in the museum—of finding my way through the frictions of competing universal “truths” in the making of specimens and the “natural truths/natural knowledge” of a genomic universality—I found it was necessary to begin again and again, as Tsing puts it, in the middle of things. My own narrative through the museum both reflects the local knowledge structures (through skinning birds, pinning beetles, pressing plants, freezing tissues, and extracting DNA) while at the same time reflecting this process of repeated beginnings, from “the middle of things” in the museum, in different labs, collections and their distinct cultures. In sum, I want to emphasize that my narratives are not linear progressions that tie together neatly, but are sections taken from a longer and interconnected narrative of which I was a part during my time in the museum. In the following sections I lay out my methods for collecting and analyzing my data, and how I learned to “craft nature” one specimen at a time.

Collected Data:
Interviews, Observations, Photographs and Illustrations

Between June 2013 and February 2016 I conducted fourteen months of fieldwork, mostly located in the laboratories, archives, and collections of the Smithsonian National Museum of Natural History (NMNH), the Museums Support Center (MSC), a vast collections storehouse located in Suitland Maryland, and at the Smithsonian Institution Archives (SIA), just off the National Mall in Washington, D.C.

While participating in the Smithsonian Summer Institute for Museum Anthropology (SIMA) during the summer of 2013, I worked with Joshua A. Bell, Curator of Globalization in the Anthropology Department at NMNH. Based on my interest in museums and genomics, he suggested I consider a study of the Global Genome Initiative (GGI), then still in its very early stages. The Director of

the GGI, Jonathan Coddington, was open to the idea of having an anthropologist in the midst of his project. Over the course of my fieldwork at NMNH[19] I was co-advised by both Josh Bell and Jonathan Coddington. As I followed the branching networks of contacts suggested by them through the museum, I found having co-advisors from opposite ends of the museum—an Anthropology curator on one hand and a Genomics project director on the other—provided me both a position of adjacency, and also access to much of the museum.[20]

Given that many of my subjects were located lower in the very defined hierarchy of the museum—that is, below the administrators and curators who were both visible and vocal in the decisions made—I have chosen to not to anonymize voices in this dissertation, unless explicitly asked to do so by the speaker. People named have given approval for my use of quotations. Giving voice to the makers in the museum is one of the many threads in this dissertation, but it is an important one, and follows scholarship in the social sciences (Barley and Bechky 1994; Bell 2013; Clark 2011; Clarke and Fujimura 1992; Griesemer 1992; Knorr-Cetina 2013; Latour and Woolgar 1979; Star 2014) and history of science (Biagioli et al. 2011; Galison 1997; Shapin 1989; Smith 2004; Star and Griesemer 1989) in acknowledging the role of craftspeople and skilled laborers in facilitating the production of scientific knowledge through the collection and creation of specimens, tools, apparatuses and materials. Much of my ethnographic fieldwork involved looking at practices in the "peripheral vision" of the museum, to the what Stephen Shapin (1989) has called the "invisible technician," that is, those who make the "tools" of taxonomy — —specimen collections both molecular and morphological. Materials matter, as I argue, but so do the people who assemble and transform those materials.

I conducted both structured and open-ended interviews, some sixty-two in all, primarily with the museum's many types of biologists—specimen preparators, collection managers, data managers, curators, lab technicians, computer scientists, bioinformaticians, lab managers, "tube wranglers" and "data wranglers" across the museum, including the Divisions of Mammals, Birds,

[19] Research funding was provided by a Smithsonian Predoctoral Peter Buck Fellowship (2014-2015) and a WennerGren Dissertation Research Grant (2015-2016).

[20] I began contact with people by sending out a paragraph explaining who I was (an anthropologist from UC Berkeley), what I was doing (a dissertation on natural history collecting in an age of genomics) and what I was interested in talking with them about (their work, interests, specimens, and collections). I also attached a brief research synopsis, written for an academic audience, since my subjects were highly educated museum professionals, many with doctorates.

Reptiles and Fishes, Entomology, Invertebrate Zoology, Botany, the Biorepository, the Laboratories of Analytical Biology, the Vertebrate Zoology Preparation Lab, and the Osteology Preparation Lab. I also attended the weekly Genomics Journal Club meetings, lectures, lab meetings, symposia, presentations, department coffee hours, and workshops in Divisions and Departments across the museum. I asked people about their work, how they arrived at their interests, how their practices had changed with the integration of genetic collecting techniques (or what had stayed the same), whether new technologies had transformed their methods or questions, what they considered key issues and debates around genomic collecting, how they saw their work contributing to the museum, to their discipline, and to preserving and understanding biodiversity. Many of my subjects used air quotes when asking me what "data" I was collecting for my "scientific" research—the dominance of the biological sciences over the social ones in the museum hierarchy was reiterated on a daily basis. Sometimes the informal interviews would happen as I learned techniques, sitting with people as they taught me various specimen preparation methods[21] or even during the Laboratory of Analytical Biology (L.A.B.) safety training ("Even our anthropologist did the safety training!" an exasperated GGI staff member told a visiting scientist trying to sidestep it).

A key networking venue was the weekly museum staff social on Friday nights in the Paleontology conference room. Walking through the semi-lit hallways of the nearly deserted museum around six o'clock on Friday nights, I moved past carts and tables piled with rock hammers and fossils sorted into trays, doors labeled "Type Collection (Need Key To Open)," and finally turning the corner I'd hear the voices, laughter, and click of beer bottles that told me I'd found the right place. These events drew people from across the museum, and I always met or was introduced to new people doing unexpected and interesting things. I met a visiting scholar who collected bees in the Tibet highlands using a dust-buster: "the perfect amount of gentle suction—swoosh! No damage at all, they're almost ready to pin after you blow dry them a bit to fluff out the hair—you really need to give them a blow out to see the morphological features clearly." I talked with a post-doc working to DNA barcode marine species through the use of a blender, a method called "grind and find," sorting out the genomes of microorganisms after

[21] Specimen preparation methods I learned included: making bird and mammal study skins, taking tissue samples, running DNA electrophoresis gels, pulling beetle legs for DNA extraction and analysis, pinning and point-mounting beetles, labeling, sorting and scanning cryotubes, organizing the specimen data, mapping workflows, sub-sampling tissues, filling liquid nitrogen tanks, pressing plants, and mounting them once dry onto herbarium pages.

making a slurry. “It’s where things are going,” he told me gesturing outwards, “it’s all about connections, networks, the microbiomes of organisms.” I listened to a cluster of marine mammal curators (whales and dolphins) next to a cluster of herpetology curators (snakes and lizards), each group debating the pros and cons of different methods of tissue sampling. One of their number, a post-doc in marine mammals who was busy drilling hundreds of dolphin teeth collected over a century, was apparently getting good quality ancient DNA.

When I arrived at the Smithsonian in August of 2014, the GGI consisted solely of two people: the project’s Director, Jonathan Coddington, and a project manager, Katie Barker. I began attending GGI weekly meetings with the newly hired staff, and for all intents and purposes functioned as an (adjacent) part of the GGI staff in a role somewhere between project photographer, historian and media developer. Part of creating the GGI’s genomic collecting protocol involved mapping the different “life histories” of specimens from field to lab to freezer, looking at how each reflected different “collecting scenarios” across disciplines. I collaborated with the GGI in mapping these processes, as a method of giving back to my source community during my fieldwork, working with them to visualize the flow of specimens and their transformations into tissue tubes, DNA extracts, and data sets. These transformations were illustrated through various infographics and photographs of different stages of the process, triggering discussions about how, where and why specimens were transformed, through different assemblages and circulations within the Smithsonian as well as their movement out to partner institutions.

Methods, Part I:
Engaging Communities of Practice at the Museum

My fieldwork experience at NMNH, where I moved among the different “cultures” of Botany or Entomology, the Biorepository or the biolab, resonates with Lave and Wenger’s (1991) concept of “communities of practice,” which they use to capture the importance of activity in fusing individuals to communities, and of communities in reproducing individual practices. Within the context of these communities, learning through apprenticeship is conceived of as a trajectory from “‘legitimate peripheral participant” to “core participant” within the community of practice. While participating in this trajectory, an apprentice participates in the activities of the community, and in doing so, moves toward becoming more

central to the community of practice. By moving from an outside investigator to active participant, I earned a specific type of access to the "communities of practice" at the Smithsonian NMNH—becoming "the GGI's anthropologist," integrated into the museum culture as (almost) one of their own, which has provided a position of both mobility and adjacency. This type of cultural immersion has allowed me to gain insights into the nature of scientific knowledge production as it unfolds—facilitating access to the laboratories, collections, and staff meetings where ideas take shape and concepts of value are negotiated and put into practice. Through apprenticeships in the craft of producing scientific artifacts (Jasanoff 2004, 2005; Latour and Woolgar 1979; Lave and Wenger 1991; Lave 2011), I have been taught the craft of specimen preparation, genetic sampling and collections care, engaging my informants on their own terms and with the (bio)materials through which their narratives are formed (Coy 1989; Lave 2011; Lave and Wenger 1991, 2002; Rogoff 1990). Fundamental to the apprenticeship perspective is the notion of practice: practice as an activity that embodies and builds understandings, as well as one that has the potential to integrate an individual into a community that uses and values the particular practices being carried out (Bourdieu 1977; Coy 1989; Mauss 2007; Ortner 1984; 2006).

My study of the social practices that shape museum genomics brings together these different perspectives—from the GGI's standardization of biodiversity biobanking protocols to the different practices of "crafting nature" across the distinct disciplinary "communities of practice" at the museum—with a particular focus on specimen preparation both morphological and molecular. Using craft-as-method I look at how things are made and remade to reaffirm narratives of "nature" and "natural order" in the museum, located in a long history of collecting (Bleichmar and Mancall 2011; Findlen 1994; Pearce 1992, 1994b; Smith and Findlen 2002) and classification (Bowker and Star 1999; Daston 2004b; Foucault 1966). In the words of Glenn Adamson, "craft is not a defined practice, but a way of thinking about practices of all kinds" (2007:7). From this, I take craft to be a methodology for understanding the production of scientific knowledge, that is, as a system of methods for looking at how people, places, materials and interests are assembled into different configurations and then circulated across domains, accumulating different meanings and values during these transitions.

Through this framing I can see what is preserved in different ways and for different purposes, and the frictions as standards for genetic collecting *across*

disciplines are negotiated and implemented. What is being saved, what is being thrown away? What can these different categories of precious/detritus tell me about how a version of nature is being constructed in the different "cultures" of Botany, Birds, or Entomology? What purposes do these different iterations of "natural order" serve within these disciplinary cultures, and how do categories shift over time as old collections are re-evaluated for new uses? What kinds of "rewilded" futures are being constructed, or more pointedly—is the (genomic) potential being constructed for?

This approach has involved, for example, navigating the complex biological, social and political histories of specimen collection and archiving within different disciplines in the museum, from Vertebrates such as Birds and Mammals, to their vertebrate cousins in Reptiles, Amphibians and Fishes, to Invertebrates (Terrestrial, Marine and Parasitical), to Botany and the very different lives of plants, to the distinct cultures of lab-within-museum of the Laboratories of Analytical biology, and to the collection of collections, the Biorepository. In each I had to gain an understanding of the protocols being established to regulate the global access to and mobilization of genetic material for taxonomic research through the interactions and negotiations between the Global Genome Initiative, its own global network of collaborators (the Global Genome Biodiversity Network, or GGBN), and the curators, collections managers and specimen preparators in each Division and Department at NMNH.

By focusing on the strategies of making and remaking "nature" in the museum's distinct communities of practice, these strategies are rendered visible through the material practices of assembling and circulating collections within and between the Division and Departments of the museum. Through tracking the way these practices work together to create newly productive assemblages, which in turn can accumulate new kinds of value and meaning as they circulate between museum domains and beyond. These regimes of value and natural order that are negotiated and re-inscribed by these circulations, I argue, are a key part of what shapes contemporary biodiversity biobanking as a standardizing force, shaping a collective continuity with the museum's past and a specific relationship to its future. Several types of time can be discerned from these lines of exchange and their trajectories — —within the museum the ethos of preservation looms large, as the Tree of Life is gathered and frozen from these distinct "cultures" of preserving different types of living things, as we move inevitably towards a future of extinction and continuing biodiversity loss at unprecedented rates.

Negotiations continue between the Division of Birds and the GGI about what legacy tissue samples should go into the biorepository and be "visible" to the outside world. Location data for endangered bird populations, as well as the public's response to contemporary collecting of living things, is controversial at best. One of the "populations" being protected by the omission of certain data types were the specimen collectors themselves, in a conscious choice to shield the museum staff from public backlash about killing individual birds to protect the species as a whole. Such moves to obscure or highlight, to keep or discard certain kinds of specimens, tissues, or data (about both human and non-human animals) were a recurring theme as I dug deeper into the "culture" of each department and division. The preservation within the museum community of historically tested collecting methods (which have embedded within them ways of existing in the natural world) are enacted in many registers, layers of history and habit folded into each other. These methods include the conservation of collections and of the collectors themselves. Beginning the process of unfolding those layers is laid out in the chapters of this dissertation.

Methods, Part II:
A Visual Anthropology of Specimen Preparation

As part of my research I photographed the operational sequences of specimen preparation processes, different types of preservation methods in collections, genomic collecting and lab processing, and biobank storage and curation. I use a variation of *chaine operatoire* methodology (French for "operational sequence"), which has been used since the 1960s when Leroi-Gourhan coined the term (Leroi-Gourhan 1964, 1993; Schlanger 1994). The traditional model of *chaine operatoire* investigates the sequential stages involved in producing an object—such as its technological, social, and aesthetic characteristics—and attends to how these elements are linked, expressed, and negotiated in the everyday practices and decision- making of the craftspeople who make the objects. This approach emphasizes a step-by-step analysis of the technologies of production and the properties of raw materials, and has been used extensively in archeological scholarship in reconstructing the operational sequences of producing, for example, tools (Knecht 1991; Semenov 1964), ceramics (Soffer

and Vandiver 1994), textiles (Soffer et al. 2000) and beads (Stiner 2003; White 1997).

However, my approach is aligned with a view that emphasizes technologies as both material and social (Dobres 1999, 2000; Lechtman 1977; Lemonnier 1993), such that the *chaine operatoire*—or a variation inspired by it, such as I use in this dissertation—has the capacity to simultaneously chart both technological and social sequences of production at different scales of granularity, from the movement of a beetle leg under a microscope to the movement of specimens across global borders. I suggest that any clear distinction between "technology" and "craft" begins to blur in making specimens, tissues and datasets as embodied skills and tools combine, each set of practices relying on a combination of handwork and mechanization. Genomes, from this perspective, are crafted as much as study skins. I focus on the entanglements of craft and technology in the museum's back rooms, examining "the reasons rather than the causes driving local technical processes . . . unraveling the interlacing of practices and discourses that leads to the[ir] 'coming-into-being'" (Coupaye 2009:433). In other words, through following the sequences of producing genomic collections I look to the key moments in the flow of crafting specimens—moments that connect to both the disciplinary histories in the museum and the various imagined futures for biodiversity biobanking. My version of "operational sequences" thus integrates deep past and imagined futures, examining how they are enmeshed in the everyday practices and decision making of museum staff as they craft "natural" artifacts with technologies both old and new.

During my fieldwork I shot just over 20,000 images, many of them in rapid sequence following a procedure or process such as skinning a bird or running a DNA gel. After doing a photo shoot I would share the images with the collection manager, lab tech or curator, who in turn used the images for their papers or presentations. This form of reciprocal exchange worked well for gaining access to both collections and their keepers. The time during the photo shoot—walking through the collections, handling the specimens to shoot a particular feather, claw or shell—provided a particular kind of opportunity for talking, one very grounded in the biomaterials, quite literally, at hand. The photos and illustrations included in each chapter are assembled from documenting these museum practices and from my own preparation of birds, mammals, insects, and plants, their genetic samples, and data sets. Included in each chapter they form an

integral part of my fieldwork, providing a core of visual anthropological analysis to the project (Pinney 1997; Pinney and Peterson 2003).

Continuing in the vein of understanding-through-making, and building on scholarship that has theorized the photograph as a provoker of ethnographic material and orientations to "fossilized" moments of time (Bell 2009; Bell et al. 2013; Benjamin 1979; Bishop and Cubitt 2013; Burgin 1982, 1986; Collier 2001; Jacknis 1988; Edwards 1992; Gordon et al. 2013; Mead 1995) I have combined archival material with my own photographs documenting these processes and practices. These performances of preservation and use are particularly informative to deconstruct visually, as they are the everyday spaces of scientific production (Clarke and Fujimura 1992; Fujimura 1996; Stewart 1992). Through these displays of skill—from pulling a beetle leg to the delicate pinning of a bird's outstretched wing—I began to make sense of the craft of scientific knowledge and how it was made.

Photographing in the museum has been an integral part of my research, informing the way I "learned to see" during specimen preparation, but also as a tool for communication and exchange with the people I was studying. Often I would shoot several frames, and then flip the camera around so they could see what I had photographed on the LCD display on the back of my camera. This back and forth led not only to building trust—they could ask me to delete images if they were uncomfortable with what I'd shot (a very rare occurrence). Far more often they would make suggestions about what to shoot, organizing small displays that frequently mimicked the historical preparation manuals which were a source of inspiration for myself and the specimen preparators (see Figures in Chapters 5—Birds, Chapter 6—Beetles, and Chapter 7—Trees). I shot thousands of photographs of hands holding things out for me to see and photograph. This in itself speaks volumes to me about the relationship between the museum staff and the artifacts they produce and maintain—it suggests they in part see themselves *through* the specimens they produce, and their sense of being valued in the hierarchies of the museum are in part transmitted through the value of the specimens. The photographs, from this perspective, serve as an index of this relationship. As the photographer and theorist Victor Burgin suggests:

"In relation to the 'site specificity' of my works, what is 'indexed' here is not simply the material substance of the place, or the optical imprint of the light reflected from it, it is the registration of the material world on a consciousness. The 'image' is not simply a material thing—a photographic print or the variegated light on a screen—nor is it just an optical event, the physiological imprint of this light on the retina. It is a psychological process." (Burgin cited in Bishop and Cubitt 2013:23)

The process of photographing and sharing the images went beyond merely registering the material world and the relationships within it, but as Burgin suggests, the act of photographing a place is a psychological process where the boundaries of authority and access are tested—for those on both sides of the lens. Besides photographing in-the-moment and sharing the images with my subjects, I also printed over 300 photographs from every Department and Division I'd visited, as well as the "sense of place" shots from around the museum—everything from the reorganization of the coral collection, to a taxidermied tiger on a bank of metal cabinets, to the retired displays under plastic sheeting in the attic [Figure 2-1].

I covered the walls in my small office at the museum with 8"x10" prints, floor to ceiling, and during interviews the wall of images provided unexpected prompts for recollections about people's histories in the museum, how they'd seen collecting practices change, or moments in the life histories of specimens they were particularly connected to, or even questions about other parts of the museum and its collections they had never seen during their decades of working there [Figure 2-2]. Many chose photos from other Departments and Divisions—curious about the exotic "other" inside of someone else's collection cabinets. In my adjacent role to a wide array of Divisions and Departments, I was able to gain access and engage with collections and their collectors in ways staff members rooted in their own departments were not, and I found myself explaining collections and specimen preparation methods "sideways" across these boundaries.

The photographs were key to these boundary crossings of sharing knowledge and experience. Visual anthropology, as Christopher Pinney (1997) has pointed out, surfaces key components to documenting local knowledges and technologies, and renders visible the hierarchies of who knows what, who is permitted to share that knowledge and in what ways. My experiences in the museum with my camera bore witness to this, particularly during my apprenticeships to a variety of specimen preparators, as my view of the process was "curated" to a lesser or greater degree.

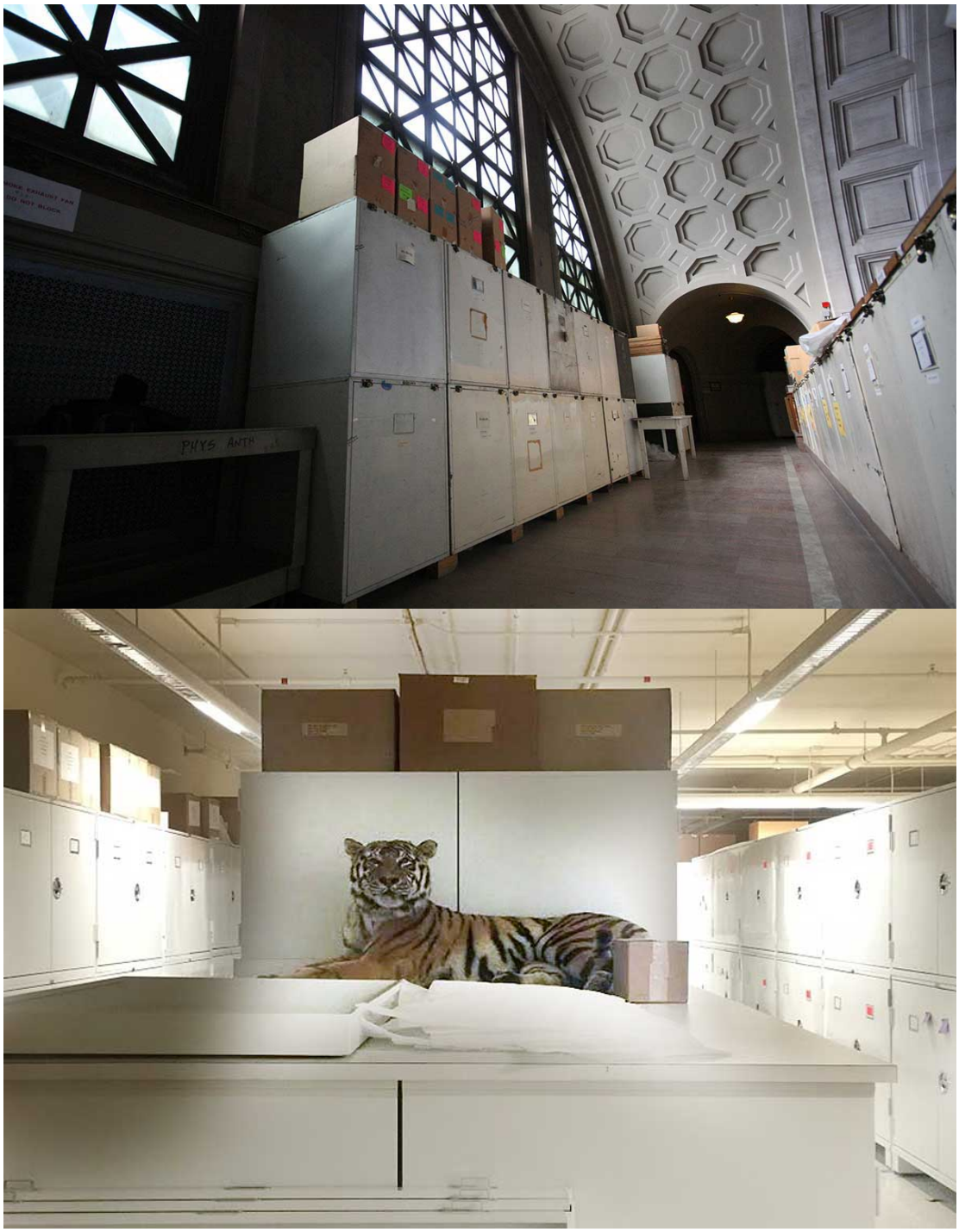

Figure 2-1. In the backrooms of the Smithsonian NMNH (August 2014)

Figure 2-2. Photographs from my fieldwork displayed on the walls of my office.
I kept the door open and passers-by would come in and share thoughts and histories.
(Smithsonian NMNH, August 2015. Photos: William Francis)

The photographs I took of material culture displays served yet another purpose as a source for creating line drawings with a key to the objects displayed, a literal visual index to the assembled objects. In Frederick Ratzel's *History of Mankind* (1896) a series of plates in the multi-volume work caught my eye—color plates of arrayed material culture, such as "Turkish and Mongolian Fabrics and Ornaments," (1896:326) or "Malay Fabrics and Weapons" (1896:100) [Figure 2-3], were displayed opposite line drawings, every piece circumscribed and labeled in the adjoining key. With a long history embedded within "readings" of material culture, this trope of display is still used in contemporary museums as a visually efficient way to communicate details about objects in display cases.

As I continued to photograph operational sequences and assemblages of specimens and specimen-making equipment I decided to adopt this method of abstracting my own photographs, as a way of "redrawing anthropology" (Ingold 2011b). I did this as a way to both interrogate the objects in question as I collaborated with museum staff to correctly label items, and as a way to visually and conceptually embed my own documentation of museum genomics in longer histories of material culture representation [Figure 2-4].

Returning to the concept of photographs as "fossilized moments of time" (Benjamin 1979; Bishop and Cubitt 2013; Burgin 1982; Edwards 1992; Mead and Bateson 1977), I also took this as a way to think through the ethnographic episodes in this dissertation. Inspired by what has called an "ethnography of the present" (Hastrup 1990:45; Sanjek 1991:613), I chose to present my ethnographic encounters in the present tense, as a way to both evoke the immediacy of my experience and have the descriptive text map as closely as possible to the photographs of those captured moments. Creating an "ethnography of the present" also highlights the inherently constructed aspect of any ethnographic endeavor (Clifford 1986; Comaroff and Comaroff 1992; Marcus 2008; Marcus and Cushman 1982; Okely and Callaway 1992; Sahlins 1993; Sperber 1985). While I narrated my experience through various spaces, practices and exchanges I was also aware of carefully framing what I choose to leave in the ethnographic narrative or in the camera's frame. As I came to learn over the course of my fieldwork *what is left out*—of the narrative, the frame, the specimen, the tissue tube, the data set—is just as important as *what is left in*.

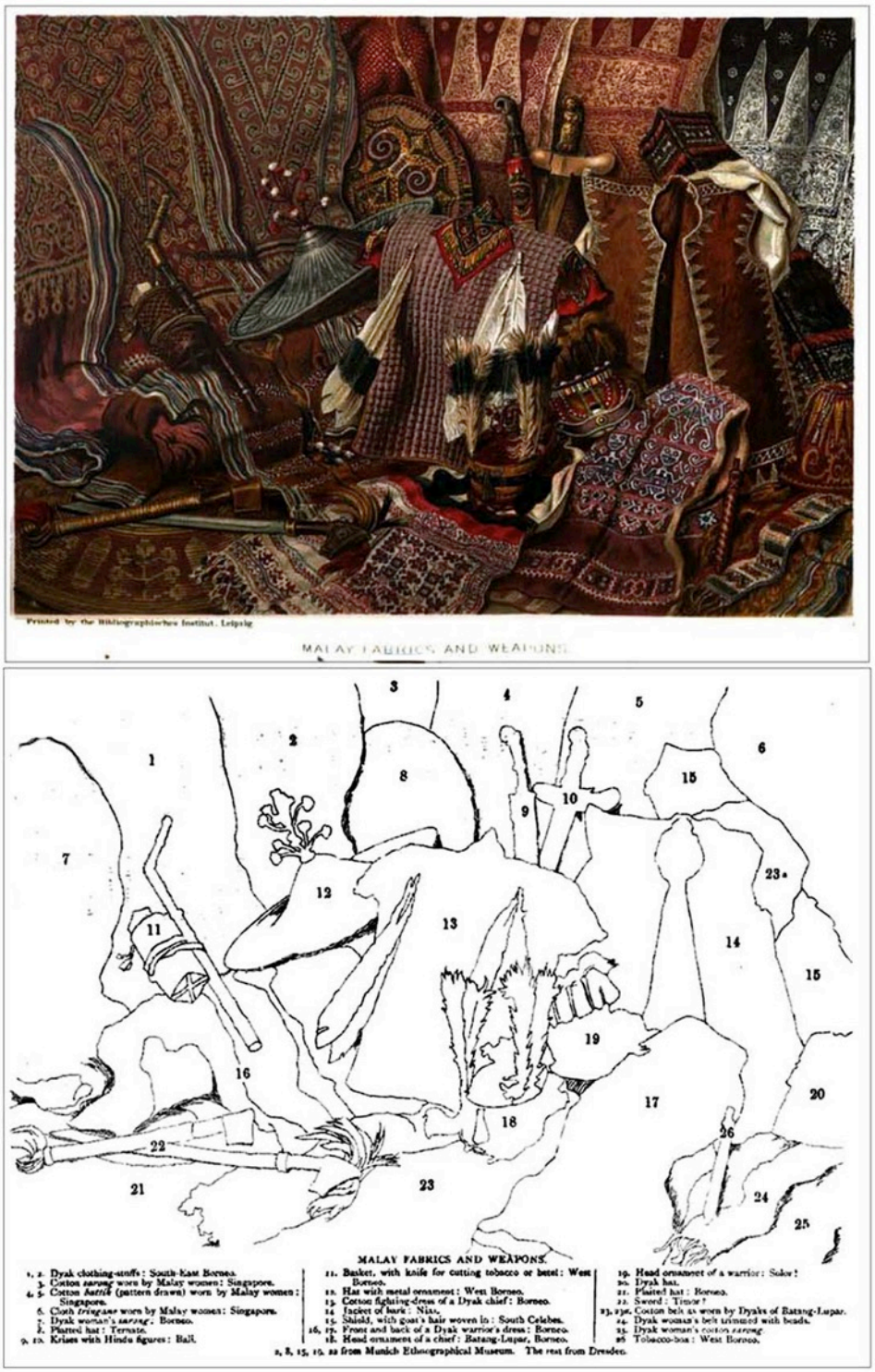

Figure 2-3. “Malay Fabrics and Weapons” in Frederick Ratzel’s *History of Mankind* (1896:100).

Figure 1 Items in the specimen preparation kit: [1] Cigar box; [2] Cotton wool; [3] Superglue, bottle with precision applicator tip; [4] brush for removing corncob "dust' from feathers; [5] tissue tube; [6] Sharpie for marking tissue tube with collection number; [7] measuring tape; [8] cotton thread; [9] sewing needles; [10] scalpel blades; [11] identification tags, pre-strung with thread; [12] pointed scissors, medium; [13] pointed scissors, small; [14] round-tip scirssors, two pairs; [15] plastic ruler, marked in mm; [16] scalpel; [17] pointed tweezers (one featherweight), four pairs; [18] angled tweezers; [19] wooden dowels and bamboo skewers, to use in wings and as "backbones" in smaller birds [Photo and illustration by author].

Figure 2-4. A photo and line drawing illustrating the specimen prep kit I used in the Division of Birds, (from Chapter 6: BOUNDARIES/BIRDS, Flight Paths in the Museum).

The Lives and Afterlives of Collections

The concept that objects as well as persons are composed in relation to one another, living and moving through social lives, is useful for examining the creation, movement and negotiated value of genomic collections. By demonstrating that objects move between different cultural spaces and multiple regimes of value, Arjun Appadurai (1986a) argues for a recognition of these circuits of value as biographical constituents of objects. By highlighting the embodiment, by biological specimens, of multiple regimes of value I want to acknowledge the layering within the object of past, present and future social lives as they shape the forms of value that reside within them.

My examination of the social lives of specimens, tissues and data fits within the already productive convergence between science and museum studies, exemplified by the work of scholars exploring on the afterlives of museum menageries (Alberti 2005, 2008), the symbolic relationships of objects, people and natures (Munn 1986; Pearce 1994c, 2010, 2013), in the disciplinary structure of museums (Bennett 1995), the circulation of material culture in and through museums (Alberti 2011; Bell 2013; Gosden et al. 2007; Joyce and Gillespie 2015; N. Thomas 1991), and how natural order is created and classified (Ingold 2011a; Daston 2004b; Daston and Galison 2007). Their work explores museum objects in biographical terms, as mobile, polysemic and transformative of institutional and human relationships. Each of the authors mentioned above—and each in a different way—argue that artifacts harbor political, social and ethical visions, which in turn stretch out to connect and take part in a playing out of the world. In using their work to begin to frame the production and movement (that is, the assemblage and circulation) of specimens, frozen tissue samples and genomic data I seek to bring attention to the multiple lives and afterlives of collections.

Attention to the multiplicity not only between but also *within* objects, as brought about in part by the changing (human, material, epistemic) relationships in which they participate, raises many important questions. These concern what kinds of practices might play a role in the shifting epistemic (what is knowable) and "ontological"[22] (what is taxonomically namable) nature of biological specimens (Bowker and Star 1999; Clarke and Fujimura 1992; Latour 1999b).

[22] I use "ontology" in this particular context to reference different naming strategies used by natural history taxonomic communities (Latimer and Miele 2013; Leonelli et al. 2011; Nadasdy 2007), a usage that derives from a long history of specimen-as-data, which I detail further in Chapter 3: *Crafting Data, Standardizing*

Things and people are constantly engaged in what Karen Barad (2007) has called "intra-action," continually undergoing change and refiguring their subjectivity, value, and possibilities for agency: “Matter,” writes Karen Barad, “is substance in its intra-active becoming—not a thing, but a doing, a congealing of agency" (2003:822). Following this line of thought, genomic collections in museums embody multiple kinds of significance, telling complex biographies which are both generative of—and witness to—vitally different possibilities for the orderings of “nature.” It is these possibilities, located in the material transformations of the specimens, which need to be perceived as a vital component of the object’s biographical structure. This requires identifying and following specimens as they travel and are transformed by different processes, “makers” and “users” in their movement between different sites, communities of practice and epistemic expectations. In doing so specimens become invested with different kinds of classificatory value as they stand for, or “tag,” varying accounts of “natural order.”[23] From laying out a conceptual framework for examining how value is created as specimens are assembled and circulated, I now turn to the various cultures of natural history in the genomic museum, locating them in longer histories of collecting and classification.

Biodiversity. In anthropology and philosophy, “ontology” defines *a way of being*, not merely *a way of being named*—though one might argue that there have been recurring slippages between naming and knowing throughout the various histories of science (Viveiros de Castro 2009; Kohn 2013; 2014).

[23] “Tag” is Charis Thompson’s characterization of the ability of Kenyan elephants to stand for “competing philosophies of nature” (Thompson, 2002).

Chapter 3
STANDARDS / DATA

Crafting Data, Standardizing Biodiversity

standard—an idea or thing used as a measure, norm, or model in comparative evaluations. From the Middle English *standard*, denoting a flag raised on a pole as a rallying point, later used as the authorized exemplar of a unit of measurement.[24]
data —plural of datum, a single piece of information, an item of data. From the Latin *dare*, a thing given.[25]

One person's data is another person's noise, and knowing which is which in any particular instance is not a simple matter. . . Indeed, what's noise today may be viewed as important signal tomorrow.
— K.C. Cole (1997:40)

This chapter examines the problem of transforming life into data, looking to the standardization processes of making specimens from different disciplinary histories fit into a single schema. In the introduction I examined the shifting value of natural history collections and their articulation as untapped resources, looking at the conceptual framing of collections as "biological libraries," that is, as sites to extract data relevant for fields such as agriculture, national security, disease control and as storehouses of knowledge for biodiversity conservation. One aspect of conservation is preservation, which I argue can be understood as a return to eighteenth century encyclopedic collecting now utilizing contemporary genomic tools. Frictions between these two orientations—to conserve for future use or to preserve in perpetuity—are brought into focus through the specific practices of crafting data standards for genomic collections, which I turn to in this chapter.

First I examine the contemporary standardization of biodiversity to make it "knowable," computable and sharable, examining the Global Genome Initiative's creation of a "genome-quality" tissue standard. This leads me to look at longer histories of specimens-as-data within the museum. Tracing back to seventeenth century cabinets of curiosity, I examine how every age has been one of "data deluge," faced with the challenge of incorporating new categories of "life" into existing classification systems. Following these histories of standardizing

[24] Online Etymological Dictionary (http://www.etymonline.com/index.php?term=standard)
[25] Online Etymological Dictionary (http://www.etymonline.com/index.php?term=data)

biodiversity in museum work, I connect on-going debates on creating a "biodiversity commons" data standard to the friction of and flow of biodiversity as specimens move into the National Museum of Natural History collections—points in a trajectory towards organizing biological life into an abstracted open-source project.

Through exploring the reassessment of natural history collections as untapped resources, as biological libraries of "life's code" and as the setting for the standardization of biodiversity data, I examine the drive to create an entire corpus of human knowledge of life through the Global Genome Initiative (GGI). This urge to archive all life connects issues of care for biodiversity, as well as its potential loss—as taken from one specific and culturally situated perspective, a perspective that fundamentally orients collection and preservation strategies. I consider the way that the biodiversity biobank-as-archive holds together particular ideas about future orderings of nature and culture, and facilitates new collaborations around the "unbound" biological objects in its care. This leads me to ask: How has molecular biology caused a re-evaluation of natural history collections? For what purposes and what audiences, or "users"? And finally, how has this shift in viewing life as reducible to data oriented the encyclopedic collecting projects such as the GGI? To begin to answer these questions I turn to the histories of classification in the museum, examining type specimens and vouchers.

Red Labels, Red Ribbons, and Wooden Blocks: Type Specimens, Vouchers and the Urge to Archive

Anthropologists, sociologists, and historians have long been fascinated by human classification practices (Bowker and Star 1999; Daston 2004b; Durkheim and Mauss 1963; Ellen 1993; Lampland and Star 2009; Needham 1979). There is perhaps an idea that classifications of things do not in themselves exhibit a preexisting logic in nature: rather they are of cultural origin and perform cultural roles and meanings, even while reflecting systematic attention to selected qualities or orientations in nature. The relationships between classes, from this perspective, are not simply to do with the correspondence between the world and the classificatory scheme but also concern the collective construction of meaning (Bowker 2005a; Durkheim and Mauss 1963; Foucault 1966). Such processes also need to be interpreted historically. While making collective meaning through classification continues across cultures (Bleichmar and Mancall 2011; Levi-

Strauss 1966), it also changes in materials, forms, and the details of how a classification system is “anchored” over time. This includes, in my particular context of the contemporary natural history museum, the “anchors” of red labels and ribbons marking (one might argue, ritually adorning) particularly precious type specimens. This is in contrast to the debates over what counts as a “proper” voucher specimen—another form of anchor—for tissues, DNAs and the genetic data derived from a specimen.

In her essay on the history of naming the diversity of life-forms on our planet, historian of science Lorraine Daston (2004) explores precisely this point of type specimens and the standardization of naming protocols. Daston describes the fear afflicting eighteenth- and nineteenth-century plant taxonomists, for example of the catastrophic confusion that could be wrought by the proliferation of different names for the same plant species or genus - a confusion known within taxonomy as “synonymy.” The urge to discover unity in nature has been a defining epistemic and normative feature of scientific modernity, and this fear—of a bewildering lack of correspondence between names and kinds—continues within contemporary taxonomy. Daston describes how taxonomists negotiate the tension between, on the one hand, keeping names for organisms stable (and therefore able to be collectively known and understood) and, on the other hand, allowing for change in naming and classification, as understanding of species, their boundaries and their relations developed. This tension has to be actively managed through collectively agreed conventions, such as the “type specimen,” designed to maintain a stable, collectively understood connection between a scientific name and a “natural” kind. The ontological status of specimens (and their vouchers) as they speak for order is not something that can be assumed based on the National Museum of Natural History's genetic voucher debates, but is something that is worked and reworked to achieve its "natural" status. The patterns taxonomists divulge through close and lengthy examination and comparison of different organisms, if they are presented to the taxonomic community (and society) as a credible theoretical classification, require material guarantors against which research can be assessed and calibrated. This evidence takes the form of "voucher" specimens deposited and preserved in permanent collections the world over. In the nineteenth century, naturalists agreed that a "type specimen,” the first specimen used to describe a species, would define the species, whether it happened to be typical or not (Daston 2004b).

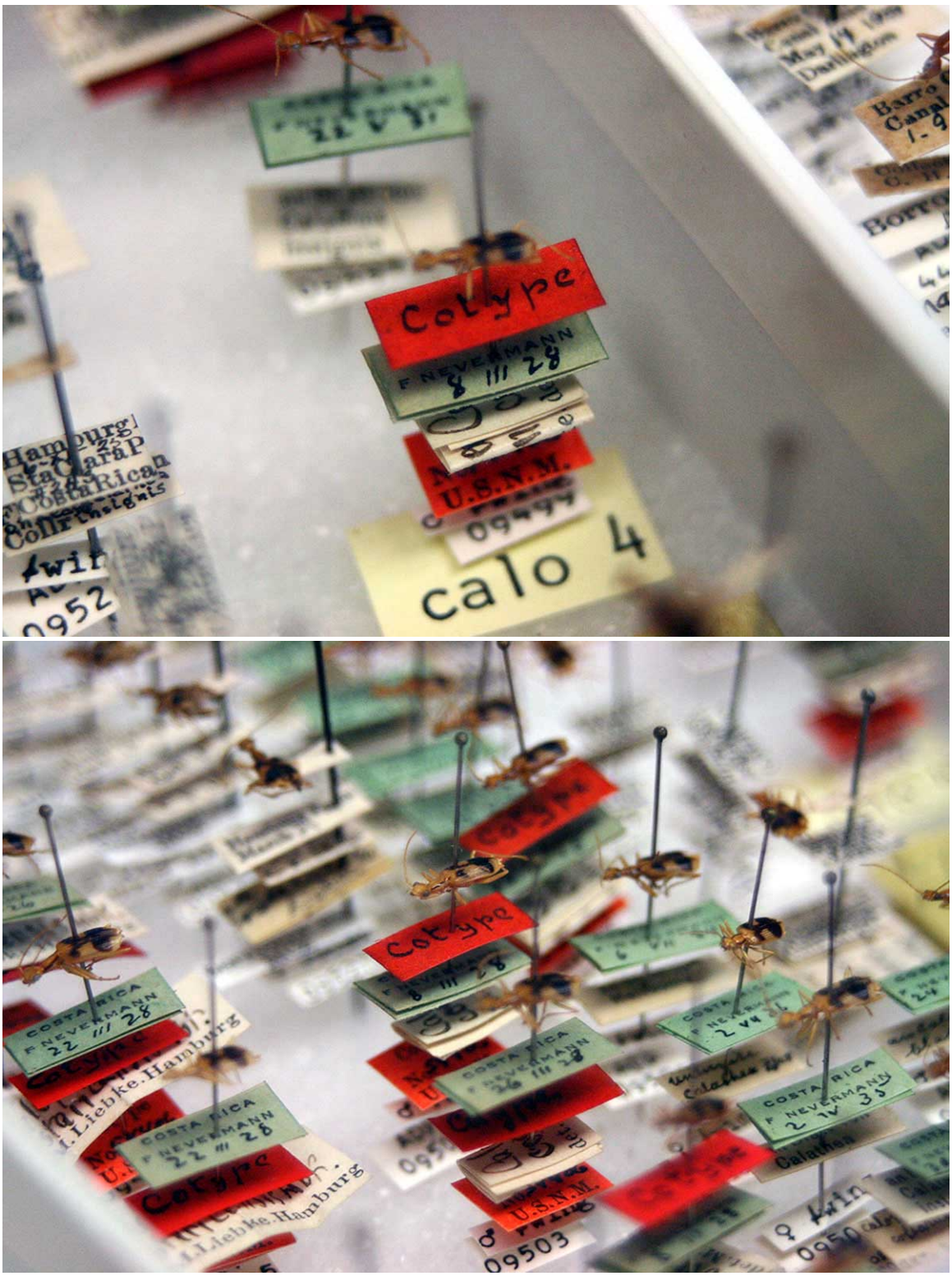

Figure 3-1. Type labels on pinned beetles (Smithsonian NMNH Department of Entomology, June 2014)

Figure 3-2. Type specimens with red ribbons (Smithsonian NMNH Division of Fishes, February 2016)

Figure 3-3. Type specimen block placeholder for *Cacatua sulphurea abbotti* (USNM 181453)
(Smithsonian NMNH Division of Birds, February 2015)

Figure 3-4. Box of discarded type specimen blocks
(Smithsonian NMNH Division of Birds, February 2016

A history of the characterization of "type"' specimens – those specimens which serve as the permanent reference point for a classified organism's name – has been described as one sign of the rigor and discipline which have characterized the taxonomic sciences since the mid-nineteenth century (Daston 2004b). “Type specimens,” as Lorraine Daston observes, “are not typical” (2004b:158). Indeed, the special nature of these specimens was signaled in the materials of the collections with red labels on type specimen cabinets, red labels on the dry specimens in drawers and red cotton ribbon tied around the alcohol preserved specimens in jars [Figure 3-1, Figure 3-2]. Separated from the rest of the collections, the type specimens are locked away with collection managers and curators holding the keys. The "holes" left in the collections are traditionally filled with wooden blocks, plain, unfinished pieces of wood about four-inch long with a paper label glued to the top [Figure 3-3]. This proxy type specimen keeps the sequence in order, the taxonomic chain complete and unbroken [Figure 3-4].

For taxonomy then, the value of biological specimens and the natural order(s) they are taken to represent are upheld by meticulously observed chains of connections vitally linking the specimen to information, to nature and back again. These connections are built from data–data that is derived from the materials of the specimens themselves, from what is preserved versus what is discarded. Each discipline values and discards different pieces, as seen in one of the parasitologists I worked with defining her "field site" as the intestines of birds, part of the specimen that would have been thrown away by the ornithologists (more on this in Chapter 5: Boundaries/Birds) [Figure 3-5]. Despite the fact that the classification of nature has been widely acknowledged as a quintessentially human activity (Foucault 1966; Levi-Strauss 1966), and one closely associated with and shaped by hopes for its protection and exploitation (Hayden 2003a; Hornaday and Walcott 1914; Lowe 2006; Richards 1993; Spary 1996; K. Thomas 1991; N. Thomas 1991; Tsing 2005), the taxonomic sciences were, arguably until 1992, perceived as a rather esoteric set of knowledge-generating practices somewhat disassociated from the more urgent needs of society. One consequence of the signing by over 150 nations of the Convention on Biological Diversity (CBD) in 1992 was an unprecedented focus of global attention upon the significance of taxonomic knowledge as an underpinning prerequisite for the protection of an ever-dwindling global biodiversity. The United States, it should be noted, was not one of the signatories of the CBD, though the "best practices" of the collecting and curation of the Smithsonian's natural history collections,

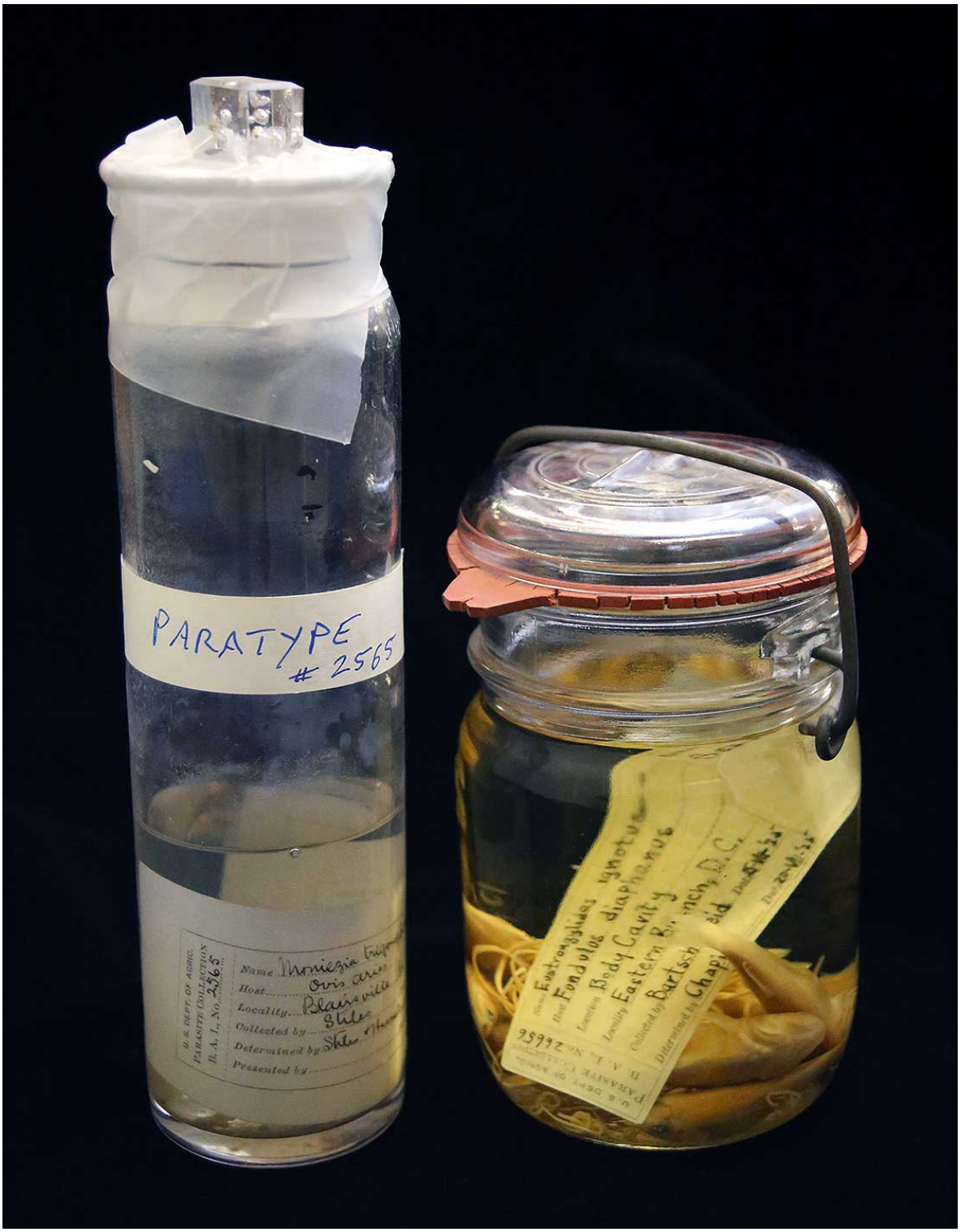

Figure 3-5. Alcohol-preserved parasite “paratype” specimens
(Smithsonian National Parasite Collection, July 2015)

I was assured by everyone from collection managers to the Assistant Director of Collections, the Head Register of the NMNH Carol Butler, that "it's not only the legal thing to do, even if we aren't a signatory, it's the right thing to do" to follow the Convention on Biological Diversity and the Nagoya Protocol. Biodiversity, then, is shifting from being defined simply as a network of all living things to being defined as a (continually emerging) network of interests negotiated between nations, institutions and individuals. Museum collectors are but one stakeholder in this web.

Extending the Collections: Capturing Genomes

"If you take the entire living biosphere, that's the assemblage of 20 million species or so that constitute all the living creatures on the planet, and you have a genome for every species, the total is still about one petabyte, that's a million gigabytes - that's still very small compared with Google or the Wikipedia . . . And somehow mother nature manages to create this incredible biosphere, to create this incredibly rich environment of animals and plants with this amazingly small amount of data."
— Freeman Dyson (1999:112)

January 2016. Another snowy afternoon, now a year after the Smithsonian Institute for Biodiversity Genomics (SIBG) launch at the Castle. I'm sitting in the conference room across from the Laboratories of Analytical Biology (L.A.B.) at the Natural History Museum. It's a long thin room with a large flat screen monitor at one end. Half a dozen of us are sitting at the table, all heads turned towards the images on the monitor—two DNA gels. [Figure 3-6]. Rows on either side of the images are the "ladders," the positive controls that let you know you've run the process successfully and what you see in between the controls is what you have to work with. It is a matter, I come to learn, of contrast. The darker the small square smudges down the "lanes" of the gel, the higher the molecular weight of your DNA and therefore the higher the quality [Figure 3-6].

The goal of this meeting was to finalize a paper titled "Capturing Genomes," a protocol for how to measure the quality of the DNA in one's collections—be they collections in the NMNH Biorepository or one of the (at last count) thirty-four

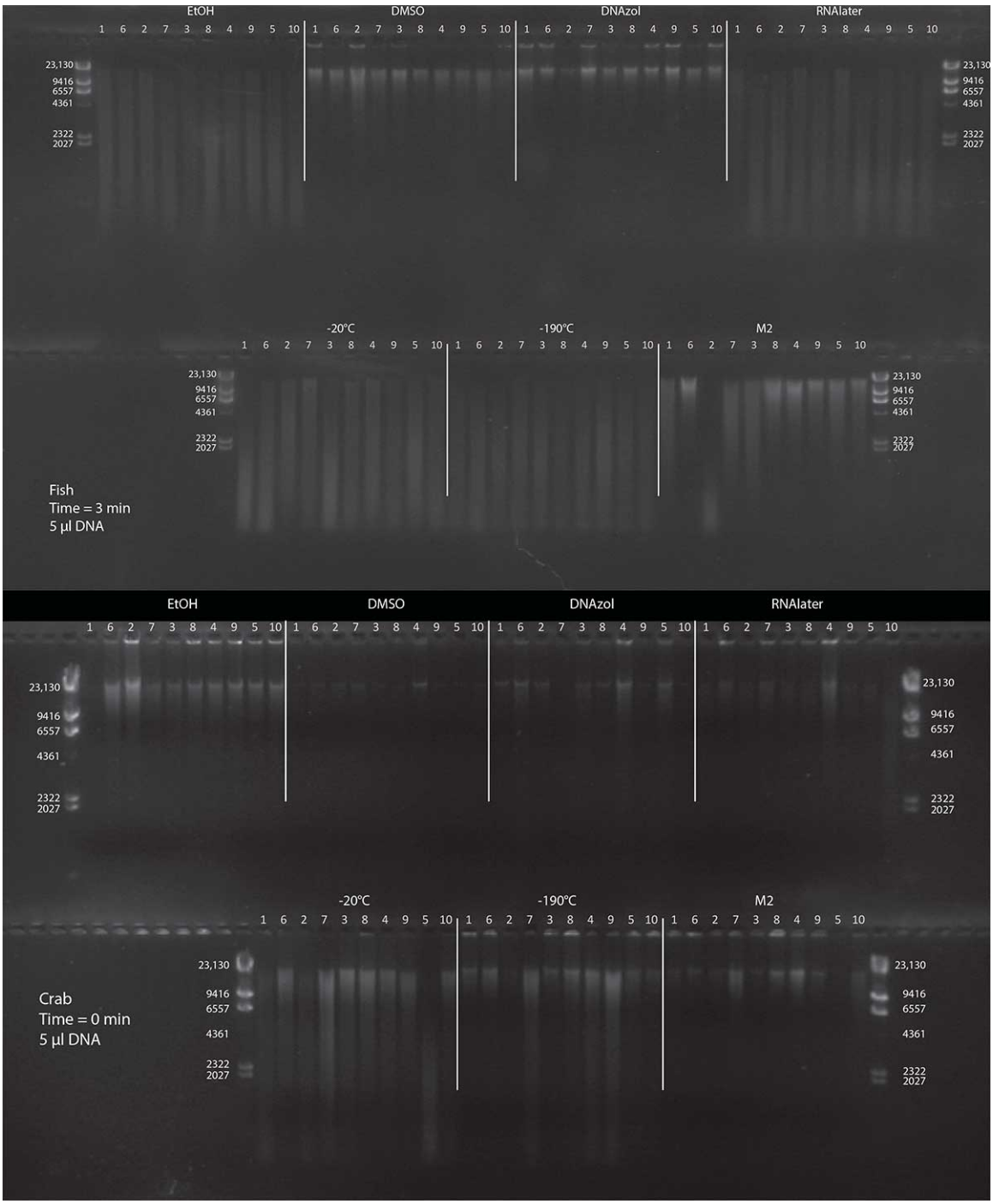

Figure 3-6. Capturing Genomes: Fish and Crab DNA gel images
(Smithsonian Laboratories of Analytical Biology, January 2015)

collaborating institutions worldwide, a distributed collection and preservation program: the Global Genome Biodiversity Network (GGBN). The Capturing Genomes paper had been through many iterations, and was a core piece of the puzzle for the GGI to move forward with its goals—a standard was needed to determine the quality of the collections being made in the GGI's name, and across the other collecting activities of the GGBN. Since the GGI's stated purpose is "Preserving and Understanding the Genomic Biodiversity of Life on Earth," it was key that what was being collected and preserved was in fact "genome quality." Precisely what determined "genome quality" was under scrutiny as well, and went through a number of iterations, but the "working answer," as one curator put it, was to settle on a DNA fragment length of 9kb (kilobase pairs), "for the time being," since "things change so quickly."

The meeting today was to go over the remaining issues about the paper. These included looking at the gel images that had been run by the GGI lab tech, Dan Mulcahy, of a fish and a crab—the two test cases for the paper. And then there was the issue of vouchers—the specimens that would go into the collections as the reference for the tissues of the fish and the crab. For now, we collectively stared at the screen, looking at the smudges of black and gray on the DNA gel with furrowed brows. The gel images were not as hoped, and there were many wrinkled foreheads. The paper was overdue, but the results from the gels didn't seem viable.

But first, a little background on the how and why a DNA gel is made.

Agarose gel electrophoresis is used for separating DNA fragments by their size and visualizing them for analysis. It is a commonly used diagnostic procedure in molecular biological labs, and has the benefit of being relatively cheap and accessible. The technique of electrophoresis is based on the property of DNA being negatively charged at neutral pH due to its phosphate backbone. When an electrical potential is placed on the DNA it will move toward the positive pole, and the rate at which the DNA will move toward the positive pole is slowed by making the DNA move through an agarose gel. A buffer solution mixed with the gel maintains the proper pH and salt concentration. Mixed together the hot buffer melts the agarose gel and is cast into a plastic well plate. "Combs" are inserted into the gel while still wet to forms "wells" for the DNA to be pipetted into once the gel has cooled and solidified to the consistency of "old Turkish delight" as one lab tech described it [Figure 3-7]. The agarose forms a porous lattice in the buffer

solution and the DNA must slip through the holes in the lattice in order to move toward the positive pole, slowing the molecules down. Larger molecules are slowed down more than their smaller counterparts. As a result, a mixture of large and small fragments of DNA that has been run through an agarose gel will be separated by size. Indeed, as I periodically checked in on the gels I ran in the L.A.B., I could clearly see the bands of low molecular weight move (relatively) quickly through the gel while high molecular weight bands moved slowly. In the wells on either side of the DNA being "run" molecular weight markers are put in place as positive controls—a "ladder" of DNA fragments of known molecular sizes that are used as a standard to determine the sizes of the unknown fragments. After "running" a gel, the DNA is stained with a fluorescent dye (the traditional, and highly carcinogenic, ethidium bromide was replaced by "gel red" during the period of my fieldwork) and a photograph of the finished gel is taken under Ultraviolet (U.V.) light [Figure 3-8, Figure 3-9]. The resulting image is assessed for the amount of "high molecular weight" DNA, that is, DNA fragments that are longer [Figure 3-10]. The unit of measure for DNA is in base pairs (bp) or kilobasepairs (kb)—9kb being equal to 9,000bp, as the prefix kilo- suggests—with the more base pairs the better where genomics are concerned.

As we examined the gels on the screen in front of us, the fish and the crab were pale smudges compared to the ladders. Beyond that, and far more problematically, they were *inconsistently* pale. The process that had been devised for assessing the quality of the DNA from the gel image involved a simple set of steps. First, invert the image so you had black and gray against a white background (instead of the white against black that the U.V. photo capture automatically spit out). Next draw a box around the lane of DNA you were testing using open-source image software called ImageJ, originally developed by the National Institute of Health (NIH) for human biomedical purposes, now adopted by biodiversity biobankers. Finally, convert the amount of light and dark in your selected box into numerical values, selecting a peak which will tell you if your sample is over 9Kb (current genome quality) or not (run your sample again to be sure, and then go collect more).

The trouble with the fish and the crab was their variability—the same sample "run" on two gels, mixed and cast at the same time, returned wildly different results. The general consensus (after a careful recounting of the process to make sure an error hadn't been made), was that the results were unusable.

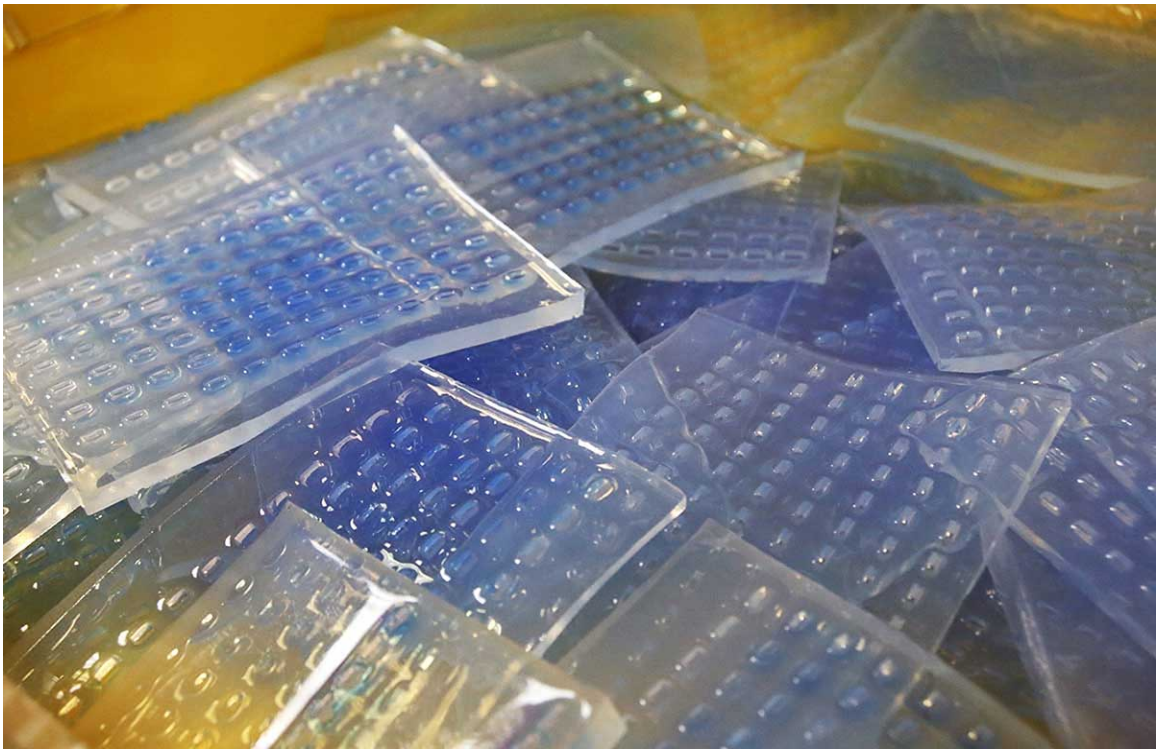

Figure 3-7. Tray of gels discarded after imaging under UV light
(Smithsonian Laboratories of Analytical Biology, June 2015)

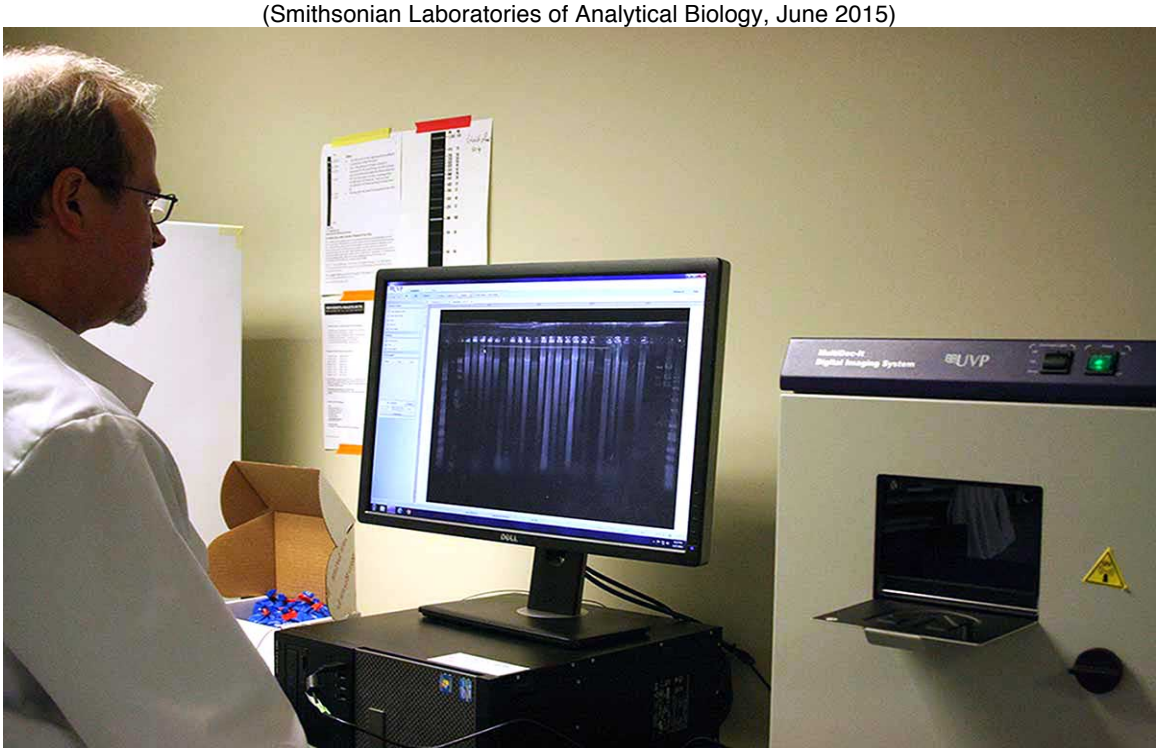

Figure 3-8. Dan Mulcahy photographing a DNA gel.
(Smithsonian Laboratories of Analytical Biology, June 2015)

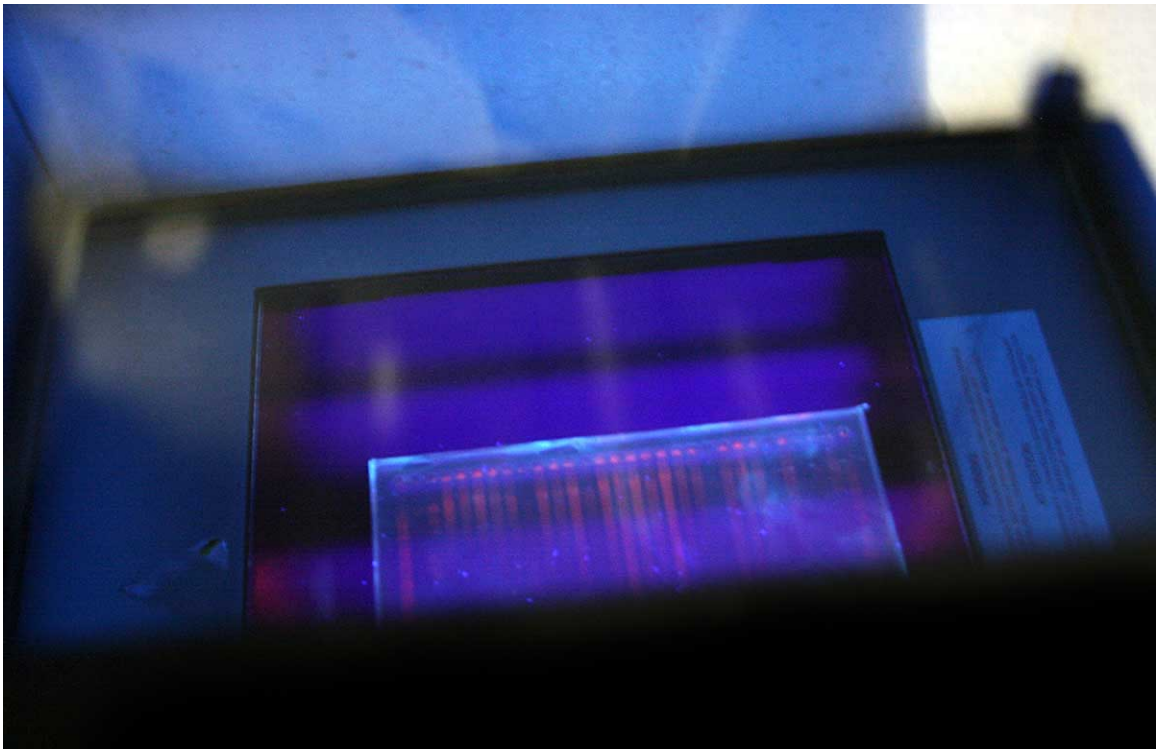

Figure 3-9. A view inside the UV box during imaging.
(Smithsonian Laboratories of Analytical Biology, June 2015)

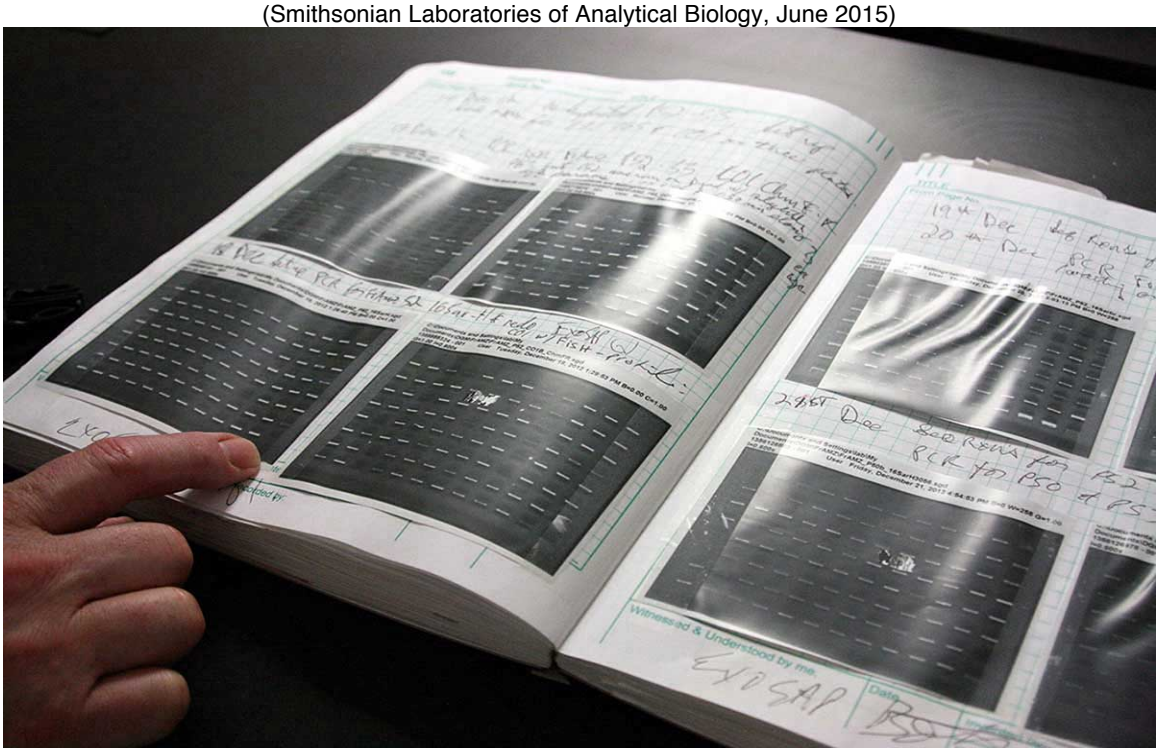

Figure 3-10. Lab notebook with images from gels.
(Smithsonian Laboratories of Analytical Biology, June 2015)

“We’re making a standard for everyone in the GGBN [Global Genome Biodiversity Network] to use, it has to be *rock solid*. “And this isn’t it,” said an Invertebrate Zoology curator. The protocol being put forth in the paper was going to be an addition to the GGBN Darwin Core standard, the results from user’s ImageJ assessments listed in the GGBN public portal as “DNA threshold” and “Percent above threshold,”—not just sideline suggestions but integrated into the collecting practices of the full network of collaborators. Questionable data were not acceptable. Debate ensued, going over the details of the numbers, redoing the calculations, asking what was the best way to standardize against the opacity of the gel, how to equalize the contrast in the image, visiting the possibility of re-doing it all from scratch. Time, funds, labor and accessibility of specimens were all factors against a re-do. Not to mention the need to get the protocol tested and out into the GGBN community. Conversation lulled into silence.

“What’s the standard deviation for the TapeStation?” the Invertebrate Zoology curator asked into the silence. Heads popped up from behind sheets of paper and laptops. More debate ensued, but with a renewed pitch of excitement. This might be a way through. To ensure that genomic DNA is of the quality required, the group agreed, each sample needed to be screened to determine its suitability before committing the time, money, and resources to preserving it in a biorepository, taking up space for its voucher.

Assessing genomic DNA is usually performed by agarose slab gel (as described above). However, “this is a slow, labor-intensive, and manual process that can take several hours, and is in stark contrast to a largely automated, overall experimental work flow,” according to the manufacturers of the TapeStation, Agilent Technologies (Agilent Technologies 2016). Their Genomic DNA ScreenTape is a credit-card-sized device made of three separate polymer layers designed for the separation of biomolecules through a gel matrix in 16 separated channels. Genomic DNA is vortex-mixed with buffer, and then placed in the TapeStation instrument for automated analysis. A “plug-and-play way to get your DNA’s molecular weight” as a lab tech later told me.

In this narrative the traditional agarose slab gel is considered outmoded, slow, and ultimately somewhat unreliable given its handmade quality. However, the very cheapness of the handmade slab gel is precisely what makes it appealing for a global collaboration stretching across institutions with varying amounts of labor, funding and equipment, such as the GGBN. Microwaves to heat up buffer

and melt agarose gel, UV lights, and electricity to run a traditional gel were accessible to those with even limited means. TapeStations were not. A quick scramble as heads bent back to their laptops, clicking away as the variability rates for the TapeStation were looked up from previous projects. “The variability of the results of the fish and crab aren’t really different than the TapeStation,” another lab tech offered up. “I think we’re ok.” The mood in the room swung in a sea change, it was almost jubilant. The details of where and how to word the protocol were nailed down; the process of collating edits and comments into one document organized. Another lull in the discussion, and someone asked, “What about the vouchers?” More silence as we looked at each other.

The original specimens had been collected off the coast of Panama, at the Smithsonian Tropical Research Institute (STRI).[26] This was an efficient way to collect specimens, I was told, with a minimum of permits and paperwork as the research station and collections made within its boundaries are considered *a priori* part of the Smithsonian. “Were they collected before October 14, 2014?” Katie Barker, the GGI Project Manager asks one of the lab techs. He checks the paperwork and nods. “Good, before Nagoya.” She’s referring to the Nagoya Protocol, a piece of international legislature that came into effect during my fieldwork at the museum, a refinement of the Convention on Biological Diversity from 1993. In defining the biowealth sovereign nations and their control over their flora and fauna, it also changed the political topography of moving specimens across international borders.

Specimens were getting much more difficult to get, to move and to keep. The crab and the fish, however, predated the entanglement. Not much of them was left however. Apparently, the fish were collected as “little fish fillets” into a jar of ethanol, and the only remains of the crab was the left claw. “We need a phylogenetically valid voucher somewhere,” Jon Coddington, Director of the GGI says, “at least two tubes in the biorepository, if nothing else. If there’s a claw in a

[26] The Smithsonian Tropical Research Institute (STRI) is a bureau of the Smithsonian located on Barro Colorado Island in the Panama Canal Zone “dedicated to understanding biological diversity” (STRI 2016). Begun in 1923 as a small field station, the current institute’s research activities extend across the tropics. These include STRI’s Center for Tropical Forest Science that uses labeled forest plots to monitor tree demography in fourteen countries located in Africa, Asia and the Americas, and STRI marine scientists conducting a global survey of levels of genetic isolation in coral reef organisms as well as providing fish and crab specimens for the GGI (STRI 2016).

jar in IZ [Invertebrate Zoology], fine, but we need to have these live on GGBN before [the paper] gets published." Heads nod. "Voucherless tissues?" someone asks. "The vouchers are the tissues," he replies, and pauses before adding "for now." The possibility of getting a substitute voucher for the fish tissue is talked about briefly—what's referred to as an allotype, one of the same species (usually verified through DNA barcoding these days, as well as being a visual, morphological match), but not the specific individual that the tissue sample came from.

Population sampling is a common practice in various Divisions and Departments across the museum. For example Invertebrate Zoology collectors often sample various marine creatures in a colony, pickling one whole one as a voucher. Similarly, collectors for Botany take samples from fields of the same plant and then press one full individual as their voucher specimen. The relationship of one-to-many in the collections made in these disciplines runs counter to the one-to-one relationship in other disciplines, such as Vertebrate Zoology. The fish's voucher would just be a bit out of sequence—tissue first and allovoucher second (at some point in the future). Someone suggests putting the jar of "little fish fillets" in the Division of Fishes as the voucher. "It just looks like *meat*," says one of the lab techs with a dismissive note, "why would it go into the Icthyological collections? Just put it in a tube in the Biorepository—that's where it belongs. Meat in a tube." The matter seems sorted. Notebooks and laptops are closed, and we shuffle out, turning off the monitor with its looming glow of DNA gels. They, too, have been sorted into their appropriate category of unexpected results, which though at first considered too variable, were then rendered into results that were *no more variable* than other practices already in place.

Standards were kept, boundaries of acceptability negotiated and maintained, vouchers found or a future slot positioned for them. The fish and the crab were misbehaving, or more precisely the "read" on the molecular weight of their DNA was misbehaving (and certainly their vouchers were misbehaving). However, they were not misbehaving substantially more than the TapeStation or other vouchering methods. Therefore, it was an acceptable amount of "misbehavior" and could be accommodated. Despite their resistance, standards were being crafted to accommodate their idiosyncrasies and make them do the work necessary—that is, provide a method for "capturing genomes" for the Global Genome Initiative and its partners.

The Friction and Flow of Biodiversity: How to Make Life into Data

It is perhaps useful at this moment to stand back and ask what are genomic natural history collections trying to accomplish through collecting—what, exactly, is being collected? Representations of life, or life itself? How do these conceptions of the collection (as authentic original or copy) resonate with collecting practices of mining historic collections or extending them with new genomic samples? "We're essentially asking the same questions as [Charles] Darwin did," said Mike Braun, one of the first scientists at the Smithsonian to do genetic work, a specialist in birds, "We're just asking them with new tools . . . Tools that are changing the Tree of Life in interesting ways."

The same questions asked by Darwin about the relationships between diverging forms of life are, it seems, still being asked in the contemporary museum—but now the answers are being sought with new (bio)technological tools. This leads me to ask how these tools have shaped the frame of reference for collecting practices—are the questions being asked and answered in purely molecular terms? It is only from the perspective that genomes are fundamentally what we are—or to invert Hayden's (2003) argument, it is not just what life *does* , but what life *is*—that makes sense of the project of "capturing" all life's diverging genomes and mapping their differences. Practices of archiving of life in natural history museums have always broken down individual creatures into pieces and parts, such as a skin and a skeleton, an insect and its genitalia. However the move towards molecular specimens shifts these practices into new types of abstraction and disembodiment, transforming individuals into tangled webs of data and matter where subjects become ever more difficult to locate.

As Hayden (2003) further points out, it is not the identification of interests that explains social processes—that is, the explanation that collectors have particular interests in preserving nature as a resource—rather, it is the analytic assembly that combines these interests, materials, values, and individuals. For example, the particular assemblage of nature-making in the museum takes on new meanings as it changes. As it reassembles in response to new contexts or requirements—such as the integration of genomic collecting techniques—the analytic assembly of the biomaterials of specimens, the interests of collectors, curators, preparators and policy-makers, and the values created and perceived all shift according to the new contexts.

This perspective allows the analytical focus to shift from an oversimplified assessment of the traits of a particular project or discipline—such as the view that museums remove and concentrate valuable objects from others parts of the world, to "understand and preserve"—instead shifting attention to the assemblage of interests and materials, to values and individuals. Analyzing these assemblages refocuses the analytical frame onto the work they do for those who use them, such as the museum scientists collecting for the GGI. Interest, value, and material transformations then become ethnographic objects that are actively combined in making and remaking specimens, tissues and data. Such a focus helps demonstrate that, following Marx, "there can be no production of value without processes of subject formation," (Marx 1867; Coronil 1997:6; cited in Hayden 2003:59), and the individuals and communities defined by disciplinary boundaries produced within the museum are seen as products of interest and value themselves. This would include not only the human subjects, I would point out, but also the non-human subjects laid out in drawers, pickled in jars and sampled in tubes. How much material does one need to constitute a subject in these terms? When does the biology unbind, in Helmreich's terms (2009:280), so far that the biological entity is fundamentally transformed? These kinds of questions begin to examine the ways "subjects" are assessed within a particular paradigm, in this case emerging protocols for standardizing biodiversity biobanking.

Standardizing Biodiversity, Crafting Data

From the standardization of “genome-quality tissue” and specimens reclassified into standard categories, I now turn to the contemporary recasting of life as another kind of interconnected network, the tangle of life encapsulated in the term “biodiversity,” a version of life that can be collected and stored in museum collections. This move can be seen as one of standardizing life into comparable and computable units, one in a long history of the modern episteme’s reduction and abstraction of life into molecules—proteins like beads on a string waiting to be unstrung. Defining biodiversity as the interconnected framework within which life thrives or is threatened provides a beginning point.

Biodiversity, a contraction of “biological” and “diversity,” came into common usage in science and environmental policy in the mid-1980s to describe the variety and variability of life on Earth (Cardinale et al. 2012; Dasmann 1968;

Soulé 1990; Soulé and Wilcox 1980). Defined by the United Nations Environmental Program as "the variety of life on Earth, it includes all organisms, species, and populations; the genetic variation among these; and their complex assemblages of communities and ecosystems" (UNEP 2010), it also refers to the "interrelatedness of genes, species, and ecosystems and in turn, their interactions with the environment" (UNEP 2010).

In the intervening thirty years "biodiversity," as both a concept and a research paradigm, has been characterized as being "merely" the collection and cataloguing of biological data of living entities. This perspective provides little towards understanding the relevance of biodiversity data within larger systems of ecological interaction and (human) intervention. These larger systems are framed as being in crisis, with increasing extinctions, threatened by pollution, habitat loss, and the circulation of invasive species—in essence becoming increasingly *vulnerable* and increasingly *valuable*.

Biodiversity, as the planet's precious collection of genetic information, is reframed as being sustained by complex global networks, which moves concerns for the preservation of biodiversity into a broader context of global processes that are mediated locally. As Tsing writes, "The common assumption is that everything can be quantified and located as an element of a system of feedback and flow." (2005:128). By looking to the emerging practices of the Global Genome Initiative (GGI), I was able to track the flow of specimens from country of origin to biorepository, of the increasingly valuable collections of genetic information embedded in the biological containers of plants and animals to a site for preservation. However, this "system of feedback and flow," though informative, was also a form of reduction, one which does a certain violence of interpretation (Baudrillard 1994) to the complexity and nuances of how (global) biodiversity is (locally) biobanked.

During my fieldwork in the museum standards for various kinds of collecting were being created and revised, as seen in the episode of standardizing what, at least for the moment, constitutes "genome-quality tissue" that will be used to "extend" the existing collections. Another set of protocols around destructive sampling of the collections—what many in the museum called "mining"—was also under scrutiny. Though samples had been taken from the specimens in the collections for decades, the quantity of the requests were rapidly increasingly as new "users" with new biotechnological tools "discovered" the collections, looking at them not

as museum collections to be preserved but instead as readymade biobanks for research. According to collection managers I spoke with, requests for destructive samples came not just from taxonomists but increasingly from researchers doing biomedical, agricultural and environmental microbiome projects. As one collection manager told me, “They [the outside researchers] make these [destructive sampling] requests for all our ‘samples’ of a particular species, asking how often we replace our ‘inventory.’ Replace them! . . . They aren’t ‘samples,’ they’re *specimens,* and they have no idea - no idea! - how much time, effort, money, permits, prep time, curation, maintenance, everything that goes into making the collections. . . . We can’t just call up the warehouse and order up more biodiversity ‘samples’ . . . They really just have no idea what they’re asking for.”

This friction between different views of the proper use of a collection was apparent in every section of the museum I worked in, with each Department or Division deeply committed to its own particular view. These different beliefs about the use of collections can be traced not only to the different disciplinary histories—Botany creating and organizing its collections differently from Invertebrate Zoology, for instance—but also, I argue, in the materials of the collections themselves. *Materials matter,* and, further, *materials are made to matter* (Barad 2003)—in this project it is useful to think through the biomaterials of the collections themselves, attending to the capacities and limitations of what the collections are made of.

The Division of Mammals, for example, carefully collects individual specimens, some prepared as a traditional skin with others “pickled” whole in a jar of ethanol. A traditional study skin even on the smallest mammal (a shrew) has plenty of places to take a destructive sample without causing excessive damage to the specimen—a small chip of bone, a snip of dried muscle. However, under current genome-quality tissue collecting protocols, if the specimen is going to be “pickled” in ethanol, a tissue sample has to be taken beforehand. This means the collector has to imagine various future uses for the specimen and its associated tissue samples during the preparation process. In contrast, The Department of Entomology frequently collects large quantities of specimens during their collecting expeditions, filling jars of ethanol with thousands of insects ready to be pulled out, identified and pinned. This means there are (usually) specimens to spare for destructive sampling, though if individuals of the species in question are very small, multiple insects may be needed to get the genetic data required. This

means there will be no voucher specimen, and the one-to-one relationship of individual specimen to tissue sample to data is disrupted.

This highlights one of the current core issues under debate in the museum, namely the creating of standardized protocols so that genomic collections can be made (and be made coherent) across Departments and Divisions, as well as to outside institutions. This move towards standardization required many negotiations between the Administration, genetic collecting projects such as the GGI, and each distinct “culture” in the Divisions and Departments such as Botany, Birds, Mammals, or Invertebrate Zoology. I examine one such debate on “genetic voucher specimens” in the following chapter. For the moment, however, I turn to look at several examples of the different uses made of collections—from toepads to bone fragments, to feather mites—and the different kinds of valuable data these perspectives provide for researchers.

Histories of Specimens-As-Data

As long as the centuries continue to unfold, the number of books will grow continually, and one can predict that a time will come when it will be almost as difficult to learn anything from books as from the direct study of the whole universe. It will be almost as convenient to search for some bit of truth concealed in nature as it will be to find it hidden away in an immense multitude of bound volumes.
—Denis Diderot, "Encyclopédie" (1755)

Museums, even in their earliest forms, have always had to deal with data management – the continued and meaningful association of information to artifact, of data to object. Scholarship in the history of science in particular has demonstrated that perceptions of an "information overload" or a "data deluge" have emerged repeatedly from the Renaissance though the early modern and into the (post)modern periods – each time specific technologies emerged focused on dealing with the perceived overload (Ogilvie 2003, 2008; Rosenberg 2003; Strasser 2012b). "Every age was an age of information," Robert Darnton has written, "each in its own way” (Darnton 2000:1 quoted in Strasser 2012b:85). Bruno Strasser’s (2012b) exploration of the concept of "data" in the sciences, connecting wonder cabinets to electronic databases, explores the similarities and differences between past and present data-driven life sciences, from early modern natural history to current post-genomics.

Most importantly in the context of my own research, Strasser underscores not only continuity in scientific collecting and its accompanying data, but also the centrality of the collections themselves in producing scientific knowledge. Collections are his unit of analysis, charting their movement through historical contexts with an emphasis (similar to his other work on biological data collections and atlases) on the split between experimentalists and taxonomists. However, Strasser's focus on collections used by experimenters and taxonomists treats those collections as homologous units, and I argue his analysis is not attuned to the nuances of their material and social construction nor the on-going negotiations for their use. Perhaps his focus on serological collections has skewed his analysis, as the more stable material properties of blood drops on strips of paper or frozen in tubes is less problematic than some other collections. Egg shells that must be bundled in cotton, pickled whole gorillas in steel tanks of ethanol, whale skulls on custom welded steel boat trailers, or multiple gigabase genome sequences on dedicated servers–these are but a few of the artifacts I encountered that defy the perhaps too-neat-categories of what is dismissed or deemed valuable by experimentalists as opposed to taxonomists.

In charting the role of data as having been always already integral to collections, Strasser demonstrates that Renaissance naturalists were no less inundated with new information than contemporary genomics labs, with the systems of knowledge inherited from Greek and Roman texts expanding and extending as new categories of natural objects began to circulate back to European naturalists from New World expeditions (Strasser 2012b:85). New systems of preserving specimens for longer journeys (Findlen 1994; Kohler 2007; Poliquin 2012; Smith and Findlen 2002) as well as new forms of note-taking, printing (the so-called "paper museums," that is, printed catalogs of collections that circulated where the specimens could not), and classifications systems emerged to organize and manage this data (Ogilvie 2008; Strasser 2012b). In thinking through the global assemblage of genomic collections, it is useful to locate the practices in a longer genealogy of museum collecting (R. J. Baker 1998; Bowker 2000; Leonelli and Ankeny 2012). Indeed, as Strasser points out "natural history has never been free of ontological assumptions." (2012b:85).

The underlying ontologies (both taxonomic and philosophical) that organize the freezers in the Biorepository or the Laboratories of Analytical Biology at the National Museum of Natural History in the twenty-first century share an affinity with the ontologies organizing the sixteenth century cabinets of curiosity. Though

based on different conceptions of nature, each still operates with an encyclopedic view of nature as knowable, namable and ultimately obtainable. In a sense it is a view of nature with one of everything and everything in its place, be it a frozen tube of crocodile heart-muscle-liver representing the family *Crocodylidae*, or the body of a crocodile, stuffed with salt and spices to preserve it and hung from the ceiling of a wonder cabinet, representing a connection through alchemy to the Divine [Figure 3-11].[27] At the National Museum of Natural History a collection of mummified crocodiles classified as "cultural" objects are part of the Anthropology department, while other crocodiles classified as products of "nature" have circulated to the Division of Amphibians and Reptiles, Department of Vertebrate Zoology [Figure 3-12, Figure 3-13, Figure 3-14]. The same biomaterials crafted to hold very different meanings, held in place in their webs of significance (Geertz 1973:21) by the data structures and "natural orders" of the museum.[28]

Cabinets of Curiosity: The Order of Things

Data within the museum has always been a central concern, and I began to think about both natural history and the larger histories of nature in the context of genomic collecting, its data and expanding networks of tissue tubes. What began as studies of local flora and fauna in the sixteenth century Europe was soon complicated and broadened by objects, specimens, and even living humans brought back to Europe from explorations to the New World and traders returning from expeditions (Daston and Park 1998; Findlen 2002; Greenblatt 1992; Impey and MacGregor 1985; Olmi et al. 2001; Pomian 1990). Collecting provided a means to not only to assemble the newly discovered, but to make sense of it—a cabinet of curiosity built in 1648 demonstrates a complete cosmos in miniature combining coral and shells from expeditions with a clock, biblical scenes carved into semi-precious stones from around the world, and a hidden pharmacy with jars carved from African ivory [Figure 3-16].

[27] The crocodile that features so predominantly in depictions of cabinets of curiosity is likely an allusion to the Egyptian origins of the word "alchemy." Following this thread into Egypt, the earliest known accounts of alchemy are in Hellenistic Alexandria. A cult devoted to worshipping crocodiles flourished in the twelfth and thirteenth Egyptian dynasties (1991 BC—1650 BC), centered on the Egyptian god Sobek (Zecchi 2010). Some temples devoted to Sobek maintained pools where sacred crocodiles were kept; these crocodiles were hand-fed meat, decorated with gold, and were ritually mummified when they died (Zecchi 2010: 20).

[28] The "webs of significance" in the museums are many and tangled, if one follows Clifford Geertz's assertion that ""Believing, with Max Weber, that man is an animal suspended in webs of significance he himself has spun, I take culture to be those webs, and the analysis of it to be therefore not an experimental science in search of law but an interpretative one in search of meaning." (1973: 21)

Figure 3-11. Stuffed crocodile skin hanging on ceiling
in the curiosity cabinet of Ferrante Imperato, Naples 1599.

Figure 3-12. Taxidermy crocodiles in storage after removal from a diorama
(Smithsonian Museum Support Center, Reptiles and Amphibians collections, March 2015)

Figure 3-13. Stuffed crocodiles skins in a different kind of cabinet of wonders.
Collected in 1926 in Thailand (*Crocodylus porosus* USNM 72730, 72731, 72732, 72733)
(Smithsonian Museum Support Center, Reptiles and Amphibians collections, March 2015)

Figure 3-14. Type specimen of a *Crocodylus acutus* in storage (USNM 211273)
(Smithsonian Museum Support Center, Reptiles and Amphibians collections, March 2015)

Figure 3-15. Recreation of the museum of Ulisse Aldrovandi, complete with stuffed crocodiles on the wall
(Palazzo Poggi, Bologna, Italy, April 2012)

Figure 3-16. The Ausburg kunstschrank, 1658 (Photo: Getty Collection)

In addition new technologies facilitated the preservation, circulation, and documentation of collections in new ways—such as specimens preserved in alcohol, and an outpouring of books that catalogued, categorized, inventoried and illustrated the collections in printed catalogs that could circulate far further than the stuffed, pinned and pickled specimens they represented (Findlen 1994; Zorach et al. 2005). Massive collections spanning fields of knowledge and new areas of the world were amassed, organized, displayed, and circulated. Laying a claim to the value(s) of biological specimens thus raises a whole range of questions concerning what a specimen can ultimately stand for and forces us to imagine what it might mean to scale-up from a specimen in a mahogany drawer in the sixteenth century or in a liquid nitrogen tank in the twenty-first century to an appreciation of (potentially multiply constituted) "life itself".

Tracing this thread of encyclopedic collecting and ordering of "life itself" back to Renaissance *wunderkammer* or curiosity cabinets offer up to the contemporary eye an array of materials grouped in seemingly haphazard configurations – with animal skeletons, displayed next to minerals, fossils, botanical specimens and ancient sculptures, coins, paintings, scientific instruments, automatons, and the occasional unicorn horn (fashioned from a narwhal tusk). Taking up cabinets of curiosity as an assemblage of objects that have the potential to stand for multiple and overlapping interests casts their impressive variety and number of objects displayed as a means to order nature as well as express political and intellectual prestige.

The *wunderkammer* (literally “room of wonders,” or wonder cabinet of curiosities), was regarded as a microcosm or theatre of the world, conveying symbolically the patron's control of the world through indoor miniaturized reproduction (Greenblatt 1992; Pearce 1993; Pomian 1990; Stewart 1992). Contrary to contemporary views of the *wunderkammer* as a random accumulation, they were instead purposefully constructed according to detailed “views,” and "ways of knowing" (Greenhill 1992; Pearce 2010; Pickstone 2001). Though specific organizing principles varied between cabinets and were driven by the particular vision of its owner, each was governed by the concept that objects had intrinsic meanings laid down during Creation, and that it was possible to reconstitute a "mirror of nature," or "universe in microcosm" through the collection and organization of specific items, which would aid in the ciphering of the divine text (Daston and Park 1998).

In *The Order of Things* (1966), Foucault draws our attention to the concept of "resemblance" and its meaning in the sixteenth century, which is now unfamiliar to us: collections of objects could share affinities, and meaningful proximity, juxtapositions and alignments between objects and arrangements of objects could indicate underlying symbolic resemblance. Curiosities, such as natural objects that mimicked other objects—such as a piece of coral that resembled a miniature tree, or genetic aberrations such as dwarfism or hirsutism—were particularly sought-after commodities, as they were seen to both to increase the understanding of the inherent nature of the world and simultaneously to represent God's divine logic through the "power to alter the course of nature" (Shelton 1994:184). In effect, God had crafted some interesting "prototypes" in His search for a true natural order, and their scarcity matched their value. This valuation of the rare and exotic has echoes in the contemporary biodiversity biobanking of endangered and extinct species—the harder they are to obtain, the more valuable the tissue samples become.

The recirculation of classical learning that shaped and inspired so much of Renaissance culture rekindled interest in Aristotle's writings and methods. In the words of Jeffrey Abt, "What began in the 1400s as a widespread effort to translate Aristotelian texts directly from the Greek and disseminate them through the new medium of printing, evolved by the 1500s into ambitious enactments of his empirical methodology" (Abt 2011:43). The accumulation, study and classification of specimens from nature were among these (re)enactments, often with reference to Aristotle's writings in order to verify or gloss his texts. Spurring these new collecting practices was "the empirical explosion of materials that wider dissemination of ancient texts, increased travel, voyages of discovery, and more systematic forms of communication and exchange had produced" (Findlen 1994:3). In other words, what began as studies of local objects soon became complicated and broadened by objects, specimens, and even living humans brought back to Europe from explorations to the New World and traders returning from expeditions (Greenblatt 1992; Findlen 1994; Smith and Findlen 2002).

Collecting provided a means not only to assemble the newly discovered, but also to make sense of it (Greenblatt 1992), an orientation, I would argue, that holds true for frozen tissue samples in the Biorepository as much as the *de rigueur* stuffed crocodile hanging from a *wunderkammer* ceiling. Distinct from either the royal collections of the treasury or the religious accumulation of saints' relics (both precedents for this type of assemblage), these collections were displayed in

spaces designed and dedicated for display using a systematic arrangement in cabinets, cases, drawers, and other specialized furnishings, often in specially built rooms in the homes of royalty, scholars, and wealthy amateur collectors. New technologies allowed for the preservation, circulation, and documentation of collections in new ways—such as specimens preserved in alcohol, and an outpouring of books that catalogued, categorized, inventoried and illustrated the array of findings, catalogs and inventories on (newly accessible) linen paper.

A variety of terms were employed to characterize these collections, their internal logic, the encyclopedic ambitions of the collectors, their physical structure and setting, and the types of object collected: *pandechion, studiolo, gabinetto, or Wunderkammer, galleria, Kunstkammer, Kunstschrank,* or *musaeum*. The last of these became the most widely accepted and broadly applied term for characterizing this particular form of collecting, whether it be spaces filled with objects or books filled with illustrations and descriptions. Several scholars assert that the use of the term indicated a desire by the collectors to recapture part of the aura of Alexandria's illustrious institution as described in recovered classical texts (Findlen 1989; Weil 1995). For Renaissance scholars, ". . .the trail of words leading from the ancient Greek ideal of the home for the muses, and the campus library of Alexandria, marked the transformation of the museum from a poetic construct into a conceptual system through which collectors interpreted and explored their world" (Findlen 1994:67). This specific joining of objects and inquiry located in architectural and textual spaces was taken up and replicated with increasing frequency, and ever widening encyclopedic breadth, over the course of the sixteenth and seventeenth centuries in Europe. Massive collections spanning fields of knowledge and new areas of the world were amassed, organized and displayed.

Objects are made meaningful according to how they are placed within relations of significance. These relationships, in turn, depend on who is determining what counts as significant. Objects are therefore likely to be spoken, rather than to speak (Haraway 1997). This is not to say that all meanings are of equal value, of the same power, or of the same validity. In relation to objects, meaning is to some extent constrained by material character, but the material character of an object can be given many different interpretations (Ingold 2010; Pearce 1994c).

A narwhal tusk shifting value is dependent on whether it is embedded in a seventeenth century Wunderkammer, represented in a nineteenth century etching for an ethnographic treatise, or rearranged for contemporary audiences in displays of biodiversity conservation. The exotic object in these displays becomes, reflexively, the historical concept itself, where the Renaissance scholar, Victorian ethnologist or the contemporary geneticist become curiosities in of themselves. In turn, the narwhal and its tusk can be seen in their multiple lives—as commodities with imagined lives, as mythical creatures or exotic specimens, and with actual lives as *things in motion* (Appadurai 1986; Joyce and Gillespie 2015), the motion which "illuminate[s] their human and social contexts" (Appadurai 1986:3). The narwhal tusk, in this assessment of its social life, can signify multiply as it moves between temporal and disciplinary boundaries (Bowker and Star 1999).

From Aldrovandi to Linneaus, from Darwin to DarwinCore

Naturalist and professor at the University of Bologna in the mid-sixteenth century, Ulisse Aldrovandi (1522–1605), was arguably one of the first encyclopedic specimen collectors, organizing collecting expeditions and creating the university of Bologna's botanical gardens in 1568 along with his own extensive museum (Castellani 1970:108–110) [Figure 3-15]. Aldrovandi hired various artisans to create a detailed visual catalog in woodblock prints of the more than 11,000 specimens in his collections of *diversità di cose naturali*, or "various natural things," including a narwhal tusk displayed on an elaborate wooden stand. These printed volumes were one of the first "paper museums" that circulated within early modern European scientific communities—the catalogs reaching audiences that Aldrovandi's hand-crafted basilisks and stuffed crocodiles could not (Findlen 1994; Zorach et al. 2005) [Figure 3-17].

These “paper museums” can be seen as an early version of cataloging museum specimen data, a form of analytical chain between original specimen and its derivatives being built and then circulated. Aldrovandi's collection laid the groundwork for systematic collection and organization of the collection by direct observation, and Carl Linnaeus referenced Aldrovandi as the grandfather of natural history (Farber 2000; Schiebinger 1993). This perspective was echoed in

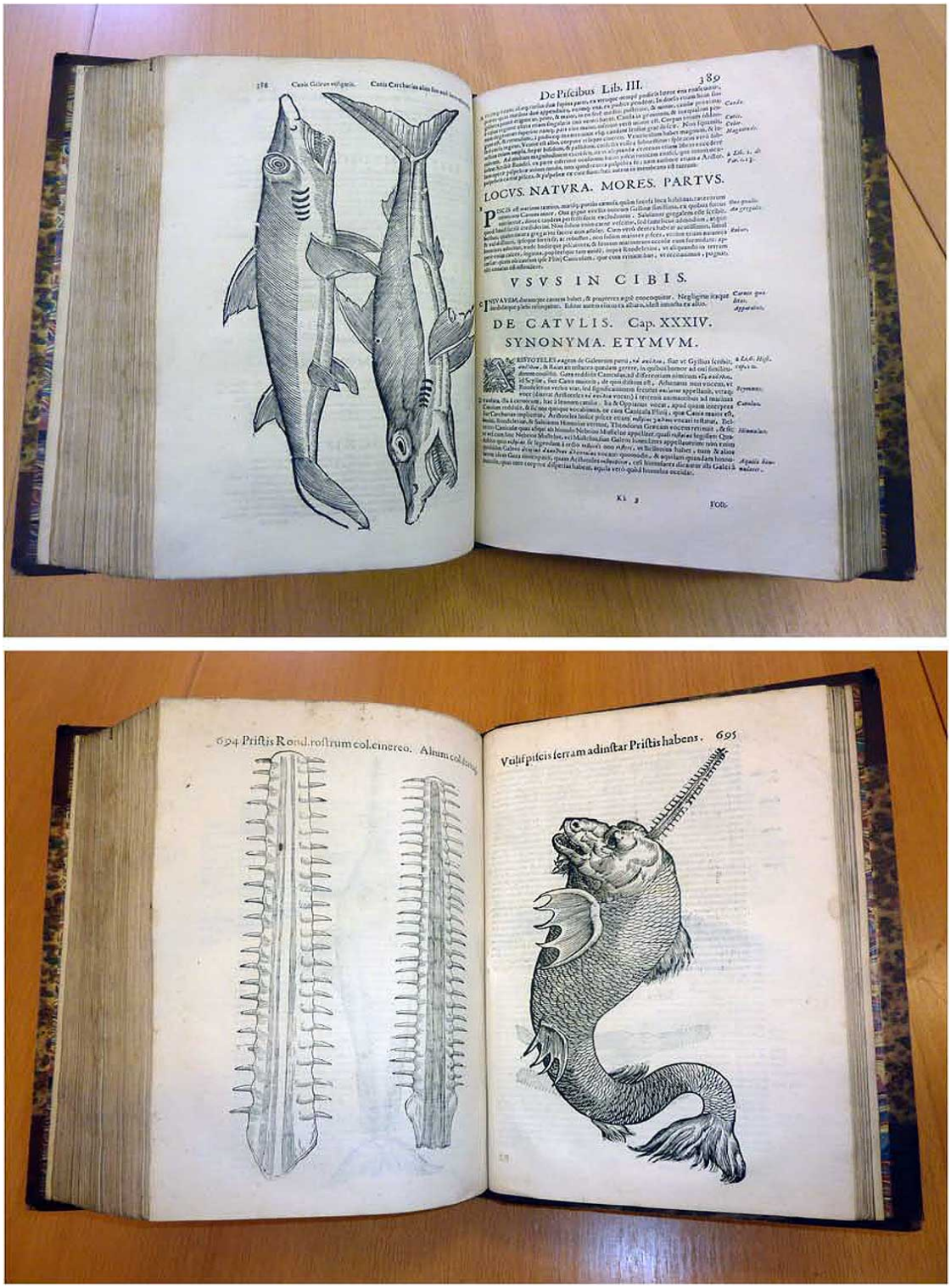

Figure 3-17. Ulisse Aldrovandi, etchings of marine creatures real and imaginary from his museum catalog (Palazzo Poggi, Bologna, Italy, April 2012).

my interviews with systematic biologists at the Smithsonian NMNH, many of whom began their narrative of phylogenetics with a reference to Carl Linnaeus' (1707-1778) formalization of binomial nomenclature in taxonomy, then Charles Darwin's (1809-1882) theory of evolution, natural selection and a common ancestor for all species, followed by Francis Crick and James Watson's description of the structure of DNA in 1953 (Crick and Watson 1953), and finally to their own contemporary "tree-thinking" and the reorganization of the Tree of Life with molecular techniques, including the future potential of emerging technologies such as CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats), a new method for genome engineering (CRISPR/Cas9 Guide 2016; Cong 2013; Lander 2016; Wright et al. 2016).

New taxonomic information is used to extend the aptly named DarwinCore—a body of standards for organizing and sharing "information about biological diversity by providing reference definitions, examples, and commentaries" (Biodiversity Information Standards 2015). The DarwinCore is primarily based on "taxa, their occurrence in nature as documented by observations, specimens, samples, and related information" (Biodiversity Information Standards 2015). The scientists I interviewed detailed their entanglements with reordering taxonomies and frequently underscored the vital importance of their particular branch of the Tree of Life: mammals have their emotional appeal ("how can you compare anything else to a whale?"), birds are beautiful ("in a word: feathers"), insects organize the world ("you know how much insect biomass there is?"), plants are more primordial ("fauna is easy, flora—now that's interesting"), and onwards. The flow of specimens in and through the museum is embedded in these narratives as specimens are divided into pieces, each being valued in different ways [Figure 3-18, Figure 3-19].

Aldrovandi also recorded the names and occupations of nearly 1,600 visitors between 1566 and 1605, though only those whose nobility or reputation warranted documentation made it into the books (Findlen 1991). It is worth noting that prestige, access, and the authority to represent and narrate the meaning of assembled objects continue to be focal points for the creation and conservation of collections. Whether it in the Papal court of seventeenth century Rome or

Figure 3-18. Leatherback sea turtle skulls (*Dermochelys coriacea*, USNM 237702 and 237703) (Smithsonian Museum Support Center, Reptiles and Amphibians collections, March 2015)

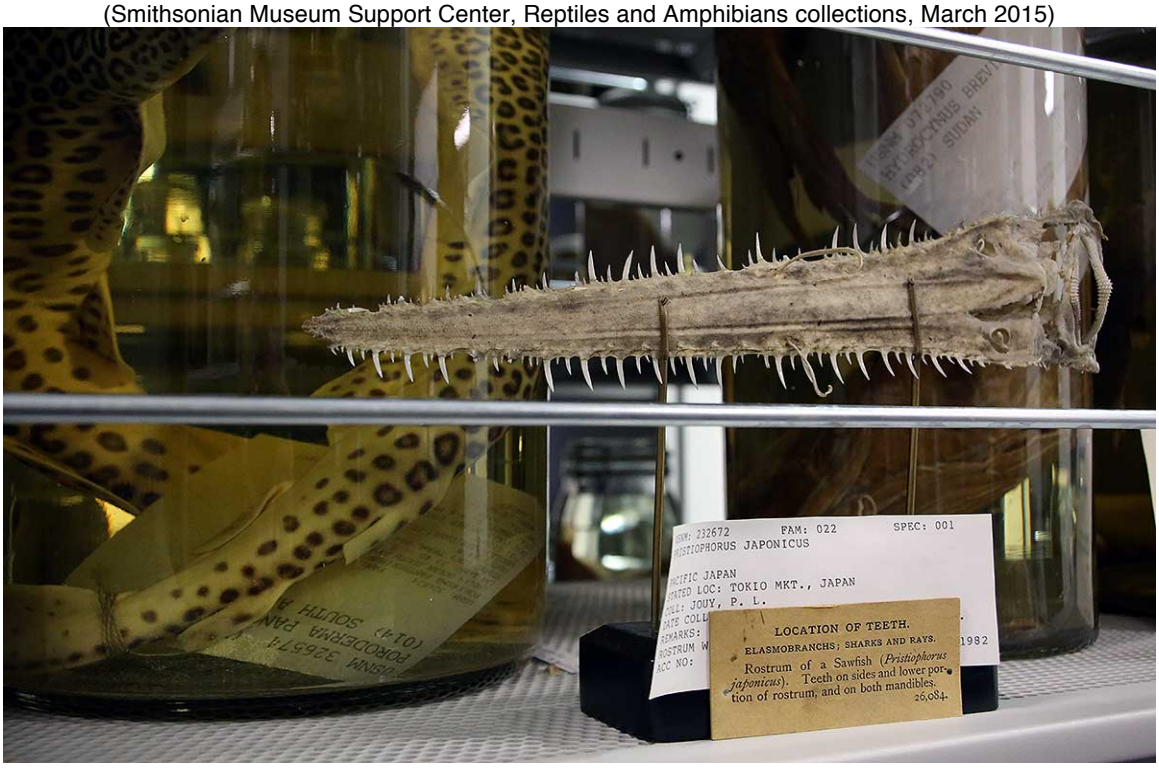

Figure 3-19. Rostrum of a sawfish (*Pristiophoras japonicus*, USNM 233672) displayed much like a curiosity in a *wunderkammer*, one of several such displays used on tours of the collections (Smithsonian Museum Support Center, Division of Fishes, March 2015)

Smithsonian genomics in the twenty-first century, who gets access to the collections and for what purposes continues to be highly scrutinized (Alberti et al. 2014; Bell 2012; Clifford 2004; Karp and Lavine 1991; SIBG 2015). In this vein the "curiosity" of the curiosity cabinet can also be seen as a commodity in and of itself, one used for the promoting a view of the non-European world as an eclectic spectacle to be bought, sold, or created—as well as understood and classified.

Far from being opposed, Pamela Smith and Paula Findlen (2002a) argue that often presumed oppositions—art and nature, objects and their representations, theory and craft, experimental science and alchemy—can all be conceived of as partners in the production of knowledge. Similarly, they argue that physicians, artists, naturalists, clerics, pharmacists, merchants, and princes actively collaborated in the commerce of collecting that swept over Europe in the early modern period. Early modern collectors, as co-producers of consumption, art, and science, engaged in an international market for the finely fabricated hydras and basilisks—avidly sought by European collectors among "other hybrids of the imagination" (Smith and Findlen 2002:128). These were traded not as real animals, but as examples of the "art of invention"—valued based on the skill and creativity of the craftsman (Smith and Findlen 2002:128).

This marks merely one point in the long genealogy of crafting specimens for natural history collections, and foreshadows the forms of hybrids being constructed in biotech labs—such as the attempts to de-extinction a menagerie of long-gone organisms such as the passenger pigeon (Revive and Restore 2013) or the wooly mammoth (Church and Regis 2012; Shapiro 2015; Zimov 2005), along with species of extinct frogs, goats, butterflies, trees and other charismatic flora and fauna that have met an untimely anthropogenic end (National Geographic 2013; Seddon et al. 2014; Sherkow and Greely 2013). Another form of hybrid is created through what I came to think of as "folding time"—where different historical understandings of an object are layered together, such as a historical "unicorn horn" from Aldrovandi's cabinet of curiosities superimposed and folded into the narwhal tusks in the Smithsonian marine mammal collection, both obtained through networks of biological and social relations.

Conclusion: Thinking Through (Formerly Living) Things

The move towards a stable (taxonomic) ontology of biodata and the corresponding claims towards the "data deluge" of contemporary science obscures a much longer history of biological collections as data sources. In other words, current museum genomics recasts natural history collections as sites for mining data. This perspective of "new uses for old collections" does not take into consideration the long history of collections as sites for data extraction—museums have always been "data banks," and each era is one of "data deluge." As the life sciences increasingly become the biggest of Big Data projects (Leonelli 2013a, 2014; Page et al. 2015), surpassing even astronomical datasets (Stephens et al. 2015), it is crucial to contextualize them in a longer genealogy of museum collecting.

The entangled histories of natural history museums and bioscience research can be followed through the divestment and reintegration of lab science in the museum in the early twentieth century to the present, a timeline that also corresponds to the emergence of anthropology as a discipline. However, in this chapter I have looked further back to the origins of the natural history museum, examining the shifting assemblages of specimen-as-data and the global networks of living (and formerly living) things in the first natural history collections in early modern European cabinets of curiosity. In contrasting these with contemporary genomic collecting, I have begun to think through the continuities and ruptures in the material practices of nature-making in museums.

Recasting collections as genetic resources, with different values emerging for different communities or "users groups," underscores some of the issues being negotiated as life is transformed into data within the museum. This raises questions such as: How do museum genomics characterize life? How does it shape collecting practices? How has molecular biology caused a re-evaluation of natural history collections? For what purpose and what audiences, or "users"? How has this shift in viewing life as reducible to data oriented the encyclopedic collecting projects such as the GGI? Museum genomics is the most recent iteration of viewing the natural world as a data set to be collected and analyzed. This perspective has led to many projects that have re-evaluated the collections as sites for mining data for different users, for research from agriculture to national security to disease vectors. It has also been used to map climate change, habitat loss and (de)extinctions. The rhetoric of these projects is to

"reinvigorate" the collections, recasting them into vital resources for wider audiences.

Framing natural science collections as databanks reconfigures the collections as valuable to expanded audiences, transforming them into resources—and potential solutions—for contemporary crises both social and biological. These include more obvious projects such as biodiversity conservation in the face of mass species extinction, as well as less obvious projects such as agriculture negotiating the influx of invasive species, national security dealing with invasive-species-as-potential-bioweapons (Dudley and Woodford 2002), disease control by charting contagion vectors from historic specimens (Suarez and Tsutsui 2004), and even the improbable de-extinctioning of species such as passenger pigeons (Revive and Restore 2013) and mammoths (Church and Regis 2012; Poinar et al. 2006; Shapiro 2015; Zimov 2005). However, it is also worth considering what kinds of labor and interests are involved in reconfiguring collections as resources.

Different forms of life, including biodiversity, have been increasingly defined by molecular biology (Bowker 2000; Keller 1995a, 2009; Radin 2012; Strasser 2006; Sunder Rajan 2006)—where the metaphor of DNA as a code (Kay 2000) or a text (Ridley 2000) to be written or rewritten replaces the sticky materiality of the thing itself. As Evelyn Fox Keller recounts:

> "For almost fifty years, we lulled ourselves into believing that, in discovering the molecular basis of genetic information, we had found the "secret of life"; we were confident that if we could only decode the message in DNA's sequence of nucleotides, we would understand the "program" that makes an organism what it is. And we marveled at how simple the answer seemed to be . . . But now, in the call for a functional genomics, we can read at least a tacit acknowledgment of how large the gap between genetic "information" and biological meaning really is." (2009:7–8)

Attending to this gap between "genetic 'information' and biological meaning" (Keller 2009:7–8) is another productive way to think through how specimens become data. The details of an organism's genome, its parts and interrelated functions increasingly define what it means to be "alive" in the contemporary moment, as determined by human biomedical and biodiversity genomics and then dispersed and "naturalized" into larger cultural domains (Genome 10K Project 2016; Gibbon and Novas 2008; Ingold and Palsson 2013; Kowal et al. 2013; Parry 2004). Species, in this conceptual framework, become their genomes in one sense—the protein sequences extracted from frozen samples,

“read” and sorted into the “book of life”,” (Canguilhem 2008; Kay 2000; Ridley 2000), ready to be read again or rewritten as needed with emerging technologies such as genome engineering (CRISPR/Cas9 Guide 2016; Rabinow and Bennett 2012; Wright et al. 2016). From this standpoint capturing genomes and collecting “all life on ice" become plausible endeavors, based on a view that life is reducible to a 2ml cryovial, the tissue inside it, and the genomic data that can be extracted from it. The diversity of biodiversity is in the process of being transformed into stable, standardized categories to enable its collection, preservation, analysis and use within an existing ethos of "natural order"—an ethos that privileges the rarity of the species, the high molecular weight of the sample, the analytical chain of permits and vouchers, and the accessibility and visibility of the genomic data to institutional infrastructures (The Castle) or partner networks (the Global Genome Biodiversity Network) —all pointed towards preservation for an uncertain future.

Forms of life understood as “nature” or “natural” are continually being re-appropriated and transformed, expanding the boundaries of what can be defined as biological. “The Watson-Crick era,” as the molecular biologist Richard Strohman argues, “which began as a narrowly defined and proper theory and paradigm of the gene, has mistakenly evolved into a revived and thoroughly molecular form of genetic determinism” (1997:194). The ensuing consensus in the life sciences around the gene as “ultimate control agent,” according to Strohman, has had the effect of “diminishing the concept of the organism,” leading organisms to be seen only as “devices” that permit the study of the mechanisms of gene control in experimental biology (1997:194). This resonates with the recasting of natural history collections as devices or tools for (molecular) inquiry and biodiversity conservation. However, it also echoes Haraway’s (2008:28–30) criticism of Deleuze and Guattari (1987:243) for their lack of genuine curiosity about animals as “others,” and not simply as metaphors. If an animal skin is merely a “device,” how does this delimit the relationship a researcher has with the specimen, and further how does this relationship reduce the specimen to a stand-in for something else, such as an entire species, genus, or family? Further, what kinds of labor go into creating and maintaining these transformations of different “forms-of-life” (Agamben 1998:9)?

The expansion of knowing the world through biological means shifts the power to define “forms-of-life” into the realm of the life sciences—a move described by

many[29]—with the biodiversity biobanking practices at the Smithsonian NMNH merely one example of crafting what Giorgio Agamben (1998:9) calls "bare life" (*zoē*) into "qualified life" (*bios*).[30] The transformation and standardization of biodiversity from "bare life" into "qualified life" is at work in the examples throughout this dissertation as birds, beetles, plants and their genomes are crafted by hand and by biotechnology—combining people, places, histories and materials in the making of "natural" artifacts that attempt to fill the gap, as mentioned above, between "genetic 'information' and biological meaning" (Keller 2009:7–8). In other words, biodiversity conservation through genomic collecting orients museum *sociologies, biologies* and *ecologies*—continually engaging them in ongoing processes of remaking, re-inscribing, or removing the boundaries of nature and culture. In turn, these nature-culture assemblages have the potential to expand the multiple possibilities for thinking about human and nonhuman relationships in the past, present and future.

To return to the shifting value of natural history collections that I examined in the first chapter, the ethnographic episodes in this chapter have taken up creating "genome-quality" tissue standards as a way of *thinking through things* (Henare et al. 2007; Ingold 2010). The ways these standards and the objects they organize *come-into-being* (Gosden and Marshall 1999; Moutu 2006) shifts the focus to new conceptual linkages between the lives—and afterlives—of organisms, both human and non-human, as they circulate. My ethnographic engagement with biodiversity collecting in the museum and the complicated webs of interaction that define it – socially, biologically and ecologically—relate to Helmreich's work on collecting the scientists who collect aquatic microbial life (2009). His concern with the microscopic, molecular, and genomic explorations of the open ocean and deep sea point to an expansion of the concept of *bios,* of life in the alien ocean as *other life*. While his focus centers on engaging the scientists on their own particular spaces and their own particular terms—an orientation to

[29]Scholarship examining how "life" is increasingly defined on biological terms includes work that incorporates perspectives from anthropology, STS and the history of science (Clarke and Fujimura 1992; Fortun 2008; Gibbon and Novas 2008; Fujimura 1996; Keller 2009; Kohler 1994; Knorr-Cetina 1999; Ingold and Palsson 2013; P. Strathern 1999; Strasser 2006; Sunder Rajan 2012).

[30] Agamben (1998: 9).defines the difference between forms-of-life: "The Greeks had no single term to express what we mean by the word 'life.' They used two terms that, although traceable to a common etymological root, are semantically and morphologically distinct: *zoē*, which expressed the simple fact of living common to all living beings (animals, men, or gods), and *bios*, which indicated the form or way of living proper to an individual or a group." For work that uses the concept of *bios* in the context of genetics see Rabinow and Bennett (2012) on synthetic biology, as well as the media project that emerged from my collaboration with them, *Bios Technika*: http://www.bios-technika.net/ (Bios Technika 2014).

ethnographic practice I find compelling—his collection of scientists offers up a somewhat homogenous narrative of biodiversity salvation. In contrast, the creators and collectors of museum genomics in my own research offered a variety of narratives based on their own disciplines' distinct histories of collecting and preserving.

From this perspective, the scientists I worked with are in the process of transitioning from being stewards of life's diversity in distinct disciplinary ways to becoming the conduits for increasingly standardized versions of life as they integrate genomic collecting practices (such as the GGI Genomic Collecting Training Module version 1.0). Standards make data accessible, but they also draw invisible lines between what is kept and what is discarded, naturalizing the remaining data, practices, specimens and interests. The ways these different practices are entangled with different interests are explored in the following chapter, as I examine the "life histories" of tissue tubes and debates at over genetic voucher specimens—how matter comes to matter in its relations as much as in its materials.

Chapter 4
NETWORKS/TISSUES

The Social Lives of Voucher Specimens

net—a bag or other contrivance of strong thread or cord worked into an open, meshed fabric, for catching fish, birds, or other animals[31]
work—something on which exertion or labor is expended; a task or undertaking; materials, things, etc., on which one is working or is to work[32]
tissue—an aggregate of similar cells that form a structural material with a specific function; from the Latin *texere*, to weave[33]

One changes one's ideas the way an animal sheds its coat, in patches: it's never a wholesale change from one day to the next.
— Umberto Eco (1997:4)

In the previous chapters I examined a new type of museum artifact—a cryocollection of genetic samples—and placed it within an historical context of natural science collecting and the standards emerging for "genome-quality" tissues. By looking to the various "embedded logics" of encyclopedic natural history collections originating in early modern European cabinets of curiosity, I examined the relationship of the collections to changing conceptions of a natural world (Haraway 2015; Helmreich 2009; Lowe 2006). In this chapter I examine biodiversity biobanking's role in positioning a national museum in yet another changing world, one of an increasingly globalized context (Bell 2013; Hayden 2003b; Ingold 2010; Ong and Collier 2005; Tsing 2005).

Collections are increasingly distributed across various networks—voucher specimens, tissue samples and data sets all "living" in different institutions in different countries, but linked together to form a collective whole. Following several objects along these networked paths—a historic bird skin and its sampled toe pad, snakes in pillowcases on international flights, debates about genetic voucher specimens—circulates my examination from a discussion of creating data standards in the previous chapter to an examination in this chapter of the interlacing threads of data that connect vouchers to tissues to DNA

[31] Online Etymological Dictionary (http://www.etymonline.com/index.php?term=net)
[32] Online Etymological Dictionary (http://www.etymonline.com/index.php?term=work)
[33] Online Etymological Dictionary (http://www.etymonline.com/index.php?term=tissue)

extracts to genomic data in the Smithsonian's global network of distributed collections and collaborators.

Through tracking the flow of biological materials and associated data required by the Global Genome Initiative to fulfill its goals of "preserving and understanding the genomic diversity of all life on earth" (GGI 2016), I examine work involved in building and maintaining these networks of voucher specimens, tissues and data in four sections.

To begin, I ground my examination in an account of several of my own interactions and collaborations with the GGI and the NMNH Biorepository—tracking the "life history of a tissue tube" with a bioinformatician, and charting the flow of specimens and data from field to museum to public database with GGI staff. Through collaborating with museum staff to diagram the flow of specimens and their parts, specific views were articulated both visually and verbally about what kinds of nature were being collected and how they should circulate (*Circles versus Lines, Globes versus Spheres: Creating a GGI Workflow Diagram*).[34] These differing viewpoints of what version of "nature" to collect, curate and circulate were reiterated in the on-going debates at the National Museum of Natural History (NMNH) on whether genetic samples could serve as voucher specimens—that is, the core referent for all tissues, DNAs and data relating to that specimen. "Being alive," as one collections manager put it, "is just another 'preparation type'" (*How to Build a Biorepository, Part I*).

Turning to the "sticky materiality of practical encounter" (2005:3), I examine the challenges of moving specimens as they are reclassified within museum networks and across international borders – from a pillowcase of snakes and jars of octopi at U.S. Customs (extending the collections with new specimens and "genome-quality" tissues) to snipping a bird's toe pad at the Ancient DNA lab at the Center for Conservation and Evolutionary Genetics (mining the historic collections for genetic samples).

Moving from the debates on genetic vouchers and the movement of specimens to extend and mine the collections in the previous sections, I conclude by focusing on the practical details of how to divide the materials themselves,

[34] The resulting workflow diagram and photographs were incorporated into the GGI Training Module v.1 – the first official version of a field guide for genomic collecting from the Smithsonian NMNH.

following the process of subsampling tissues in a (genetic) cabinet of curiosities, the NMNH Biorepository. I photographed operational sequences of subsampling tissues, scanning cryovials, logging data and sorting tubes—processes that carefully knit together data and biomatter into an analytical chain. These material practices bring into focus the historical legacy of natural history collecting on which GGI depends, and builds, as it faces the need to access materials from a range of different locations, institutions and actors across the globe. Life from around the world is carefully condensed in the tissue tubes I documented being sampled, labeled, and scanned, passed from curator to lab tech, and from museum to museum (*How to Build a Biorepository, Part II*).

In sum, this chapter explores the labor and politics involved in the museum's procurement of living and dead biomatter and looks carefully at the ways that the GGI and its Smithsonian collectors work to extract a new "nature" from a dense variety of natural-cultural entanglements. "Shared conventions regarding what kind of things exist in the world, and how to name them," according to Bruno Strasser, "were a prerequisite for the production of standards about how to produce data about these things and how to describe them." (2012b:86). The enlightenment project of assembling all knowledge in one place has deeply informed the archetype of the archive as well as our ideas of it (Richards 1993). Following these concepts within the context of the natural history museum and its forms of crafting nature, I examine how vouchers, tissues and their data are crafted, and how they function to both create and bind together global networks of institutions, interests, specimens, and their parts.

The Life Histories of Tissue Tubes

July 2015. "I just love the data," Jamie Whitacre tells me, a contractor in the bioinformatics department. "I'm going to miss it, it's just so amazing—all these collections, all this amazing diversity packed in here. . . Especially walking past the cabinets in Botany that smell like pine needles." After nearly ten years of mapping the flow of specimens, genetic samples and their associated data across the museum, she is leaving for a job in biomedical research. Medical record data, she tells me, isn't nearly as compelling as natural history collections.

With a background doing ethnobotany, she used the tools of ethnography to map what scientists were doing with their collections—how they made them, where

they kept them, how the data was entered into the collections database . . . or not. Using the information she gathered, she helped design the new "genetics" module in Emu, the museum's collections database. Jamie and I found much common ground to talk over, particularly in our fascination about how specimens, tissues, and data sets migrated around the museum and its databases, sometimes losing the linkages between them.

We talk in her temporary office a few days before she leaves, as she's pushing to finish her work for the genetics module. One of the few things she has brought with her from her previous office is her "demo kit"—a 96-well plate for genetic samples, a collection of the different cryovials used for different departments and divisions (2ml for vertebrates, while botany used little paper coin envelopes and ziplock bags with moisture-absorbing silica crystals). Next to the tubes and plate are several life-size JellyBelly gummy spiders. I ask about the candy spiders.

"I have different ones for different 'species,' this one has stripes this one doesn't," she wiggles them as she talks. "It helps so much when I can use visuals to walk through the process with a curator or collection manager, to take a bit," she pinches the striped spider's leg, "put it in the tube or the plate . . . and then go step by step along the life story each one has." Tissue samples have discreet "lives" that aren't always clear. Jamie explains to me that when you take two samples from a specimen, they may seem interchangeable. However, they can have very different lives—one can be consumed (dissolved and extracted) to get DNA, while the other tissue tubes sit in a freezer or are lost in transit and then found. So you can have an empty cryotube, but a voucher specimen and a set of genetic data that need something to link them in the database—the "analytical chain" from voucher to tissue to data. Some scientists will link a similar tissue tube to the voucher and data, instead of linking the consumed tissue tube. "It seems wrong to some people to link a non-existent object," Jamie says, "but to get accurate data, you need to record what has actually happened. So I explain it in terms of a 'life history' of a [tissue] tube so they'll get it." I nod, tracing the paths in my head from a central specimen with tissue samples erupting out of it, and then those transforming into DNAs.

Several months earlier I'd sat in a crowded conference room during the monthly NMNH Genomics meeting as Jamie had presented the new workflow for genetic samples, a workflow that took into consideration not only the collecting practices of the different disciplines, the data habits of the divisions and departments, but

also the linkages that were required by the Registrar and the Head of Collections—links from the data set, to the tissue sample, to the voucher specimen, to the collecting permits that validated the museum's legal ownership of *everything* in the chain of things derived from it.

Specimens were no longer just a few pieces in a drawer, they were spreading ever outward into a wider web and the individual life histories of each piece needed to be considered, as changes in temperature (such as a power outage, freezer failure, or a shortage of liquid nitrogen) could adversely affect the tissues and DNA samples. The silhouette of the Washington monument was visible through the drawn window shades of the conference room again, and all faces were turned towards the projected image of a fish with a cascade of tissue tubes and DNA extracts flowing from it [Figure 4-1].

The discussion that followed traced a similar path to that of the genetic voucher debates which I detail in the next section—displays of different "ways of knowing" (Pickstone 2001) existing in parallel and coming into friction when their differences intersected in one standardized workflow. The anchor for each tissue tube, DNA extraction, packet of sequence data all (theoretically) thread back to a voucher specimen, a physical entity (some would argue one that required identifiable morphological characteristics) secured in a drawer, cabinet or freezer somewhere in the world.

The lack of vouchering for molecular samples has been a source of increasing concern in the "museomics" community (Astrin et al. 2013; Coddington et al. 2007; Nachman 2013; Prendini et al. 2002; Rohland et al. 2010). At least five different conceptions of "voucher" were in circulation in the conversations, debates and protocols I encountered at the Smithsonian NMNH during my fieldwork. The first is a *specimen voucher*, with a distinct, individual organism serving as the basis for taxonomic identification. often, but not necessarily, this is a whole organism, but it may also be a "significant" part, such as a leg, scat, or eggs. A *molecular voucher* is a sample that is "deliberately preserved and curated in a way that will conserve its molecular properties for analysis" (Astrin et al. 2013:3), and according to many (Hykin et al. 2015; Prendini et al. 2002; Seberg 2013) to be valid as a source the molecular voucher should always be linked to a specimen voucher. Other terms in circulation for a "molecular voucher"

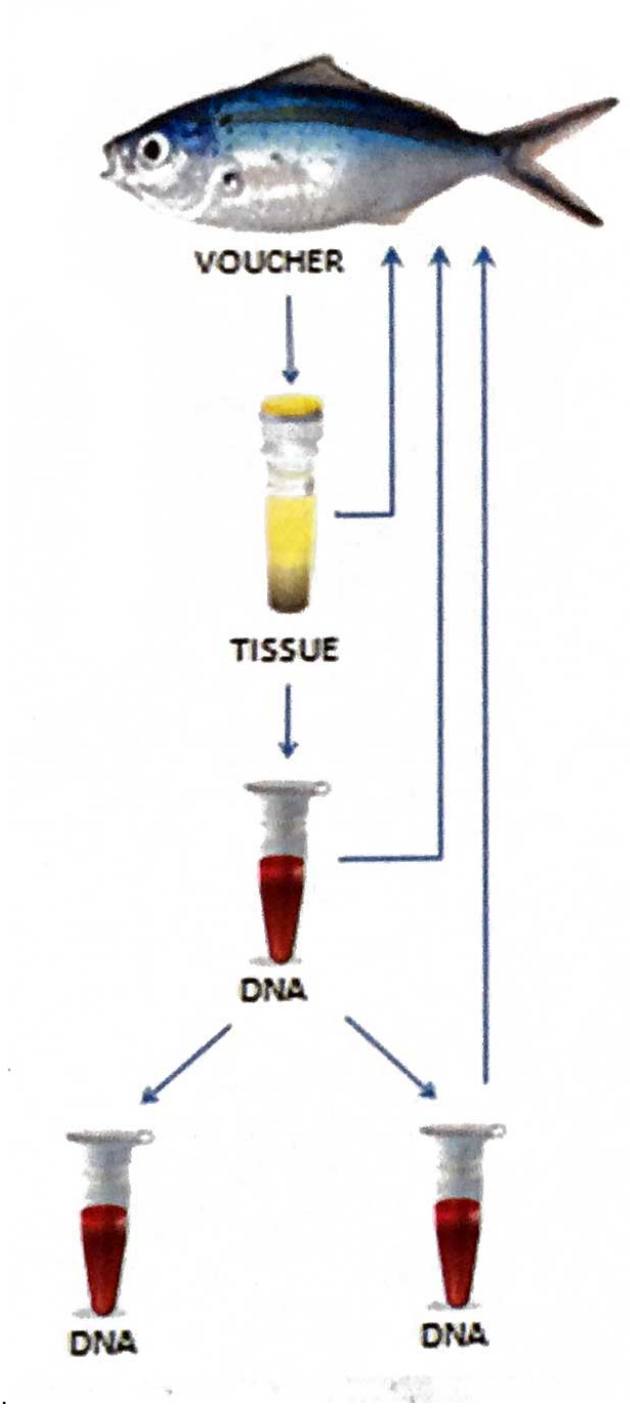

Figure 4-1. Life History of a Tissue Tube
(Source: Michelle Brown, Smithsonian Institution)

are biobank voucher, DNA voucher, tissue voucher, RNA voucher, protein voucher, or genomic sample. In contrast, a *tissue voucher* is a tissue subsampled from a specimen, or the entire specimen, and is usually frozen to "keep its molecular properties (either fixed tissue or viable cells) for future analysis" (Astrin et al. 2013:3). A *DNA voucher* is isolated and preserved, frozen or dried DNA, and as a derivative sample "a DNA voucher should not—if possible—function as specimen voucher" (Astrin et al. 2013:3). This assertion, as I detail in the next section, was a source of intense debate between the different disciplinary "cultures" at the NMNH, each doing genomic work, but with different materials, means and interests driving their practices. Finally, a *biobank voucher* references any molecular voucher curated in a biobank, essentially any sample that links to other physical objects or data. In the case of the GGI's collecting program—and a view towards future utility—the preserved samples need to contain a high percentage of an organism's unfragmented genome.

Voucherless tissues continue to be a source of concern, both ethically and practically. The Smithsonian has a wealth of legacy tissue collections that need to be integrated into its collections, many of which are without vouchers but too valuable not to keep, particularly if a project, such as the GGI, is intent on collecting all families of life. Within the legacy tissue collections thousands of species, families and genera were tantalizingly accessible—if they could be sorted out. The task of migrating legacy collections from their current location stashed in freezers throughout the Divisions and Departments of the museum to the Biorepository entails not only negotiating how much information would be visible in the public database (Birds, for example, doesn't publish location data for rare or endangered species), but also tracing the long and complex analytical chain of ownership documented in permits. Tracking down the Material Transfer Agreements (MTAs) and Memoranda of Understanding (MOUs), collection permits, export permits from the country of origin, import permits from Department of Fish and Wildlife in the U.S., not to mention connecting the collection data for the sample itself, and then connecting the sample and data to a voucher specimen somewhere in the distributed network of museums globally entangled in this process—needless to say this was not a small undertaking. Add to this that each Department and Division had multiple tissue collections created by different curators and researchers at different times, some of whom had moved elsewhere or died without leaving complete data records behind. "We think we know what something is," a staff member at the Biorepository told me, "But without complete data we can't be sure . . . If it's something incredibly rare or

even extinct (or even if it could possibly be a sample from an extinct species) it's too valuable to toss. We'll just hold onto it, we have to . . . What else can we do?"

The potential benefit for the GGI from taking on such a task as collecting, condensing and organizing legacy tissue collections was the possibility of leveraging decades of global collecting that could catapult the GGI closer to its goal of getting half of all families of life on earth stored as genome-quality tissue samples in liquid nitrogen in the next six years. Notably, most of these collections were made before the Convention on Biological Diversity and the Nagoya Protocol and are therefore exempt from an array of permitting requirements, adding to their value as accessible, legal and properly permitted (at their time of collection). Accessing the potential of these collections for the GGI, however, would first require untangling the social web of interests and values embedded in the collections.

How to Build a Biorepository, Part I

"Being 'Alive' is Just Another Preparation Type": Debates on Genetic Voucher Specimens

In the entangled spaces of the natural history museum I saw increasingly complex connections being built by staff across the museum, including bioinformaticians, collection managers, curators and administrators. These were accompanied by large debates involving many stakeholders about the connections between things *and* data versus things-*as*-data and their role in knitting together the paths between distributed networks such as sequence libraries (GBIF 2016; "GenBank" 2016), partner institutions (GGBN partners) and shifting interests (transparency and "discoverability" of specimen data, voucher-tissue-DNA-data relationships). This was nowhere more apparent than in a series of debates at the Smithsonian NMNH in the winter of 2014 centered around what constituted a "proper" voucher—the traditional referent for all things derived from that specimen, from physical characteristics to tissue samples to DNA to sequence data.

December 2014. A large group filled the conference room on the top floor of the museum, the central window framing the Washington monument that was cast in

late afternoon light. The national context of the decisions made in this room couldn't be more evident. "We don't really speak the same language as IZ (Invertebrate Zoology)," a Botanist leaned over to tell me as we waited for the meeting to begin, "*Their* ontologies aren't *our* ontologies . . . Why should they be?" A few stragglers filtered in, finding seats by the door, and discussion began about defining a genetic voucher at the National Museum of Natural History.

As questions were raised about whether a genetic sample—or indeed an even more abstracted piece of amplified DNA—could serve as a voucher specimen, I followed the back and forth between the different voices in the room, and the kinds of authority they represented, from the upper-level management such as Directors of genetic projects and the museum's Registrar, to the Curators in different departments weighed differently by the success of their (genetic) projects, publications and grants, an assortment of collection managers, data managers, lab techs, and a small cluster of bioinformatics staff and contractors trying to synthesize the input from all these voices into a coherent, ontologically-stable and mutually-agreed-upon whole. The purpose of a voucher, according to the narrative provided by the bioinformatics staff leading the meeting, was to provide a reference, traditionally a stable physical reference for the various parts and pieces that were "derivatives" from the "original." These included everything from the standard tissue samples of heart, liver, and muscle (considered to be reliable sources for "good DNA"), to fin clips from a fish to tail clippings from a lizard, to blood samples, various secretions and excretions (the list was long and somewhat disturbing), to the DNAs extracted from these biologicals, to genetic sequences in turn extracted from the DNAs—a panoply of divisions of the biological, as the pull-down menu in the genetics tab of the museum's collections database (EMu) attested. Heads across the room nodded in tentative agreement.

The bioinformatics team explained that the genetic sample workflow—that is, the handling of genetic materials and their movement through the museum, and how the steps are logged in the museum's collection database—was in the process of being upgraded. Originally deployed in 2013, the bioinformatics staff had since been interviewing other staff across the museum in every Department and Division that dealt in genetic materials. They were looking for different concepts of "fieldwork flows" for genetic samples, with the goal of standardizing some of the work done at the museum across different departments, each of which was

using different terms and practices. Earlier that January there had been an initial meeting where "a voucher was a voucher" for half of the room, however the other half wanted standard terms to use for different voucher types.

"Looking at the terms used," one of the bioinformatics staff said, "during our interviews we saw a lot of variation both inside and between departments." There was uneasy laughter across the room—which I took to be the unease of the implications of this meeting: that one model of vouchering could potentially become dominant. And that model may not be the one that was currently in use and conceptually valid for their own collections. The lines drawn between kinds of things in their collections were about to be redrawn, but exactly *how* was uncertain.

Two definitions of a voucher were then broached: a "narrow" view where a sample or preparation is of the same individual and that exact organism is the voucher; or a "broad" definition, where the sample or preparation of an organism is from the same operational taxonomic unit, or OTU. Essentially, in my assessment, a distinction between "same same" and "like same."

Apparently I was not alone in this assessment as various brows began to furrow around the room. The terms currently in use (though it was pointed out that they were far from settled in "our collective usage" as of yet) included: *voucher, individual, population, species, taxon,* and *operational taxonomic unit (OTU)*. The purpose of depositing a voucher, the bioinformatics staff continued, was that it allows long-term studies, the correction of publication errors "as we share data," and allows a "view into our process." At this point, those in the room began to weigh in on genetic vouchering:

INVERTEBRATE ZOOLOGY CURATOR 1: "Can DNA or tissues be vouchers? I certainly think so. I've done it."

MAMMAL CURATOR AND BIRD CURATOR IN UNISON: "A voucher is a voucher."

BIRD CURATOR: ". . . Or a hologenophore.[35]"

[35] "A *hologenophore* is the specimen voucher from which the molecular sample is directly derived, an *isogenophore* is a different specimen with a clonal relationship to the study organism, while a *progenophore* represents a voucher that is linked to the specimen sampled for molecular analysis by a parent-descendant

BIOINFORMATICS STAFF MEMBER 1: "Is a voucher collected at the same place and time deemed part of the same operational taxonomic unit?"

GENETICS PROJECT DIRECTOR 1: "That's an exemplar—*not* a voucher."

BIOINFORMATICS STAFF MEMBER: "That's why we have the quote marks up there, we're figuring out what you actually do—paravoucher and allovouchers in IZ [Invertebrate Zoology], phenotypic vouchers in Entomology. If it's used in the Department, then these are the terms we used [in building the EMu[36] Genetics tab]. We want to choose *one*."

INVERTEBRATE ZOOLOGY CURATOR 2: "You may not see it in the data (anemone, coral), or any rhizomatic thing such as a sponge, etc., but it's happening. A sample taken from a part of the same clonally related organism – on a coral you take one polyp and sequence it, then use the polyp next to it as the voucher."

BIOINFORMATICS STAFF MEMBER 1: "So for existing voucher 'types' we have allovoucher, photo or video voucher (catch and release), phenotypic voucher. . . Do we need to add a living voucher type?"

GENETICS PROJECT DIRECTOR NO.1: "Depends, is it in captivity? Is it catch and release [in the field]? They're both alive, but the one in the field isn't accessible again."

BIOINFORMATICS STAFF MEMBER 2: "Do any of these [voucher types] align with existing ontologies? [Looking at the other bioinformatics staff] We haven't found any in the literature. We're seeing how they're used, and trying to figure out how to make them useful."

INVERTEBRATE ZOOLOGY CURATOR 2: "They [the voucher types] are trying to align themselves with types and how types are defined. *Since that's our business*."

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or sibling relationship. A *paragenophore* is a putatively conspecific specimen voucher collected together with the 'molecular' specimen. The same applies to the *syngenophore*, except that it is collected at another place or time" (Astrin et al. 2013: 3). One of the genetic project directors who was at the genetic voucher meeting said later this discussion was like "counting the number of angels that would fit on the head of a pin—I mean, haven't we sorted all this out already, decades ago? Can't we move on?"

[36] EMu is the museum's collections database.

GENETICS PROJECT DIRECTOR 1: "They're all different exemplars of a taxonomic concept – part of the EMu record of a sample . . . So we need to define a genetic sample versus a genomic sample."

BIOINFORMATICS STAFF MEMBER 2: "Is a DNA a voucher? As of late 2000 there were only three fields in GenBank [a genetic sequence library]: voucher_specimen, voucher_culture collection, voucher_biosample (meaning an environmental sample). We need to define the history of the sample. Not just which fish it came from, but what tube it came from for reproducibility, the 'parent' specimen of the actual material should be tied to the voucher specimen and to the specific tissue tube."

GENETICS PROJECT DIRECTOR 1: "From Genbank's view it's not an exemplar of the OTU [operational taxonomic unit], but of the same individual. There are no checks and balances to make sure you're submitting with a voucher and not a paravoucher."

INVERTEBRATE ZOOLOGY CURATOR 1: "There never is – there's so much crap in GenBank. . . . A clone is defined under the same genome, but I never use the paratype [as a voucher]."

INVERTEBRATE ZOOLOGY CURATOR 2: "Slippery slope, that's not the same individual."

INVERTEBRATE ZOOLOGY CURATOR 1: "Within the same colony you can treat that as a functional individual, with different transcriptomes[37]."

BOTANY CURATOR: "We do population sampling too, but we don't voucher like you do."

GENETICS PROJECT DIRECTOR 2: "If Botany isn't going to quite agree with IZ's [Invertebrate Zoology's] definition then we're just sitting here gilding the

[37] According to various scientists I spoke with who were doing genome assembly (dealing with transcriptomes on a regular basis), they described the genome as a "store of biological information" but unable on its own to release that information to the cell. Using the biological information contained in the genome requires coordinated activity between enzymes and other proteins—a complex series of biochemical reactions referred to as *genome expression*. The initial product of genome expression is the *transcriptome*, a collection of RNA molecules derived from those protein-coding genes whose biological information is required by the cell at a particular moments. The transcriptome is maintained by a process called *transcription*, in which individual genes are copied into RNA molecules. (Lander and Weinberg 2000).

taxonomic lily. If it's propagated and then split up as individuals, then they're different vouchers. Rhizomes might be ok."

GENETICS PROJECT DIRECTOR 1: "We're talking about concepts specific to different collection methods. The member/set relation is different than the part/whole relationship. What we're talking about is the parent/child relationship versus the exemplar. Member/set is a clone organism such as a tree or a coral; part/whole is a bird, fish, insect, etc. Clone, exemplar, voucher: we're here attempting to define the usage within each Division."

INVERTEBRATE ZOOLOGY CURATOR 1: "The parent of the DNA is a tissue sample, but often that gets consumed."

BIOINFORMATICS STAFF MEMBER 2: "You have a parent at every single level, but the highest level might not be a whole organism, it might just be a tissue or even just a DNA.[IZ Curator 1 nods agreement]. We create the parent/child relationship in EMu, but we're not creating new catalog record numbers for DNAs. The DNA record may be the highest level record."

BIOINFORMATICS STAFF MEMBER 3: "We want the people who are looking at these records to understand what they are looking at. It doesn't matter what GenBank wants."

GENETICS PROJECT DIRECTOR 2: "We have to care, because we're going to be bulk uploading. We have to care about the outside world at least some. [Turns to Botany] How does Botany feel about it?"

INVERTEBRATE ZOOLOGY CURATOR 1: "It's a disaster waiting to happen. ForrestGeo has about 10 thousand tissue samples, with people wanting to add to EMu and bulk upload to GenBank."

BOTANY CURATOR: "We have tissues from three different trees and use one as the voucher."

GENETICS PROJECT DIRECTOR 2: "As a biologist I'm not comfortable with using the same place/time as enough. Is it from a physically different organism? It’s a subjective decision. Was it on the same rock, part of the same tree, the same individual? The same place/time is ecology not biology. There's no necessary

genetic relation between these adjacent organisms . . . We're reinventing something taxonomists spent a hundred years trying to erase and decided were obsolete . . . I also don't personally see the use of 'living voucher.' *Some vouchers are living, some are dead. Sooner or later that organism will be dead and it will be a dead voucher.* Then your [catalog] record will be wrong. [Grins]. But spiders don't do clones, so I can't speak to that."

ENTOMOLOGY COLLECTIONS MANAGER, MAKING AIR QUOTES: "'*Living*" is just another preparation type – it's just walking around instead of pickled in a jar, pinned in a drawer, or glued to a page."

GENETICS PROJECT DIRECTOR 1: "So herbarium pages [botany specimens sewn or glued to sheets of paper] are "catch and release"? Plants just don't get away very fast?"

BIOINFORMATICS STAFF MEMBER 2: "Ok, so we have a new list of three kinds with no voucher: an exemplar (allo- or para-), an e-voucher (photo, video, or audio), and voucher (living voucher, dead voucher)."

GENETICS PROJECT DIRECTOR 2: "Let's not go back to the idea that you need a pristine whole organism just as God made it to be a voucher. We've moved beyond that—a DNA can be a voucher itself."

ENTOMOLOGY COLLECTIONS MANAGER: "If it's going to be completely consumed then it can't be a voucher, because the point is to be reproducible."

GENETICS PROJECT DIRECTOR 1: "What we're talking about is the record of a thing in the collection. If there's nothing in the collection left, then there's no voucher."

GENETICS PROJECT DIRECTOR 2, WITH A GRIN: "There's the record of its use in the records."

From this tangled exchange between different "ways of knowing" and indeed "ways of making" the natural world from the viewpoints of Botany or Genetics or Entomology – or even of invertebrate zoology's different methods depending on what curator you were speaking with – a thin but definite line seems to exist between the biological objects and the data objects for these scientists and administrators. Some voices were adamant that "they" (meaning the institution of

the Smithsonian, and further the discipline of biology as a whole) had moved beyond “whole pristine organisms” as vouchers, while others were adamant that “a voucher was voucher” (that is, an organism, in part or preferably whole, was pickled, pinned, stuffed or frozen somewhere as an enduring reference).

Sequences on servers existed in a different ontological category than the DNAs, even if they exhibited many of the same characteristics as data sets. Digital files of genetic code were inherently different, it seemed, from that same genetic code bound up in a tube of DNA. And the process of providing a proper voucher for a specimen continues to be negotiated, not just at the Smithsonian but at other institutions the world over that serve as repositories for voucher specimens – museums, herbariums, botanical gardens, zoos, and, increasingly, laboratories and biobanks. The DNA extractions and the data sets were both abstractions of a biological entity that could be replicated, and were in some sense perceived as being simultaneously the essence of that biological entity and also a representation of it. In other words, a representation of the organism's "true" nature, extracted and written out at the molecular level, bundled up to move across domains and made stable enough to remain “legible” at those border crossings. I now turn to how I worked and reworked visualizing the pathways of specimens, tissues and data in collaboration with the Global Genome Initiative, making them “legible” for a variety of audiences. As I learned over and over again, *what was left out* what just as important as *what was left in*.

Circles versus Lines, Globes versus Spheres: Creating a GGI Workflow Diagram

May 2015. “We need some hands in there,” a staff member from the Smithsonian Communications department says, “Something to show that people are doing the collecting—right now the specimens are just floating in space” [Figure 4-2]. The GGI staff, a communications staff member and I are sitting around a conference table looking at printouts of the genomic collecting workflow diagram I’d designed. As part of my research with the GGI I offered to design infographics depicting the flow of specimens and their associated tissues and data, from “field to freezer,” as they described it. This was intended to help clarify where all the parts and pieces were going, as areas of expertise across the Departments and Divisions of the museum provided high detail in some areas but not in others.

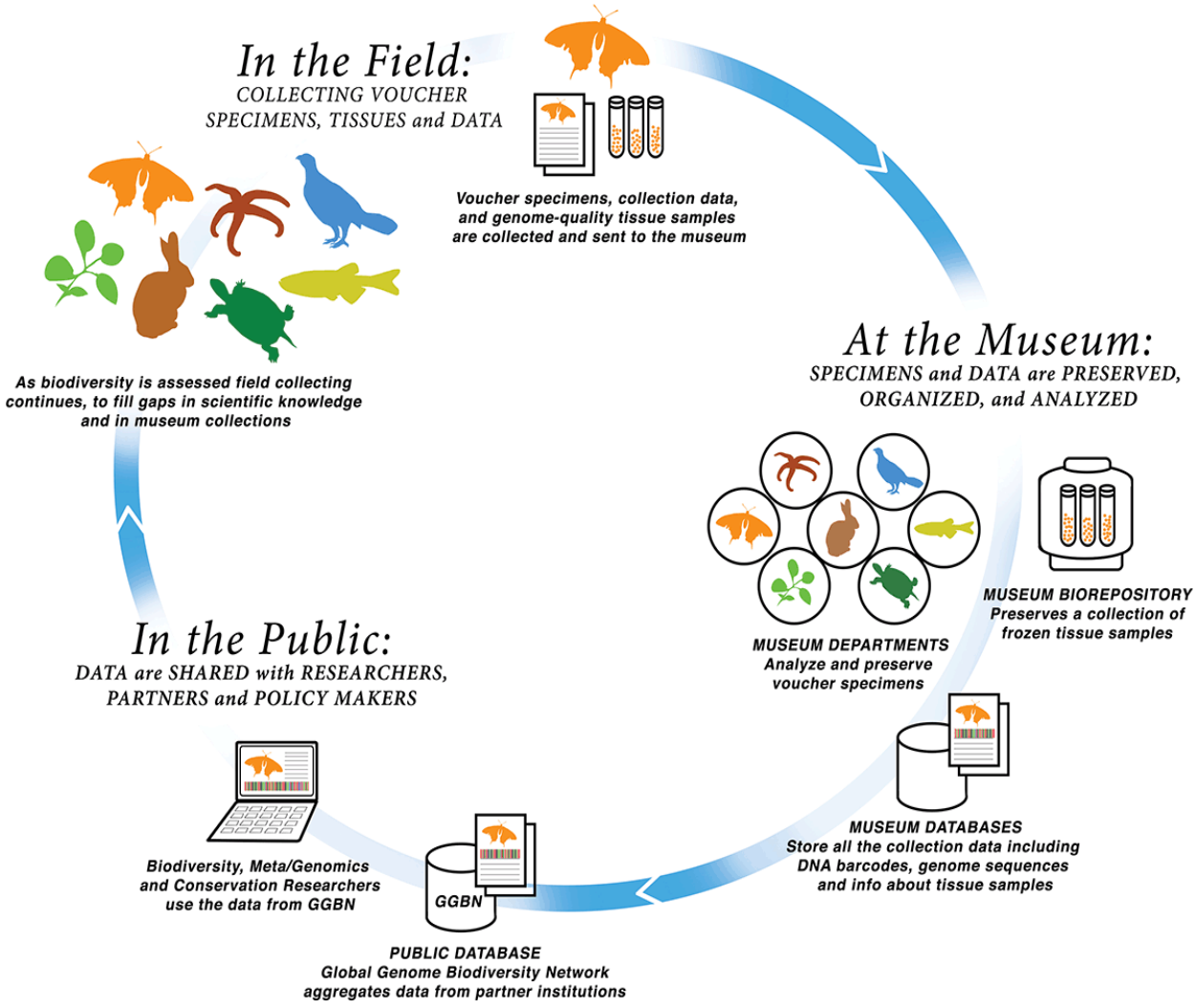


Figure 4-2. GGI Workflow diagram, (Version 7.2)
included in the first version of the GGI Collecting Training Module (August 2015)

Someone who did most of their work on extracting bird DNA in the Laboratories for Analytical Biology (L.A.B.), for example, may not be aware of the intricate details of how to collect aquatic invertebrate vouchers and tissues, such as insects, crustaceans, mollusks, or worms.

Our goal today was to review the workflow diagram and make sure it was clear to audiences outside the museum. The GGI Gardens project was about to begin, and it was decided to use this as a media event to officially "launch" the Global Genome Initiative (though work on various parts of the project had been going on for several years). Plants, it had been decided, were a better collecting subject for the public than animals. Having photos and diagrams available for the media was an important component for this event, and my diagram would be included not only in the GGI Collecting Training Module (its original purpose), but would be part of the press kit. Today I was getting feedback, and Ryan had called attention to the abstracted icons representing creatures, tissues, DNAs, PCR machines and computers. There were no icons representing the people who made and moved these objects, however.

This had been a very conscious decision on my part, as my goal in creating the diagram was to not only give back to my source community, but also to become a form of "visual conduit" for the concepts of nature, order, and value at play in the work of the GGI. Concentrated into a diagram that would be discussed and debated by the GGI staff, I could then use these images as a way to gain access to the way concepts were negotiated in a very hands-on way. Drawing diagrams in anthropology has been used in many situations for various purposes (Ingold 2011b), and using my background in art and design proved to be valuable for both my own research and for my subjects. Even more than being the photographer for the GGI (though this provided a great deal of access, putting me in the middle of things in very productive ways), being the media designer for the project was also productive as it positioned me to visualize what people were telling me, and then synthesize this into an image that was further interrogated by the group. It fore-fronted and articulated people's assumptions about what specimens were, how they moved, and what they stood for.

I found it interesting that the museum staff member responsible for human interaction focused in on the lack of human representation, while in contrast the

multiple previous versions of the diagram had evoked very different responses from the GGI staff—mostly on the details of the "life histories" of the DNAs and genomic data recorded accurately. A first version of the diagram was based on the Barcode of Life pipeline, showing a very linear flow of abstracted specimen parts moving from field to lab, and then fanning out across the museum [Figure 4-3]. This was taken as the model to work from, and as we annotated different iterations of the workflow diagram in GGI staff meetings, this led to defining specific areas of activity: *In the Field, At the Museum, In the Public*.

In one discussion we came to the conclusion that these different areas then needed to be connected back together. As we traced the movement of specimens, the path was still linear (still essentially following the Barcode of Life pipeline) [Figure 4-4, Figure 4-5]. However, collecting, sorting specimens, producing datasets and then publicly sharing the data was not a linear process, but a circular one: "it's not just about things," said Jonathan Coddington, "It's about ideas." After much sketching, drawing notes and phrases on copies of the diagram, we eventually cut much of the detail out of the workflow diagram [Figure 4-6, Figure 4-7]. The caption that had been at the bottom of the original, now became part of the "In the Field" section, closing the loop and making the line into a circle: "As biodiversity is assessed, field collecting continues, to fill gaps in scientific knowledge and museum collections." This greatly simplified version ended up providing greater clarity (through omission of detail), and provided a view into the circular nature of museum collecting as conceived by the staff of the GGI [Figure 4-2].

Throughout this process I tried to reflect the perspectives I was hearing, to provide a visual mapping of their vision of the relationship between the natural world, the collections created from it, and the way those collections circulated. Tim Ingold's concept of globes and spheres (1993) provides an analytic to begin examining these paths from field to museum and back again [Figure 4-8]. In Ingold's "sphere" and "globe" views: "[T]he lifeworld, imagined from an experiential centre, is spherical in form, whereas a world divorced from life, that is yet complete in itself, is imagined in the form of a globe" (1993:35). In a spherical perspective, Ingold suggests, the human being is set in the middle of a universe that extends outwards in a set of rings and spheres—the human subject is inside a sphere. In this perspective, the human is always embedded in the middle of a world that reveals itself through an interaction with its internal structures.

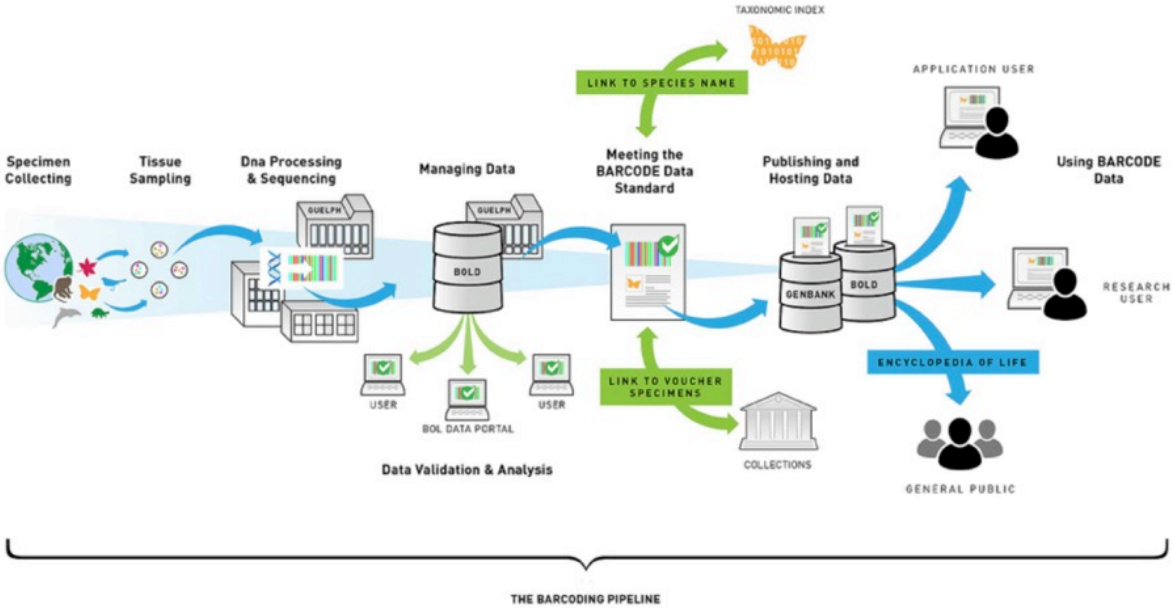


Figure 4-3. Barcode of Life Pipeline
(Source: Barcode of Life: http://www.barcodeoflife.org/)

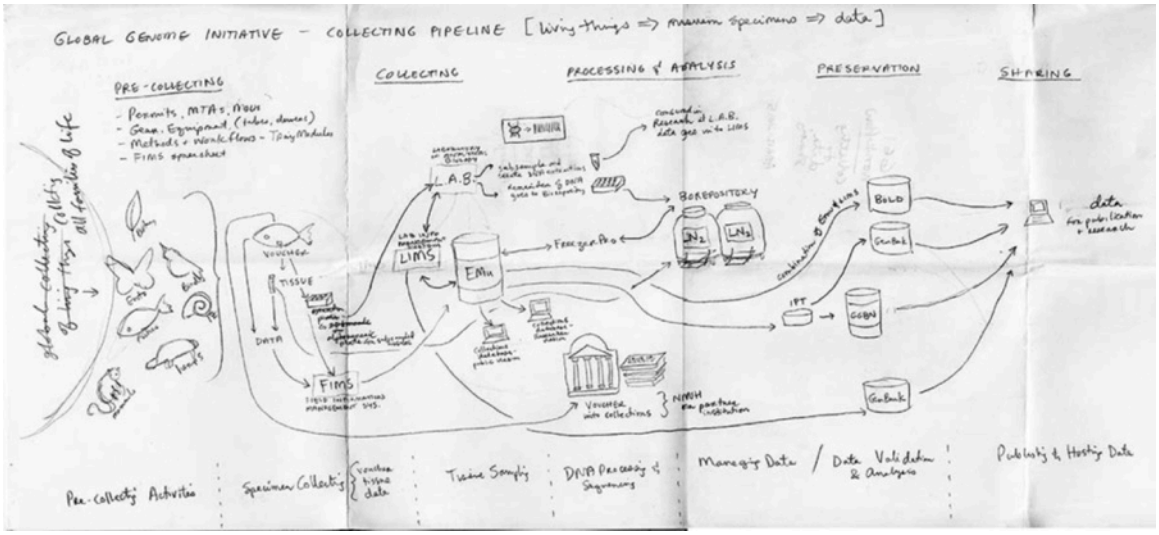


Figure 4-4. An initial sketch for the GGI workflow (March 2015)

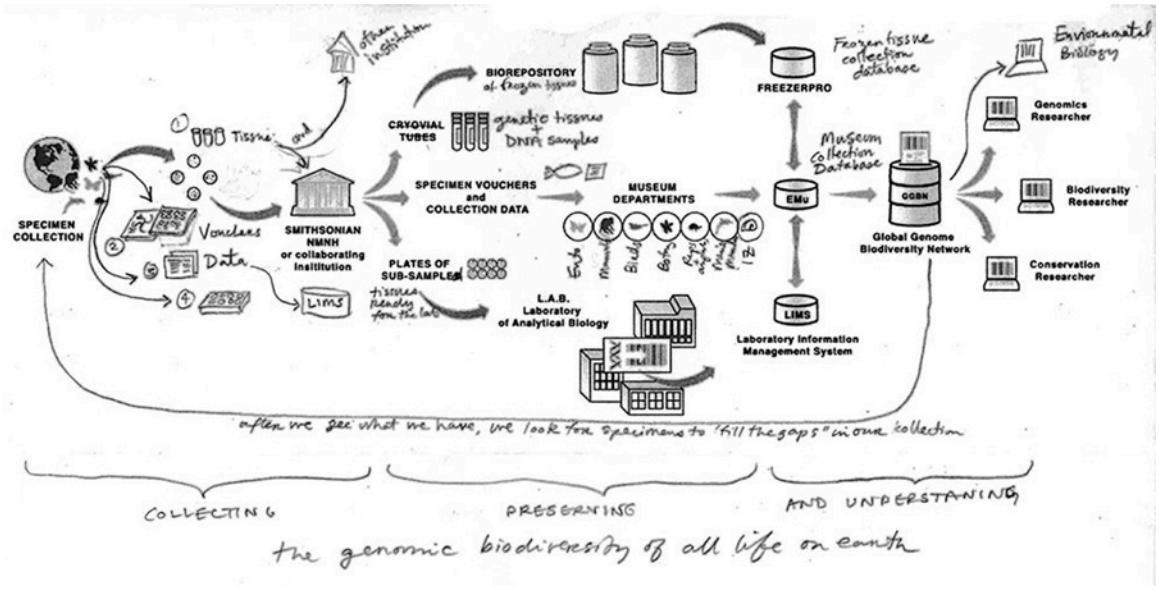


Figure 4-5. GGI workflow diagram, Version 2 (March 2015)

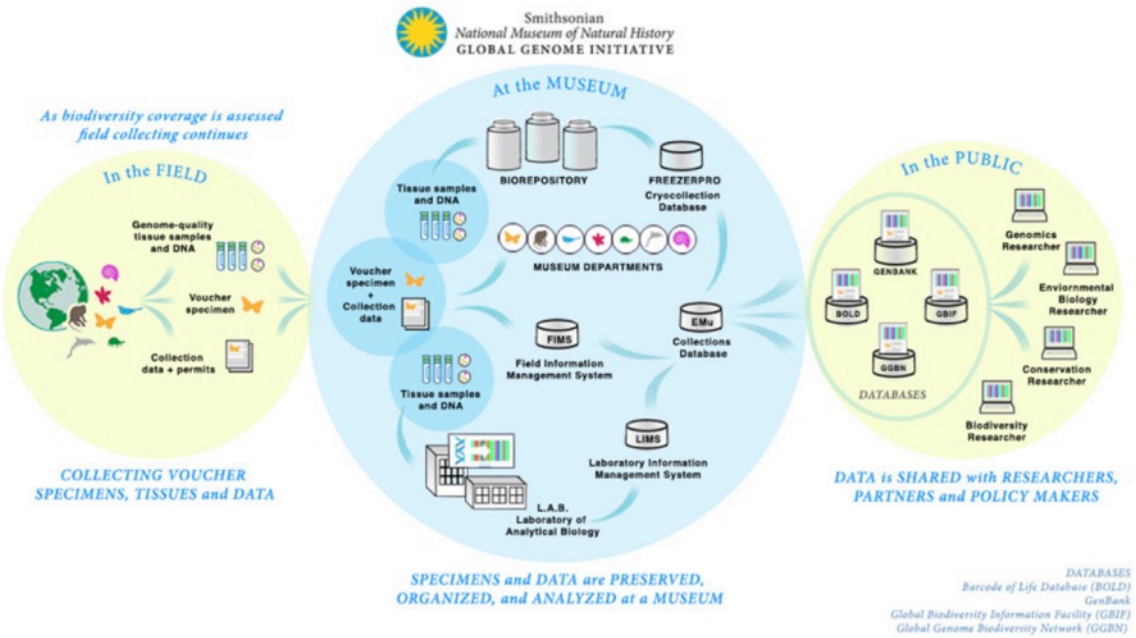


Figure 4-6. GGI workflow diagram, Version 3.2 (April 2015)

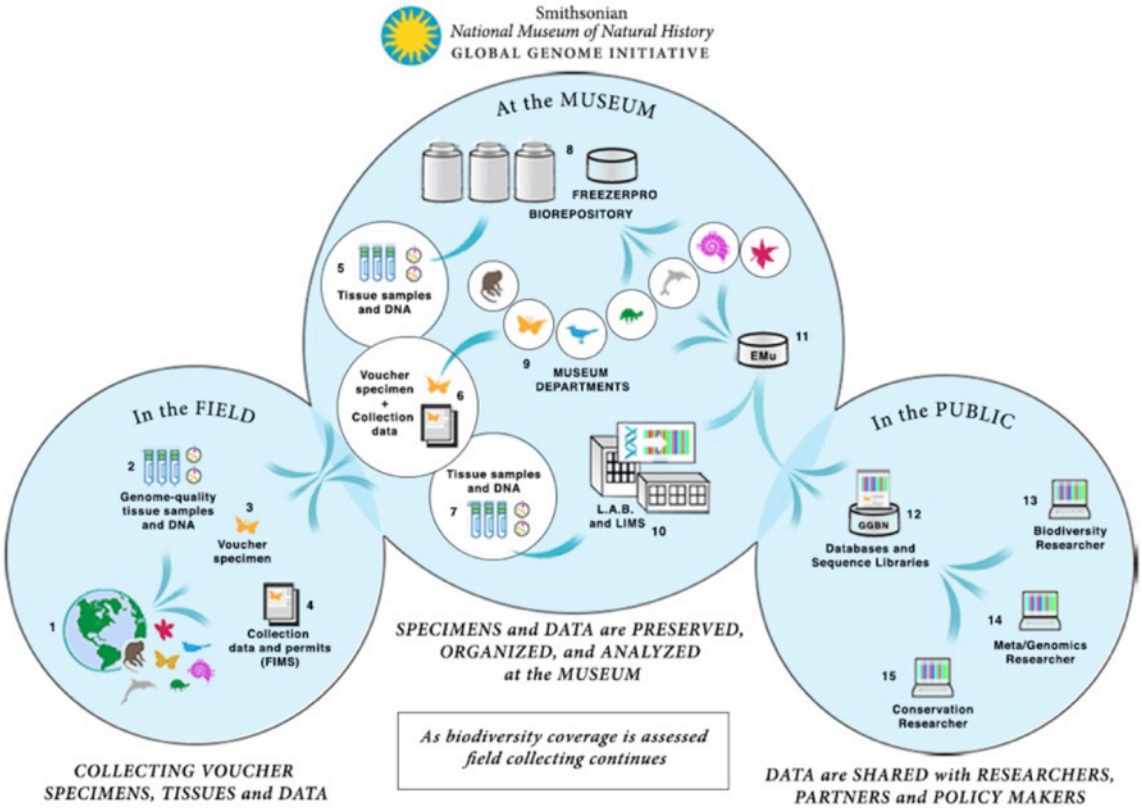


Figure 4-7. GGI workflow diagram 4.4 (April 2015)

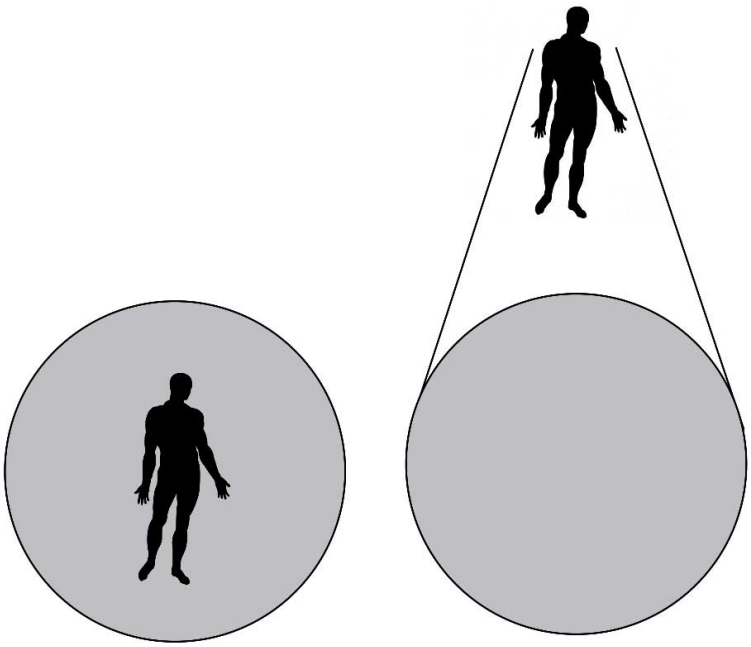
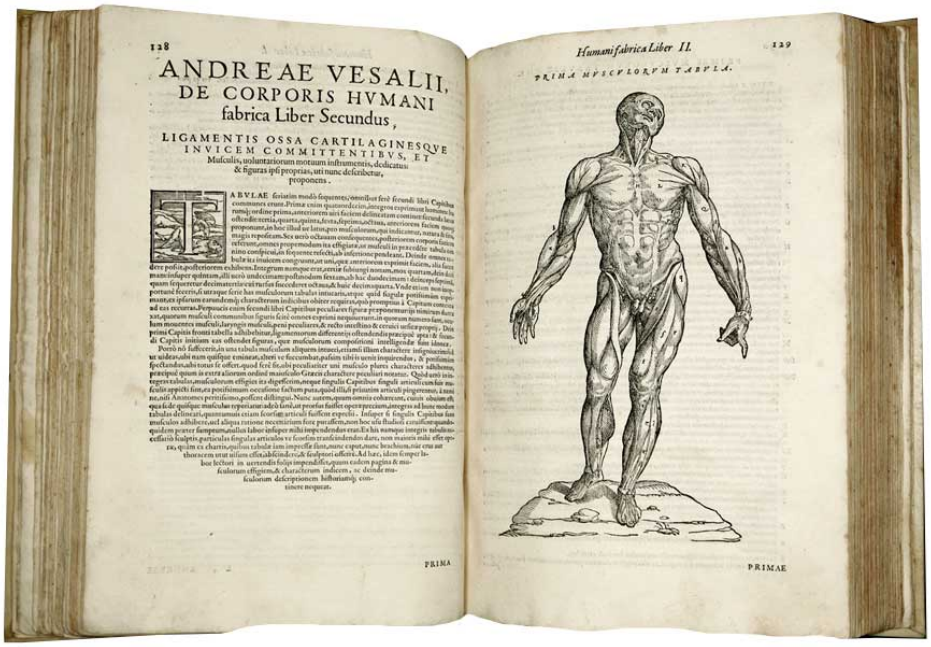


Figure 4-8. Two perspectives on the environment (redrawn from Ingold 1993), with a human figure inside the environmental "sphere" on the left, and outside the enviornemental "globe" on the right.). I redrew Ingold's original diagram using a male figure from Andreas Vesalius' *De humani corporis fabrica libri septem* ("*On the fabric of the human body in seven books"*) published in Padua, Italy in 1543 [pictured below]. Vesalius is noted for performing the dissection of corpses himself, engaging with the materials at hand in a break with common practice in the sixteenth century (Smith 2004:34). I use this iconic early modern male figure to underscore the specific histories informing collecting practices.



In a spherical perspective, Ingold suggests, the human being is set in the middle of a universe that extends outwards in a set of rings and spheres. In this perspective, the human is always embedded in the middle of a world that reveals itself through an interaction with its internal structures. In the global perspective, the world is constituted as an object apart from human beings that can be studied independently—a globe that exists outside the human subject.. Essentially, are we part of the world, or outside of it? The properties of the global perspective are very similar to the definition of reality and objectivity put forward by Thomas Nagel in his essay on (scientific) knowledge where "we may think of reality as a set of concentric spheres, progressively revealed as we detach gradually from the contingencies of the self" (Nagel 1989:5).

As represented in the GGI workflow, I see the museum as set apart from the natural world, but also entangled with it. It is neither in a globe or a sphere, but moving between the two—the Field, the Museum and the Public all exist as not-quite-discrete spheres of influence, overlapping at their borders as specimens and data, tissues and scientists move between them. In thinking through my own relationship to the "contingencies of self" in the creation of the GGI workflow, I also was adjacent and switched between modes of engagement. While I was a "conduit" for creating the GGI workflow diagram, I was also in many ways a contributor—the wording I chose to use to synthesize multiple phrases I heard, or the ways I chose to depict the objects of genomic collecting—I was both part, and apart, from the process as I visualized and "spoke" for ordering nature.

The ease or difficulty of specimens being taken apart by collectors into their museum-required components—of voucher specimen, tissue samples, and data sets—speaks to the importance of the biomaterials themselves, and these material qualities have shaped the disciplinary histories of how specimens are made, collections are formed, and scientific practices reinforced. Each discipline (Botany, Birds, Invertebrate Zoology, etc.) have their own set of these practices, and the various forms of standardization being introduced by genomics work (and funding opportunities) have to negotiate *how* to standardize at these boundaries, as discussed in the following sections on subsampling different kinds of tissues from the biorepository or from a bird skin, and the debates over what constitutes a "proper" voucher specimen.

These negotiations also happen at the borders between museum publics and museum research, particularly in how they are visualized and represented—as I learned through mapping the GGI workflow, debating what to show, how to show it, and if the hands of the scientist would be shown either literally or figuratively. In the end, the GGI workflow became circular, showing the flow of specimens, tissues and data circulating between domains. However, it didn't depict the materials and forces (Deleuze and Guattari 1987:370) that moved the objects, or any kinds of frictions encountered – the hands at work were left implicit. This resistance or ease of the particular kind of specimen to museum-ification speaks to what Anna Tsing calls the "sticky materiality of practical encounter" (2005:3). I read this as an attention to the details of how things, people and concepts stick together in unexpected ways—a focus that is aligned with my own interest in how *materials matter* in the making and reworking of the world. This "stickiness," as I discuss in the next section, can also lead to unexpected kinds of categorizations.

Extending the Collections: The Sticky Materiality of Practical Encounter

Many types of "stickiness" can be discerned in the museum, including the various and on-going frictions of different interests at work: obtaining collecting permits for expeditions to locations with convoluted bureaucracies, the logistics of transporting the samples and specimens in-county and then getting them across borders, of then processing the samples in the museum and tracking all the different permutations of the specimen, its samples and collections data, field data and lab data as different interests prioritize and evaluate each piece and part. Who controls the flow of specimens and data? How are those paths negotiated? How do the specimens change as they cross boundaries? In answering these questions I also encounter the "slipperiness" at work in the museum, the slippage between how the circulation of specimens and their data actually happen in the world, the way things slip through gray areas where protocols are written in black and white. According to one herpetologist, an expert on lizards, a common method for bringing back living specimens from collecting expeditions was to put them in carry-on luggage or carry them on your person where the snakes or lizards tied up in their cotton bags could breath, stay warm from body heat and easily be kept track of. This was before 9-11 he told me with some dismay, nothing like this would get past security now. He related one such an event.

On a pre-9-11 plane trip back to the US, he told me, his colleague had stowed several snakes in a pillowcase in his backpack. Although they had the required permits and import visas, they were unconvinced that the flight attendants would take kindly to their transportation methods. Actual snakes on an actual plane seemed unlikely to garner sympathy with the authorities. At one point mid-flight his colleague checked on the snakes and the herpetologist looked on with horror as his colleague frantically started rummaging in the bag with a stricken look. Apparently, one of the snakes was busy eating the other and his colleague was trying to pull them apart without inadvertently letting the snakes escape on the plane. "I tried to signal him to just let it happen," the herpetologist told me, "let it happen! Because of course we could always extract one from the other later after we euthanized them."

This episode struck me as an interesting example of two scientists in the same discipline categorizing the same "consumption" event as either catastrophic or inconsequential. I would argue that this slippage between specimens underscores the managing of difference—where one scientist's focus on maintaining each snake as a distinct specimen contrasts with the other scientist's long view where he could impart that same distinctness on the specimens post-mortem. "I would just add the event to the collection data for the eaten snake—you know, extracted from stomach of snake X on this date. *Not really a problem*. It wasn't going to be in there long enough to digest or anything. . . But the import permits might have been a problem if we had to explain where the other one went." He explained that numbers and scientific names for specimens have to match for the import permits, at least for some countries. "You never know when things are going to change though . . . maybe even when you're on your way back to the museum with specimens. It's happened."

Another incident of "border crossing" both literal and figurative involved bringing a collection of blue-ringed octopuses back to the US from a collecting dive in the coral reefs off the coast of Australia. The blue-ringed octopus (*Hapalochlaena lunulata*) is lethally poisonous, hard to capture and also very fragile—a poor combination for making a good specimen collection. The marine biologist in question had obtained permits for collecting and importing half a dozen live specimens for RNA research, which degrades quickly after the death of the

organism. Living specimens were the only way to complete her research, and against all odds she had managed to find, collect and transport the specimens as far as the airport, ready to fly home to her lab. To keep the water oxygenated, she had a cocktail straw that she used to aerate the water. If she had accidentally inhaled instead of exhaling she would not have survived. the poison acts very quickly, I was told. While waiting to board the plane she was blowing air into the octopus jar and noticed, to her dismay, that one of the octopi had died. Her traveling companion, another scientist with more years of collecting experience, grabbed the jar and quickly made his way to the nearest airport bar.

Ordering a double shot of vodka, straight, he removed the dead octopus and preserved it, much to the consternation of the bartender. “Better than nothing, given all the time and effort to collect it,” he told me. The two scientists, their jar of living octopi in one hand and the single pickled one in the other—all boarded the plane for the long trip from Australia to Los Angeles. At the airport in LA, permits in hand, they explained to the customs officers the scientific value of the specimens and the urgency of getting them to the lab as soon as possible. “It’s a ritual you go through every time,” another collector explained, “You tell them [the customs officers] what you’re doing, you show them what you have and in the end you just cross your fingers and hope it all works out. . . You get to know what airports to go through, some are good with knowledgable folks, others are black holes and you’ll never see your specimens again . . .”

The customs officer on this occasion was uncertain, and (according to the scientist’s recounting) when faced with the unfamiliar situation, the official decided to instead make it a familiar one. Importing octopus? The official asked them. Yes, they replied, nervous as to where this line of questioning was heading. Well, then, it’s seafood, sign here. Permit stamped, fees paid, the two scientists made their way to the lab with their bounty of lethally poisonous “seafood.” As Tsing writes “. . . it has become increasingly clear that all human cultures are shaped and transformed in long histories of regional-to-global networks of power, trade, and meaning” (2005:3). The various meanings of “seafood,” it seems, remain both a category both sticky and slippery.

Returning to the concept of scientific-epistemic objects—the Russian doll of

snake specimens, the “seafood” of poisonous octopi—it becomes clear that they are characterized by their state of continual (re)emergence, as seen in their negotiations across global borders, conceptual boundaries, and classifications of value both during their lives and afterlives. I now turn to focus on their afterlives in particular—the extended afterlives of historical specimens, and the details of “mining” genetics samples.

Mining the Collections: Toepads, Featherwork Capes and Genomes

May 2016. I’m at the Smithsonian Center for Conservation and Evolutionary Genetics (CCEG), tucked behind the National Zoological Park in northern Washington D.C. I’m here to meet with Robert Fleischer, whom I had first met at the Smithsonian Castle back in January at the Smithsonian SBGI launch. He had held up a honeycreeper skin for me to smell—“like an old canvas tent.” Returning to the bird study skins, I’m here to find out the details of how, exactly, one “mines” a specimen for ancient DNA.

Rob deals not only in bird toe pads and bone fragments, but extracts DNA from everything from a medicine ball unearthed in a second-century Roman archeological dig (“looks like a lot of alfalfa in there”) to plants used in making Hawaiian *tapa* mats (“the DNA was really fragmented, not much we could do”). During a lecture, Rob had shown an image of a Hawaiian royal featherwork cape, a dramatic ankle length cloak of bright yellow, red and black made from thousands of honeycreeper skins. “You see an ethnographic object,” he told the audience, “but I see a population sample of many thousands of honeycreepers from before avian malaria was introduced.” In the audience the Smithsonian’s Curator of the Pacific, a world-expert on Hawaiian culture and a steward of these treasured cultural artifacts in the ethnographic collections, visibly raised her eyebrows at the thought of the rampant feather-snipping. The proper use of collections would certainly be up for debate should Rob make a destructive sampling request to the Department of Anthropology.

Honeycreepers are one of Rob’s specialties, and the Hawaii *amakihi* is one of more than 50 species (over 30 of which are now extinct) of Hawaiian honeycreeper: a family endemic to Hawaii that vary in color, size, beak shape

and ecological niche. Posters of honeycreepers lean against the walls of Rob's office, on top of piles of scientific journals and papers. A complete *amakihi* genome will provide a better understanding of honeycreeper evolution and will also help conservationists in ensuring survival of endangered honeycreeper species. For his work Rob chose an individual infected with avian malaria. Very infected, it turned out. "One of the sickest birds I have ever encountered, but she survived . . . the fact that she has survived this long is a strong indicator that something about her genetics or physiology has allowed her to tolerate malaria better than other birds might . . . It also meant I could get malaria DNA sequences," Rob tells me with a slight smile, "Bonus." Malaria has killed untold thousands of birds, he tells me, and understanding how it affects them—and potentially how to help birds resist and survive it—is vital to the continued survival of the honeycreepers. Rob and his postdocs are now screening the genomes of more than 140 other individual *amakihi*, some malaria tolerant and some not, and related species, to search for the genes responsible for malaria tolerance (SCBI 2015).

We take a tour of the facilities, going through various labs in the new building next door with chest freezers full of samples and plastic bins from expeditions stacked in corners. The DNA labs look familiar, reminiscent of the Laboratories of Analytical Biology at NMNH, but on a much smaller scale. I note that PCR machines, pipette racks and centrifuges are starting to look commonplace and everyday to me, no longer exotic. It took more than ten years to sequence the human genome, Rob tells me, but as equipment and protocols have gotten cheaper, easier and faster, more genomes are being sequenced. The majority of these are either domestic animals (chickens, turkeys, and cows) or animals used as model organisms in research (zebra finch, fruit flies, rats and nematodes). With the increasing speed, ease and affordability of sequencing, more animals' genomes are beginning to be sequenced. Indeed, "It is often difficult or impossible to obtain materials suitable for traditional DNA analysis from endangered and extinct species. . . The CCEG's genetics laboratory has optimized a set of careful, controlled protocols to isolate and analyze DNA from older materials including museum specimens, mineralized bones (bones that aren't completely fossilized), and archaeological artifacts" (C.C.E.G. 2016).

As we return to the older building, the gibbons start to whoop and holler, echoing from their enclosure at the back of the zoo that sits adjacent to the CCEG. Back inside the building, we go to a compact room in the basement—the ancient DNA lab. “It may be tiny,” Rob tells me, “ but per square foot this room has perhaps resulted in more high profile publications than anywhere else in the Smithsonian.” The room is about 10ft by 10ft, with shelves and workbenches wedged in. Rob walks me through the process of sampling a toe pad from a bird for ancient DNA work: Wearing gloves and using a new sterile scalpel blade, you cut a small section off of a toe pad, then use the end of the blade to put the piece you’ve just cut off into a 2ml tube (also sterile, of course) [Figure 4-9]. “The process is actually quite simple,” he tells me, “it’s getting permission to take the sample in the first place that can get complicated.” Luckily, Rob has a very long and very good track record of getting good results from the samples he takes. This provides the cultural capital to get him into collections and to sample what he’s interested in.

This resonated with my conversations with staff across the museum, particularly collection managers who initially dealt with destructive sampling requests before they went onto the Department’s committee for review: If a scientist had taken lots of samples and not gotten results, the odds were against them getting more precious samples. Results here were marked not only by good data, but by published data—a paper in a journal with an acknowledgement of the Smithsonian, a piece of use-value to put into annual reports and budget requests, to keep the collections functioning. To get a sample to do your research you have to give back to the collection it came from, making sure the circulation of mutual benefit completes its circuit—with all the data formatted in a standardized format, tying together and making “legible” the work done across and between institutions. In other words, different kinds of information in the network needed to flow in multiple directions, to benefit all those involved. The NMNH Biorepository, it became clear during my fieldwork, was a key point in the ebb and flow of specimens, tissues and data. The millions of cryovials that fill the freezers and liquid nitrogen tanks hold not only condensed materials and values—visions for the future, frozen in time—but also implicit and explicit promises to the networks that collected those samples. I now turn to look closely at the practical details of subsampling these precious pieces of “latent life” (Radin 2013).

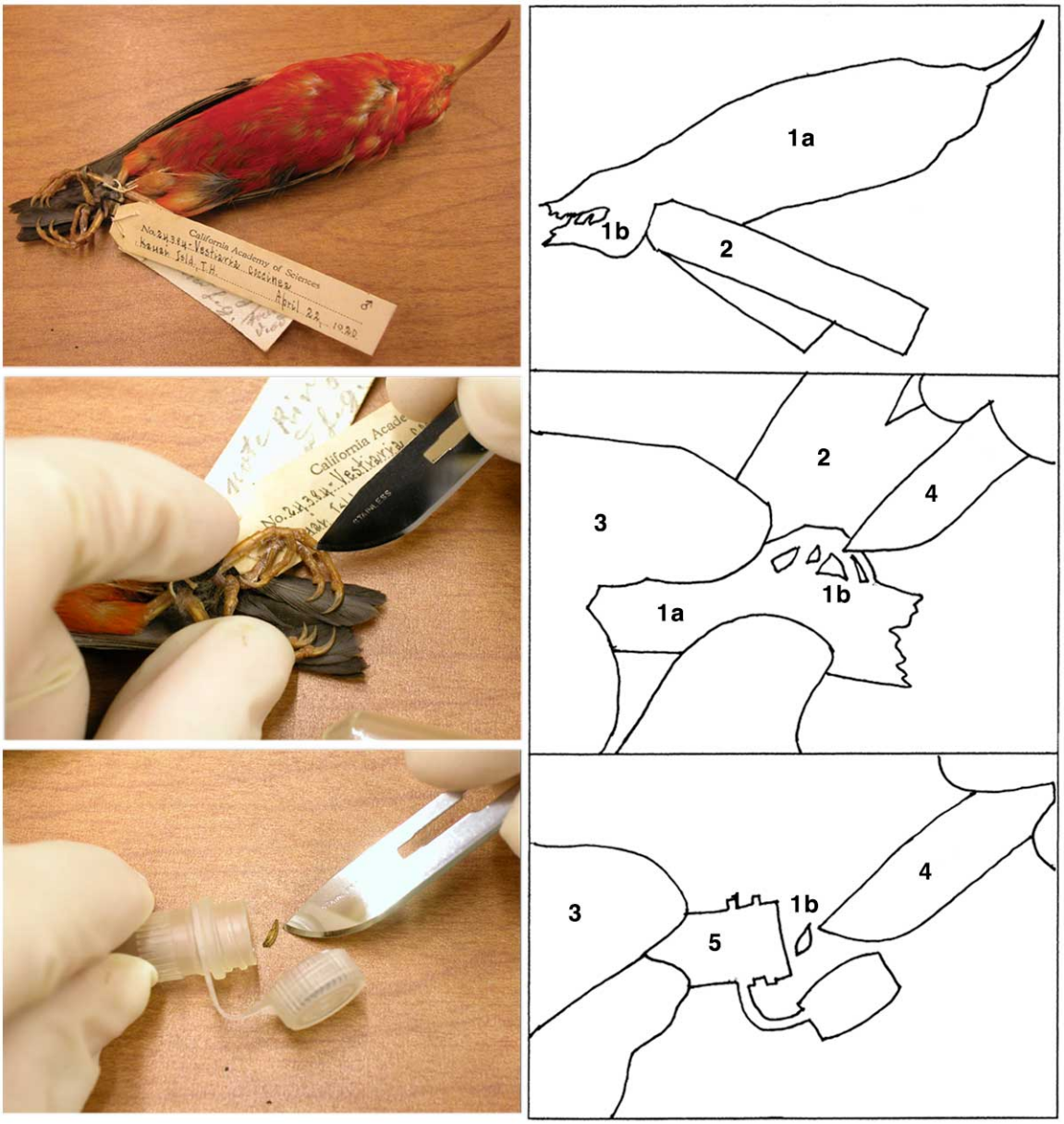


Figure 4-9. How to Sample a Study Skin: [1a] bird study skin - a male *ʻiʻiwi* or scarlet Hawaiian honeycreeper caught in April, 1922 (*Vestiaria coccinea*, California Academy of Sciences No.24384); [1b] toepad; [2] collection data; [3] sterile gloved hands; [4] sterile scalpel; [5] sterile tissue tube. (Photo: Jack Dumbacher, California Academy of Sciences; graphic by author)

How to Build a Biorepository, Part II

Sub-sampling Tissues in a (Genetic) Cabinet of Curiosities

March 2015. I'm standing on the top of a ladder holding a camera. To my left is a room of super-cold freezers and in front of me stretch rows of stainless steel tanks the size of small cars [Figure 4-10]. This is the Smithsonian Biorepository, capable of holding over 4 million specimens, though at the moment only two of the tanks are filled with liquid nitrogen and samples [Figure 4-11]. The rest of the tanks await samples from future collecting expeditions, which in turn hinge on the Global Genome Initiative (GGI) securing funding and the Smithsonian scientists securing access and permits for the sites worldwide where the desired categories of biodiversity are clustered.

Using liquid nitrogen requires certain safety requirements—it can be lethal if the liquid becomes gas, "sublimating" into an odorless, colorless cloud that replaces the oxygen in an enclosed space, that renders you unconscious and quietly suffocates you [Figure 4-12; Figure 4-13; Figure 4-14]. These constraints required that the Biorepository be built out in a specific section of the Smithsonian's Museum Support Center (MSC) in Suitland, Maryland. Other collections with particular requirements cluster together in this part of the MSC's building complex. The National Cancer Institute also needed space for their frozen collections, particularly to house their series of frozen cats with cancerous cells. Next door to the Biorepository, in a sealed cleanroom, the nation's collection of meteorites are kept in their own vacuum-sealed glass-fronted chambers. Down the hall silver nitrate film and negatives are kept in acid-free boxes in a cold, low-oxygen room to minimize the risk of their spontaneous combustion. In the midst of this constellation of wonders just beyond the walls—of tissue tubes, “cancer kittens,” meteorites and nitrate film—I focus my camera down towards the lab-coated figures below me, as their gloved hands organize the workspace in front of them [Figure 4-15]. I am here as both anthropologist and photographer, documenting the process of sub-sampling tissue in the Biorepository. The photos will become part of a training manual for the Global Genome Initiative.

Figure 4-10. Smithsonian Biorepository (December 2014)

Figure 4-11. Freezer room (Smithsonian Biorepository, December 2014)

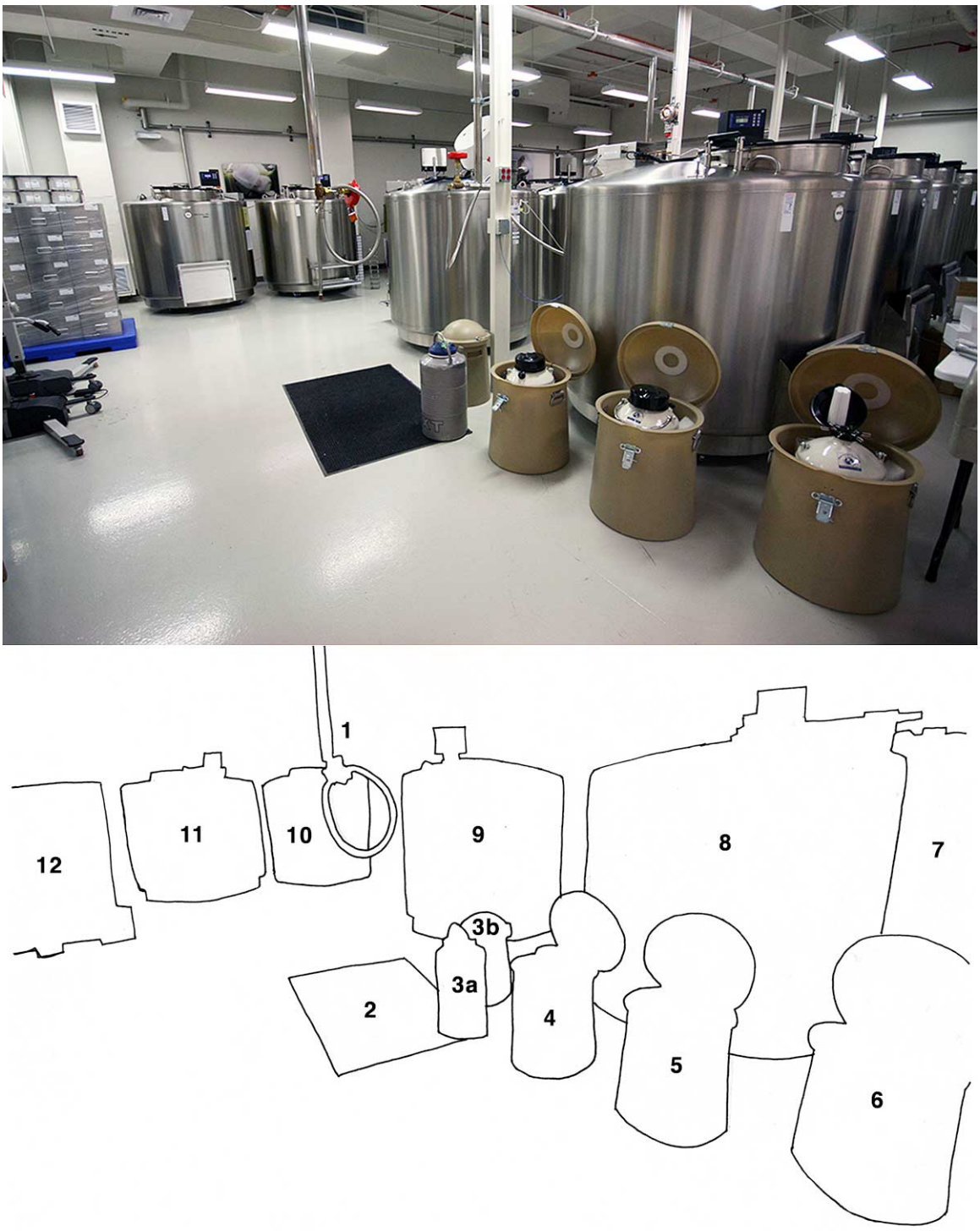


Figure 4-12. Anatomy of a Biorepository: [1] liquid nitrogen dispensing hose; [2] drip mat; [3a] dewer, inner tank; [3b] dewer, outer transport shell; [4-6] dewers ready for filling; [7-11] the liquid nitrogen tanks holding frozen specimens; [12] empty racks ready to fill up with specimens and store in the tanks. (Smithsonian Biorepository, December 2014)

Figure 4-13. GGI “tube wrangler” Steve Thornton filling a liquid nitrogen dewer.
(Smithsonian Biorepository, December 2014)

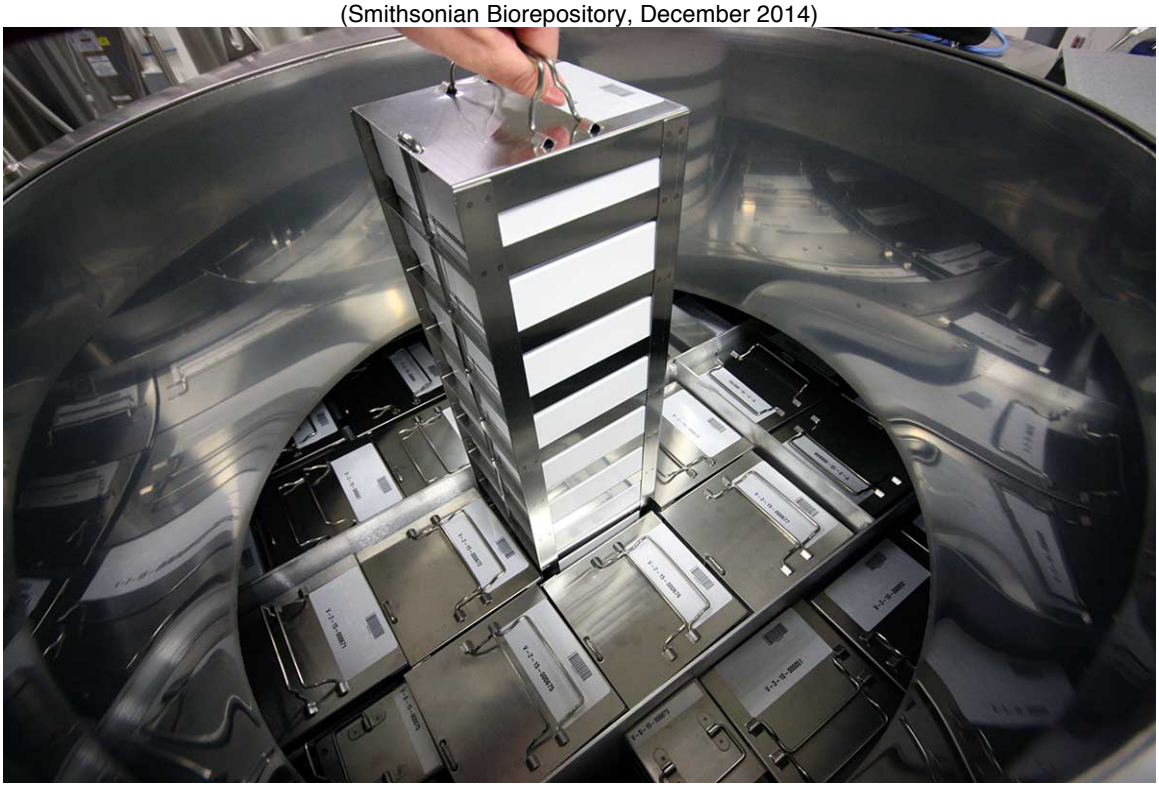


Figure 4-14. Empty racks inside a liquid nitrogen tank ready to fill with tubes
(Smithsonian Biorepository, December 2014)

Below me two people sit at a lab bench surrounded by boxes of latex gloves, coffee mugs filled with water and bleach, a pile of scalpels, small squares of tin foil and paper towels [Figure 4-16]. Between them sits a tub of liquid nitrogen with a tray of small plastic tubes [Figure 4-17]. Each tube holds a tissue sample.

On my left, a young man plucks a tube out of the tray, picks up a barcode scanner, scans the tube and checks it against a spreadsheet. He notes the number in a cell on his spreadsheet—yes, indeed, it's the correct chunk of snake tissue from Myanmar. He hands the tube to the young woman on his right, who double checks the barcode and then carefully unscrews the top of the tube. Holding a pair of tweezers she tries to remove the tissue, but it's frozen solidly inside and won't budge. She looks up uncertainly. "Hold it in your hand for a few seconds, but not too long—you don't want it to degrade. We need these things to be kept cold." The pair at the bench look up at the older scientists standing right behind them, overseeing the procedure.

The younger pair are being taught how to sub-sample tissues, a collaboration between GGI and the Consortium for the Barcode of Life (CBOL), another project at the Smithsonian focused on genetic collecting, but instead of genomic collections of tissues it collects DNA barcodes. The older scientist continues, "Figure out a workflow that will allow you to do it fast and accurately. You only need a tiny, tiny bit–most people chop off way too much (shakes head). Something half the size of a grain of rice will give you more DNA than you'll ever need. Save some for later—this may be all there is."

The precious resource of the cryovial is gripped in the young woman's hand and she manages to extract the lump of grayish-brown tissue [Figure 4-18]. Cleaning her scalpel in bleach to sterilize the blade (removing any DNA), she then dips it in water to clean it off. Moving a small square of tin foil in front of her, she carefully lowers the tissue lump onto the foil and slices off a tiny piece from the end. It clings to the end of the scalpel. She pauses, and looking up at the pair behind her asks "So, is it more important to get the sub-sample I just cut into a new tube or get the original sample back into the cold? Seems like you could lose track of what's what kind of easily." She's instructed to put the original sample back into it’s correct tube and get it back into the holding tray of liquid nitrogen as quickly as possible. It's at this moment that the sample is at its most vulnerable, at least since it was first created in the field or the prep lab. When the tissue lump is

Figure 4-15. Subsampling tissues (Smithsonian Biorepository, March 2015)

Figure 4-16. Frozen tissues floating in a tray of liquid nitrogen (Smithsonian Biorepository, March 2015)

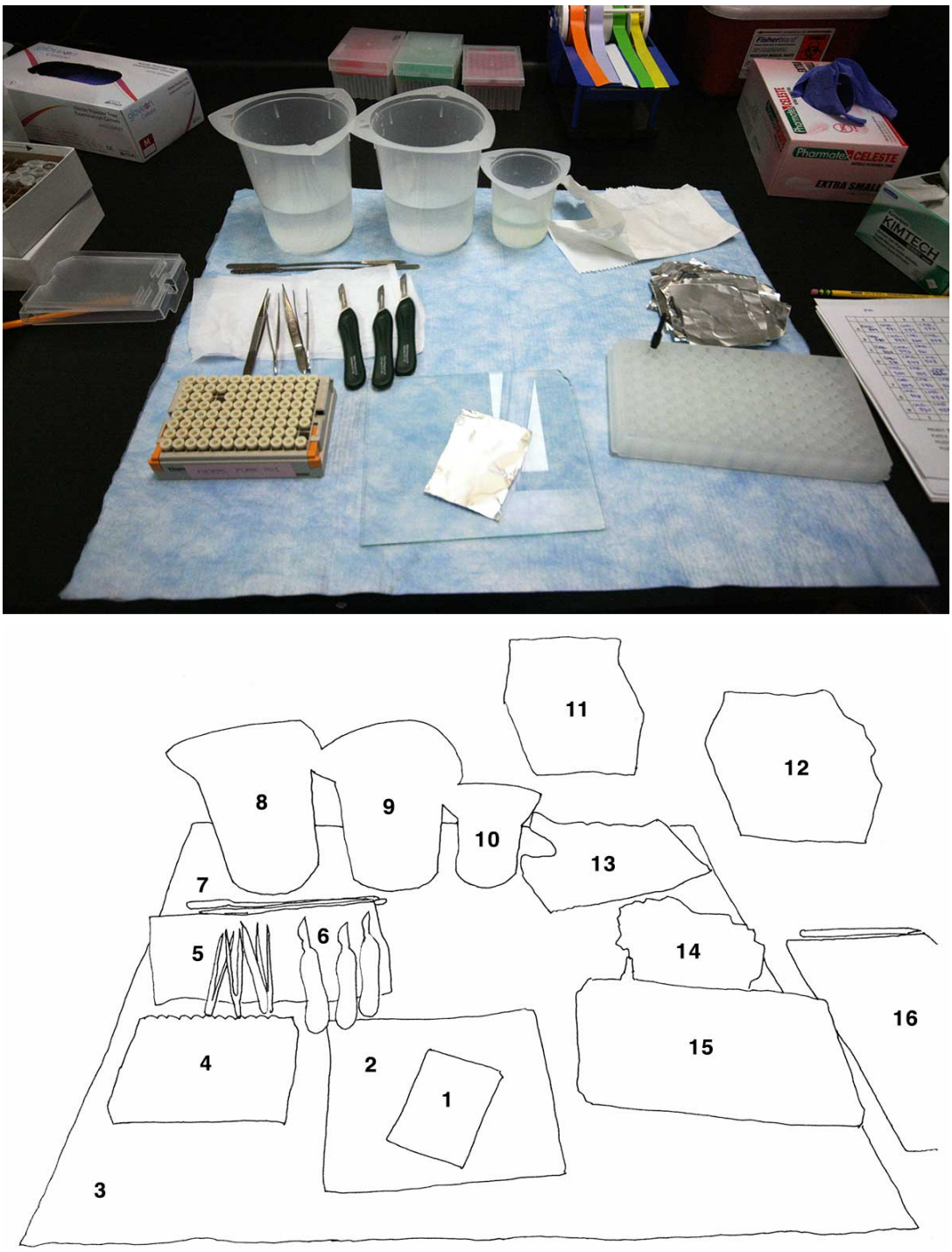


Figure 4-17. Anatomy of a tissue-sub-sampling workbench: [1] tin foil; [2] sheet of glass; [3] sterile absorbent mat; [4] frozen tissues in tubes; [5] tweezers and forceps on a sterile tissue; [6] scalpels; [7] tiny steel spatula; [8] water; [9] more water; [10] bleach; [11] colored tape to label boxes of frozen tissues; [12] the ubiquitous purple sterile gloves; [13] sterile tissues; [14] pile of tin foil for each new sub-sampling event; [15]96-well plate to hold sub-samples; [16] data sheet. (Smithsonian Biorepository, March 2015)

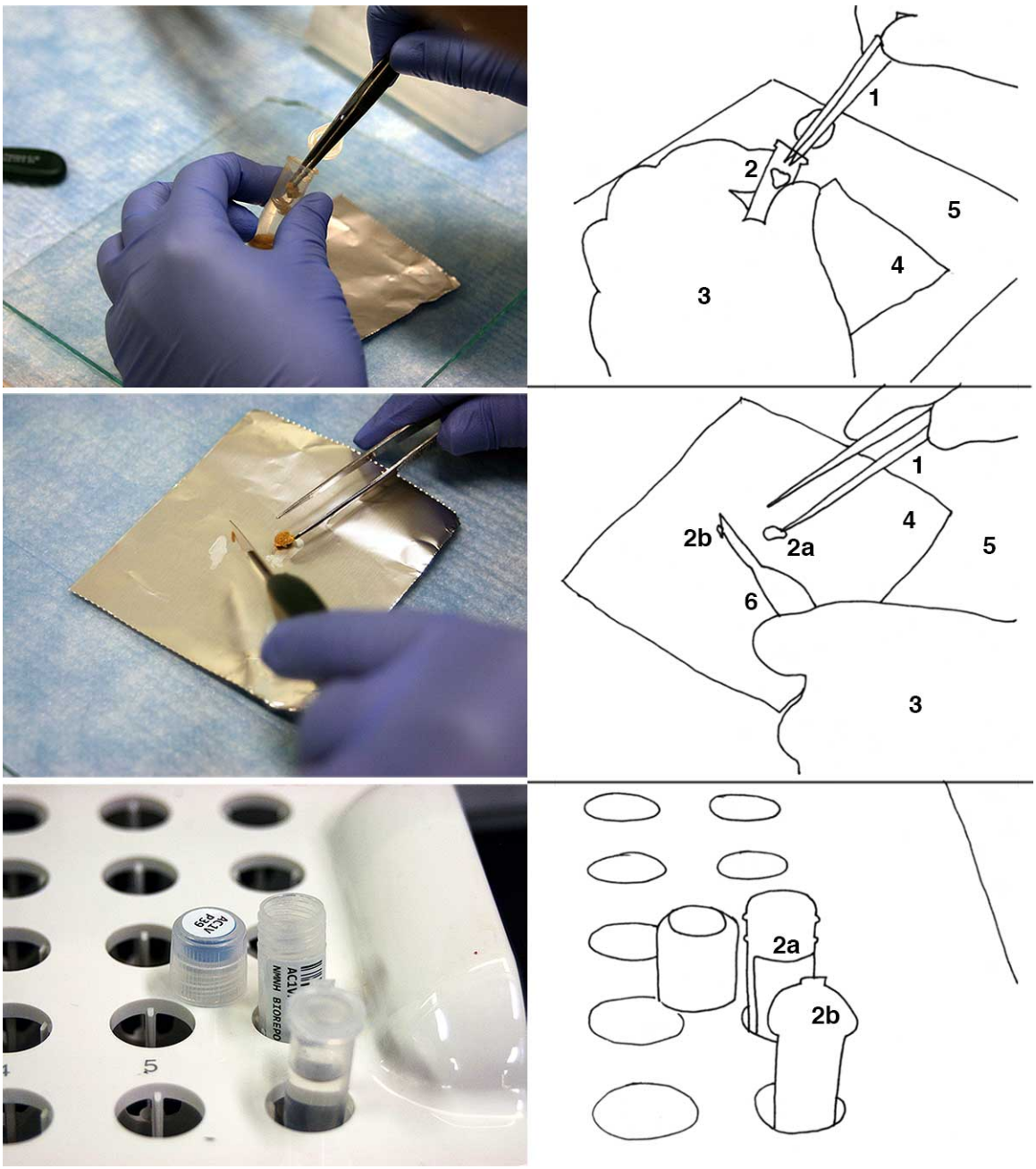


Figure 4-18. The process of sub-sampling tissue: [1] tweezers taking out tissue; [2] lump of tissue; [2a] tissue to go back into Biorepository [2b] sub-sample of tissue for use; [3] sterile gloved hands of the “invisible technician”; [4] tin foil; [5] glass plate to give a hard surface to cut the tissue on (Smithsonian Biorepository, March 2015)

separated from it's labeled tube, and from its assigned place in the rack of tubes, it has the most likelihood of ending up loosing its connection to the data. If this happens it will become, as one collection manager called it, "very expensive compost." Though the sub-sampled tissue is valuable, the original sample is far more valuable because it represents all possible future uses.

Encapsulated within the cryovial, I suggest, is a set of condensed materials, values, and interests. These include the accumulated efforts of museums and their collectors to gain lawful access to the specimen in the first place, a negotiation between nations and their institutional infrastructures. Then there's obtaining funding to go collect the specimen and transport it back to the museum, moving the parts and pieces through transportation networks of chance and happenstance—the imponderabilia of everyday life (Malinowski 2002) such as customs officials with their own ontologies, export/import permits with changing definitions, and the schedules of planes, trains, and FedEx schedules from remote locations. Once arrived, the tissue tube is sorted, labeled, catalogued and indexed into the various systems for tracking data across the museum, not all of which speak to each other in the ways staff would wish. After all this time, labor, effort and funding are invested in this tiny tube, it is then made "discoverable" for research to scientific communities the world over. At some future point the sample is found and requested, and the process of demonstrating a viable and compelling need to sub-sample the specimen begins.

All of these interests and actions are bound up, for example, in a tiny lump of liver, heart or muscle tissue, a clipping from a tail, toe or fin, or the leg of an insect. Such tiny pieces, no longer even distinguishable as part of the organism they came from, are *invested* with these values and interests. Keeping these bits and pieces of potentially "genomic nature" meaningfully attached to the appropriate data is key to maintaining their value status. One cannot tell just from looking at a molecular specimen what it is, unlike a morphological specimen whose purpose was to offer up data through visual measurement and analysis [Figure 4-19].

Though new uses for old collections of morphological specimens are ever-emerging, as discussed earlier, their ethos is one of visually representing their species, a moment in the life of the organism, its specific place and time, captured and preserved as a referent. The molecular specimen is always already

Figure 4-19. Labeled tubes ready to be filled (NMNH Biorepository, March 2015)

Figure 4-20. “Dummy” tubes of chicken liver and (authentic) Biorepository labels (Smithsonian Biorepository, March 2015)

abstracted, detached, separated and reduced; its value is signaled by the layered "frames" of the cryovial, tube rack, and freezer or liquid nitrogen tank. Without these the gob of tissue is waste or byproduct, indeed the demo tissue tubes used to show visitors how the system works are standard 2ml cryovials with biorepository labels, but they are filled with chicken liver scraps from the supermarket [Figure 4-20].

I feel a tap on my foot. Looking down I see one of the supervising scientists gesturing to the rack of tubes. "Did you get a shot of the scratched-on numbers?" I hadn't, so I clambered down from my perch and together we looked through the tube rack for the right specimen. "Aha." Holding up a standard tube, he pointed out the nearly invisible alphanumeric sequence scratched into the clear plastic. "I did that with a thumbtack in the field," he told me, "sitting in a makeshift hut 'field station,'" (he makes air quotes), "during a downpour. Specimens and tubes piling up, you have to get them done when you can. I couldn't find my roll of biorepository stickers—or sometimes you run out if you collect a lot, we're still figuring that out, as it's different between different Departments and Divisions—so it's better to do this than nothing. And of course the stickers can fall off in the [liquid nitrogen] dewer, so this is a backup. You always want a backup for field data. Always." He was referring to the on-going problem with the "stickiness of practical encounter," or in this case the very troublesome *lack* of stickiness between biorepository barcode labels and the plastic cryovials when placed in liquid nitrogen to ship back to the museum.

The friction in question here is the friction of the cryovials rubbing together during shipment and causing the frozen glue to come unstuck, resulting in several entire collecting expeditions returning home with shipments of unlabeled, blank vials mixed with free-floating labels. Several staff in the biorepository described the response from scientists upon learning that their many hours of meticulous field collecting (not to mention the funds to get to their fieldsite or the effort to get precious import/export permits), had been essentially erased, as "not good."

As one scientist told me, "I collected over forty species, fourteen families over the course of two weeks, collecting at night, carrying that heavy dewer everywhere, and finally getting it back through all the paperwork for *this* —now it's just gone." He was referring to the dewer full of his specimens in tubes, now free-floating in the nitrogen separated from their labels. The Biorepository has come up with a

functional solution, at least for the time being, of individually wrapping every vial in tin foil before it goes into the dewer.

This slows down collecting considerably, much to the dismay of those who go into the field to collect. "I used to spend my time collecting," one collection manager told me, "then at some point I realized I spent five times as much time doing all the genetic samples and recording all the data for each tube and all the other crap you have to do with that [the genetic samples], and it made collecting a lot less fun . . . It used to be the best part of the job, and then it just got to be tedious. Who wants that?"

Once back at the biorepository the vials are unwrapped, sorted into racks, scanned into the database, and stored. At some point in the (near or distant) future, someone finds the data about the sample, and a destructive sampling request is made. Once it finds its way through the review panel of curators from the department or division it belongs to, it is retrieved from the freezer or nitrogen tank and carefully extracted on the table in front me. How many species have crossed that table, a frozen menagerie on parade?

Packing away my camera, I spend the next few hours scanning tissue tubes, double-checking spreadsheets for specimen, field and Biorepository numbers and ferrying styrofoam coolers full of small cardboard boxes of tubes back and forth to the lab's freezer. We are making sure everything goes back into place. If the data gets disconnected from the specimens it becomes, in the words of one staff member "such a waste." He pauses, thinking, and adds, "even worse than just a waste—you end up with hazardous biomaterial." Based on the strict regulations governing the movement and circulation of plant and animal parts around the world, knowing what you have in your collection of generic little white tissue tubes is crucial, as is knowing where they're going and how they're being used.

Pausing briefly as I slot trays of tubes back into the lab freezer, I note the array of places these samples hail from: spiders from Costa Rica, fish from Timor, mammals from Brazil, snakes and lizards from Myanmar, the list goes on [Figure 4-21]. And the boxes in this freezer represent only what is currently being used in

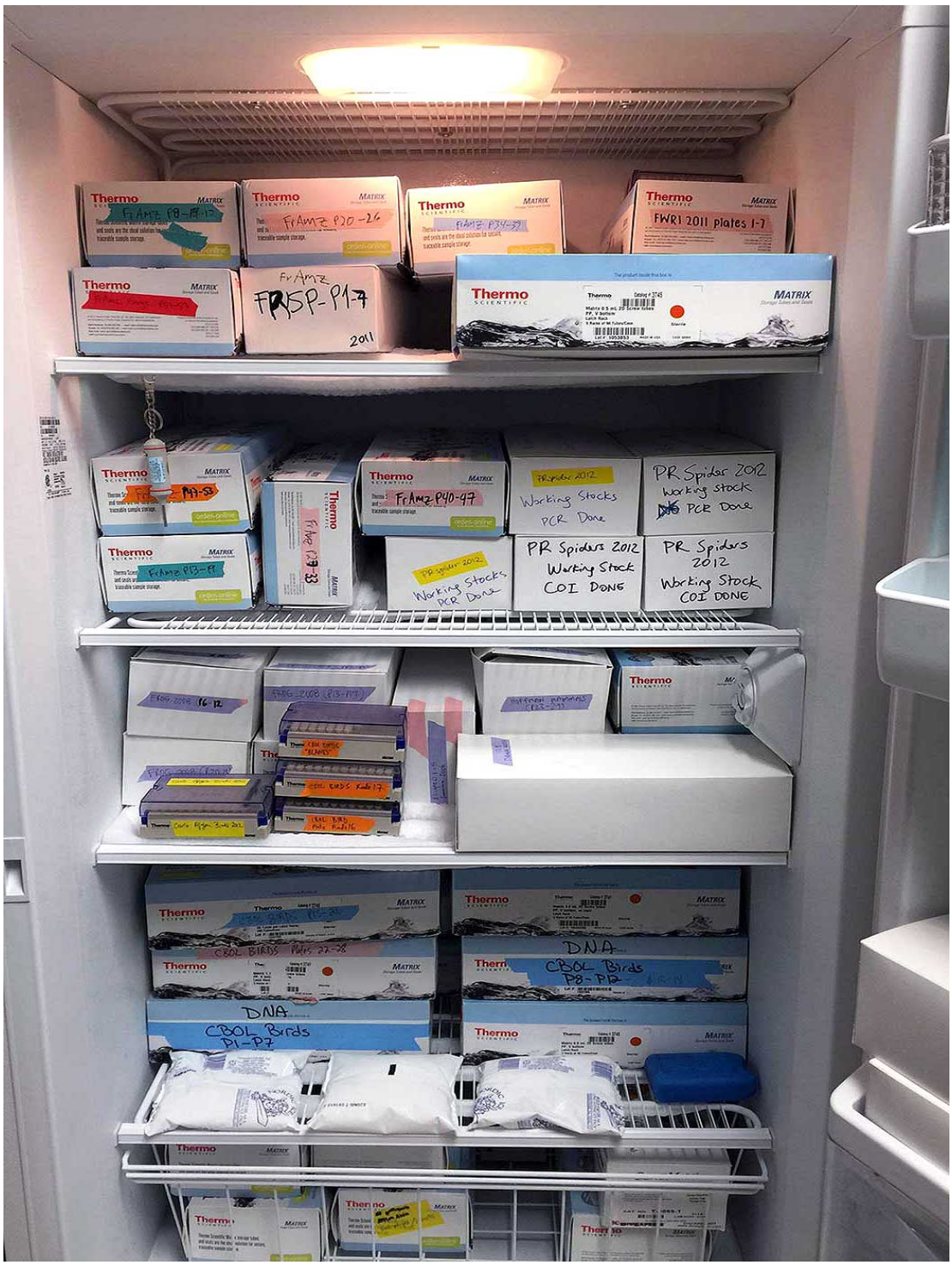


Figure 4-21. A freezer full of genetic samples – each box a project in progress, assembling the world's biodiversity into a frozen *wunderkammer.* (Smithsonian Museum Support Center Biolab, June 2015)

projects or legacy collections [38] still waiting to be integrated back into the main collections, the genetic portion of which is now (slowly) being centralized in the NMMH Biorepository.

The global assemblage of wild nature in this one lab freezer is but one of many at the museum—a mere fraction of the "latent life" distributed into hundreds of thousands of tiny plastic vials. These freezers full of trays of samples labeled with color tape and sharpie-scrawled text strike me as a contemporary form of cabinets of (genetic) curiosities, reassembling the world in (molecular) miniature. These tissue collections provide a source for imagined future uses, the possibilities for "mining" the collections expanding hand-in-hand with advances in biotechnology and the imaginations of new groups of "users." The *zoe* of "bare life" has been intricately transformed—through snipping a piece of a bird toepad or snake liver, through negotiating the threads of data to connect those pieces to a voucher specimen, through debating whether the tissue *itself* can be a voucher. Each vial now contains a small portion of *bios*, "qualified life" ready for multiple encounters in its afterlife.

Conclusion: Vouchers as Networks of Value

The exchange of specimens, their parts, and eventually DNA sequences, has lengthened the so-called "analytical chain" between raw material and information, I argue, and has introduced a further degree of fragility to the practices of taxonomic scientific inquiry. A genomic sample without a direct and transparent (clearly traceable) route to the voucher specimen, for example, becomes a meaningless artifact, or as one collection manager stated, "A voucherless DNA sample will only tell you that either the vials or data labels or your spreadsheet cells got switched, or worse that the specimen was misidentified before it flew away." Or as an entomology collections manager stated more bluntly, "The term 'genetic voucher' is an *oxymoron*. What's it vouchering? *Itself*? Ridiculous!" If high-quality taxonomic information is to be made available to a global network of

[38] Legacy collections, as discussed earlier in the chapter, are genetic samples that have accrued in Divisions and Departments across the museum over the last thirty years—sometimes donated by a scientist at the end of their career, sometimes collected for a project and often as research collections in curator's office freezers.

collaborators (such as the GGBN), such a material guarantor for otherwise "virtual" accounts of species becomes even more important.

This, as I will examine in the following chapters, has worked to raise the profile of the importance of voucher specimens stored in museum collections. It also highlights the fact that their epistemic and “ontological” status is a micro-managed achievement, negotiated on a daily basis through both *verbal* and *material* means in each Division and Department across the museum. Furthermore, the alignment, through genomic collecting, of systematics with bioinformatics and genomic technologies and approaches to knowledge production has introduced debate concerning what kind of specimen – whole or part, or extract of part – counts as a voucher able to provide legitimate back up for genomics research. It is essential, I argue, to consider the fragility of the genomic collection and the work undertaken to render it as a meaningful and "lively" object, as these moves are integral to the creation and circulation of its different forms of value. To explore these themes in greater detail, I now move from the interlaced networks of vouchers and tissues into the bodies of birds. I examine the value shifts at boundary crossings of bird parts, pieces and parasites. Value, within the context of museum specimens and their use, is relative.

Chapter 5

BOUNDARIES/BIRDS

Flight Paths Through the Museum

boundaries—something that indicates bounds or limits; past tense of "to bind," i.e. to fasten around; fix in place.[39]
birds—warm-blooded vertebrates of the class Aves, having a body covered with feathers, forelimbs modified into wings, scaly legs, a beak, and no teeth, and bearing young in a hard-shelled egg.[40]

To learn from experience is to make backward and forward connections between what we do to things and what we enjoy or suffer from things in consequence. Under such conditions, doing becomes a trying, an experiment with the world to find out what it is like; the undergoing becomes instructions—discovery of the connections of things.
— John Dewey (1916:147)

From standards and data, to tissues and networks, I now shift into the second section of the dissertation where I focus on three kinds of traditional specimens, each with different properties, practices and disciplinary histories: birds, beetles and trees. In this chapter I begin with birds, scaling down from the interlaced web of data and global networks of vouchers, tissues, data into a closer focus on a specific set of bird bodies. This move also entails scaling up from the minute space of the tissue tube, the subsampled tissue or a bird's toe pad, into a complete organism—a whole bird that I then take apart into multiple pieces for multiple purposes.

The process of making specimens is a process of manufacturing difference—making parts of the natural world discrete in specific ways to do specific work. Through the process of learning to craft bird specimens I have observed the crafting of difference and followed the on-going assemblage of techniques, technologies, interests and differently valued forms of labor that go into making and remaking collections. In this chapter, I examine how to "build a bird" in three ways.

[39] Online Etymological Dictionary (http://www.etymonline.com/index.php?term=boundary)
[40] Oxford English Dictionary (http://www.oed.com/index_php?term=bird)

I begin by preparing my own bird study skin (*How to Build a Bird, Part I*). Through learning to prepare a duck study skin and take a variety of tissue samples I examine first-hand the negotiations around integrating genetic sampling protocols into specimen preparation in the Division of Birds, thinking through the hollowed-out bird skin as a literal and figurative Body without Organs (Deleuze and Guattari 1987:161). I then follow the pieces of disassembled birds along their various circulations through the museum, what I think of as their "flight paths."

In the second section (*How to Build a Bird, Part II*) I track feathers to the Feather Identification Lab, tissue samples to the Biorepository, skeletons to the synoptic collection in the Division of Birds, and toe pads sampled from historic study skins to outside laboratories. I examine how and why the voucher specimens, tissues, DNAs and datasets circulate to laboratories, databases and to other museums, the types of value they accrue along these paths and their function as "boundary objects" negotiating meaning between disciplinary borders (Star and Griesemer 1989; Star 2010).

Finally I turn to some "entangled specimens," following the extraction of parasites from bird carcasses for the U.S. National Parasite Collection—a collection recently relocated to the Smithsonian. I return to the inside of the bird during preparation of a study skin, specifically to the intestines. These discarded innards become, for parasitologists, a fieldsite where they hunt for nematodes and tapeworms—a transformation of biowaste from the Division of Birds into valuable specimens for the National Parasite collection (*How to Build a Bird, Part III*).

Through these encounters I focus on circulation and the movement of specimens, data and concepts through the museum and beyond, looking at the structures of knowledge that are created as specimens move between contexts and disciplinary domains—from field to freezer, from lab to collection, from Birds to Parasites. These boundary crossings provide a view into the ways value is produced by context shifts, and of the labor required to transform *meat into meaning* and produce specific kinds of "natural order."

Histories of Collecting and Folding Time: A Bird Skin as a Time Capsule

Preparing a traditional bird study skin, according to several curators in the Division of Birds, is like "keeping the wrapping paper and throwing away the present." That is, the most valuable "body" of information is the actual bird's body, which is removed from the skin and discarded. The hollowed out skin is then stuffed with cotton wool and sewn shut, as I will show, the spine replaced with a wooden dowel. Some bones remain, such as the skull, some partial wing and leg bones, but what is considered most valuable at this present moment of zoological science—fresh heart, liver and muscle tissue samples—were traditionally discarded.

In current practices, tissue samples are taken and carefully preserved after which the majority of the body is discarded. However various curators, collection managers, and technicians in Vertebrate Zoology are going, as one curator called it, "the way of the fishes." The Division of Fish and Reptiles have traditionally "pickled" their specimens, that is "fixed" them in formalin and then preserved them in sealed jars of either 70% or 90% ethanol. This has the advantage of preserving the entire organism, including its digestive tract and the organism's last meal. The organism then becomes a tiny microcosm of its environment, preserved as a moment in time.

"Time capsules, that's what collections are," one curator told me, "A window back in time, if you know how to get what you need out of them. And of course if you can get the permission to get it out in the first place." The pickled specimen can be X-rayed, micro CT scanned or genetically sampled later—though the DNA may be quite fragmented by the formalin and requires ancient DNA techniques to stitch the sequences back together and produce "meaningful" data (as examined previously in my exploration of natural history collections as data sources). While these practices in different zoological disciplines have long histories—which have shaped their ways of making and ways of knowing—they each concentrate global biodiversity into a local museum setting where order and value are negotiated.

In previous chapters I have argued that scientific objects—in this case genomic tissue collections and museum specimens—were far from neutrally composed, and take on and perform multiple layers of meaning and value as they travel in

and between different sites, communities of practice and epistemic expectations (Bowker and Star 1999; Knorr-Cetina 1999, 2013; Lampland and Star 2009). I further suggested that the complexities of the biographies of scientific objects could contribute to the value they accumulate (Daston 2000b, 2004a; Graeber 2001; Rheinberger 2000). In order to return to this point, I underline the argument (rehearsed by many), that classificatory systems—rather than providing passive representations of natural order(s)—are re-shaped by preferred imagined human relationships to the natural world and in turn play a performative role in shaping human relationships to nature. From this standpoint, I now turn to preparing a bird study skin myself and tracing the shifting value of a bird carcass when it becomes a site for "mining" the parasite collection. Finally, I explore the bird collections as a context for these events, examining the kinds of preparations and practices that bind it together as a discipline.

A bird, I discover, can come apart in the back rooms of the museum in many ways for many purposes.

How to Build a Bird, Part I:

Prepping a Bird Study Skin and Folding Time

The semi-frozen duck is laid out on the table in front of me. A small round tag is tied to its left foot. "Don't lose that," Says Christina Gebhard, the museum preparator who's teaching me how to prepare a bird study skin. "That's the field tag. If that gets separated it's a bad thing. A very bad thing. All the time and effort and money that went into collecting that bird will be gone. A total waste." She pauses. "So don't lose it, just saying." I looked down with renewed appreciation at the half-inch circle of cardstock with its careful script of initials and numbers. The thread binding specimen to data—which I used as a metaphor when talking about collections as resources and the networks of tissues—in this case was an *actual* piece of cotton upholstery thread tying data (field label) to object (bird carcass). "[T]hings," as Tim Ingold points out, ". . . [are] not just one thread but a certain gathering together of the threads of life." (2010:10). The gathered threads of data networks, I was discovering, were tenuous in their many forms—from breaking a database of collections information to breaking a thread between label and specimen.

The lab coat I've found to wear in the Vertebrate Zoology Preparation Laboratory (VZ Prep Lab to the locals) is decidedly different from the color-coded and logo-embroidered lab coats of the L.A.B. This one is ridiculously large for me—but they all were as I looked through the cluster of coats hanging on an antique oak coat rack in the corner of the room. They had what one might generously call a "patina" from the activities of the room—disassembling and reassembling birds and mammals. Bloodstains, cornmeal "dust," even one with a large egg yolk stain down the front. "One of the interns found eggs in the oviduct when he was prepping. The shells were softer than he thought," Christina said shrugging her shoulders. I was reminded that "things leak" (Ingold 2010:4), in this case quite literally. And even the smallest birds (two-inch bee hummingbirds, *Mellisuga helenae*) have more to leak in terms of collecting "genome-quality" tissue than the largest beetles (four-inch Goliath beetles, *Goliathus goliatus*).

The soft-shelled eggs had broken in his fingers and rained down the front of his lab coat, leaving a yolky smear. The lab coats in the Laboratories of Analytical Biology (L.A.B.) perhaps had a little smudge of agarose gel or a drop of buffer on the sleeve. They remained white. The blood and guts, feathers, fur and viscera of the Vertebrate Zoology prep lab—the materials in circulation—left their mark. Dozens of albatross had been prepped earlier that winter for an isotope mapping project, taking tiny samples from bones, feathers and tissues for analysis in the L.A.B., or its equivalent at collaborating research institutions. These delicate extractions (snips of feathers, pieces of tissue, fragments of bone) were in sharp contrast to wrestling with carcasses that had six-foot wingspans as they were transformed into study skins. As one of the Bird curators described it, "you should have seen it—the feathers were flying!" as she spread her arms out as wide as they would go. Different practices left very different traces, I was learning, material remnants that I could follow through the museum.

The VZ prep lab was quieter today. An intern sat next to me at the long black lab table, Christina across from us with her eagle eye on our (slow) progress. Her hands moved in a blur, bright yellow and black feathers flashing as she twisted and turned a Meadowlark's limp body [Figure 5-1]. At the other end of the table a contractor worked on a collection of small brown and blue birds that he extracted one by one from a large plastic bag. Behind us one of the technicians from the Feather Identification Lab pinned out wings onto a foam board, arranging

Figure 5-1. Making a Meadowlark
(Vertebrate Zoology Prep Lab, Smithsonian NMNH, January 2015)

feathers with tweezers after he'd "anchored" the wing with pins into the right shape [Figure 5-2; Figure 5-3]. My duck lay in a limp mass in front of me, feathers ruffled with small blood spatters here and there.

Tools and Materials

Christina was pointing out the features of the room I'd be using in my bird prep. On the end of the table with the wing-pinning tech was a plywood box with a steel brush on a wheel and a plexiglass top—"the fat wheel, you clean the skin inside out. Otherwise bugs will eat all the fat, bits of muscle, whatever—and destroy the skin. There are drawers [in the collection] that are nothing but [feather] fluff and frass [beetle feces]. We haven't used arsenic for many years, so you have to clean things out really, really well. And ducks are just packed with fat . . . so you'll have fun," she says with a grin.

Behind the fat wheel a stainless steel sink is piled with enamel bowls for washing out the bird skins. A large wooden cabinet with mesh doors, reminiscent of an outsized Victorian pie safe, is full of foam boards with finished skins pinned out to dry. The African porcupine I had helped Suzie Puerach, the Mammals tech, prep several weeks earlier wouldn't fit in the cabinet. Its flattened face stared back at us from the rear workbench, where it lay pinned out with a fan pointed towards its stubbornly slow-to-dry form.

To our left were several refrigerators filled with plastic bags full of thawing birds and mammals, the freezers holding trays of tissue tubes [Figure 5-4; Figure 5-5]. "Keep the doors closed so they don't melt," I'm told. "Chris [the Biorepository manager] hates it when they have too many temperature changes. Degrades things." A chest freezer next to the fridges holds black garbage bags full of the extracted viscera, half-lumps of bodies and skeletons to be discarded. "Technically it's biohazard," Christina tells me, "so we have to discard it in a particular way." While the bird is intact as a frozen specimen, as a tagged animal in a plastic bag, it moves across borders as a discrete unit. However, I discover that once I, in my role as specimen preparator, open the bag and take the bird apart, those different pieces are assigned completely different categories of meaning and value. The hollowed-out skin is valuable if I'm making a study skin, and the carcass becomes biohazardous waste. Unless I'm making a skeleton

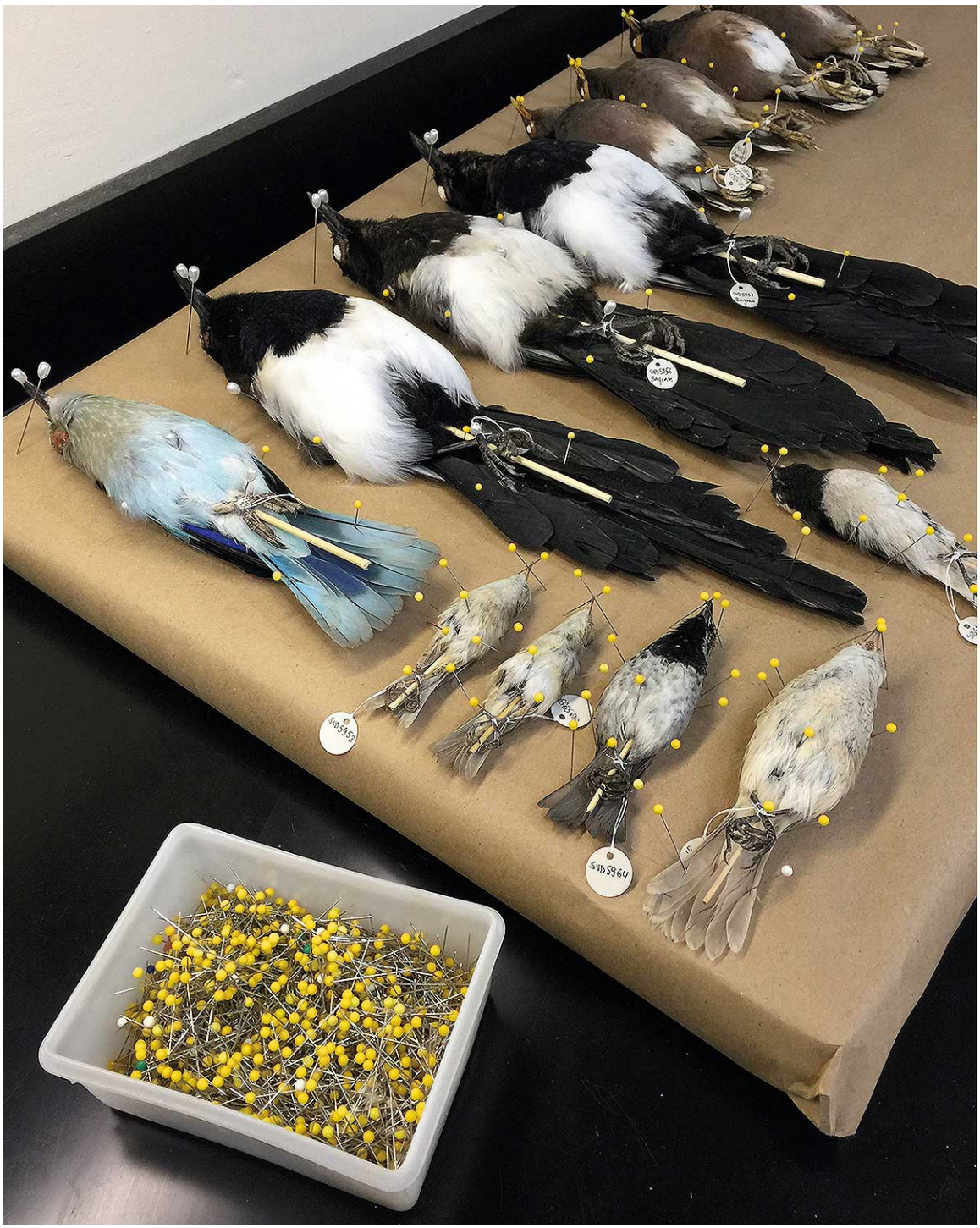


Figure 5-2. Completed skins drying in VZ prep lab
(Vertebrate Zoology Prep Lab, Smithsonian NMNH, January 2015)

Figure 5-3. Completed skins drying in VZ prep lab
(Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

Figure 5-4. Tissue samples in the VZ prep lab freezer
(Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

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Figure 5-5. Frozen birds in paper cones, to keep plumage from damage
(Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

preparation in which case the skin and feathers become biohazard and the bones become the precious commodity to be extracted. In both cases small pieces of tissue are taken for the Biorepository, but while one small fraction goes into a tube and becomes valuable—requiring an application to a Committee on Destructive Sampling to access—the majority of the carcass is thrown away. Sometimes the about-to-be-biohazard carcass passes under the hands of a parasitologist before its end, however this is another part of the life history of the bird body to which I'll return later on.

For now, I'm directed to a yellow 50-gallon barrel sitting next to the freezer, and instructed to open its hatch: "Open it, make sure there's enough 'dust' [finely ground cornmeal], and pop your skin inside." The tumbler slowly rotates, churning dust into the skin, removing the moisture. "Or use the Utz jar," the Feather Lab tech, Jim Whatton, says from the table behind us, holding up a big plastic jar that once held potato chips—now full of cornmeal "dust" and a bird skin. He shakes the jar for effect, smiling, while the bird skin inside bounces in a cloud of yellow dust. In front of the fume hood were three metal trashcans on wheels, labeled *Salt*, *Saw Dust* and *Excelsior* (wood wool traditionally used in specimen stuffing) [Figure 5-6]. "We don't really use that anymore but you can see it sticking out of some of our older specimens. They used to use a ton of arsenical soap too, but like I said we can't do that anymore. . . . Just means more maintenance, checking the collections front to back all the time [to look for pests]." Small changes in the methods and practices, even for ethical ends—such as ceasing to use arsenic (for the health of the museum staff) to adding tissue collecting to study skin preparation (to preserve biodiversity for the future)—had implications for daily life in the making and maintenance of the collections. No arsenic meant more time visually inspecting the cabinets for beetle droppings, while collecting tissue samples meant more time per bird skin. The workload, however, didn't shift to adjust for these new claims on time, a complaint I heard repeatedly across departments and divisions.

Glass-fronted cabinets along the back wall hold dowels (used to replace the spines in stuffed skins), piles of cotton wadding in different weights and textures, bins and boxes with intriguing labels such as "eggs pins," "feathers," "Djibouti 2014," next to boxes of latex gloves, an enamel tray holding cleaned bones ready to be labeled [Figure 5-7] and possibly articulated into a skeleton [Figure 5-8],

Figure 5-6. Excelsior (wood wool), Salt, and Saw Dust (“dust”)
(Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

Figure 5-7. Cleaned bones (Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

Figure 5-8. Skelton mount of an eagle, Division of Birds
(Vertebrate Zoology Prep Lab, Smithsonian NMNH , February 2015)

and a collection of cigar boxes, metal tins and tupperware—these last holding each tech's individual prep kit [Figure 5-9]. "You do not mess with someone else's prep kit," I'm told with a stern look. I took this seriously, and was meticulously careful when I photographed the different kits of the VZ Prep Lab, only fully unpacking the kit I had been loaned [Figure 5-10].

Flight Paths:
Intersections of the Technological and the Biological

What struck me most about the assembled tools and furniture in the room was the tangible history of place that emanated from them. The drying cabinet with its creaky mortise and tenon oak doors and brass hinges looked like it had been built by the museum's cabinet makers in the 1870's—and it probably had been. There had been a department of Ornithology since the early beginnings of the museum, and the first Secretary of the Smithsonian, Spencer Fullerton Baird, had been an ornithologist. Even the newer additions of the fat wheel with its simple handmade plywood box showed a long history of use—chipped edges, the plexiglass on top starting to yellow with age.

Looking at the trashcan of Excelsior one of the techs says, "We never throw anything away do we?" "Of course not," another replied "We're museum people." When I asked about the cigar boxes and the tupperware prep kits, I was told that some were passed down, most people arrived with their own that they'd assembled over time, but everyone had their own. This collapsing of time—patina of old against shiny new, juxtaposed but also in parallel use, different parts of a process changing ever-so-slowly—was a recurring theme in the Vertebrate Zoology prep lab, and indeed across many spaces of the museum. At times, it became disorienting, this play of time stretching and folding back on itself. It was also in these moments of contrast—of twenty-first century superglue and tissue tubes in the prep kit alongside nineteenth century cotton and wooden dowels—that caught my attention, signaling a shift in practices. However, these new practices were quickly becoming "natural" to the museum staff. "I don't even notice anymore," one preparator told me, "making study skins just looks normal to me now . . . Taking [tissue] samples will probably be that way too," he pauses, " eventually."

Figure 5-9. Taxonomy of specimen prep kits,
(Vertebrate Zoology Prep Lab, Smithsonian NMNH, January –August 2015)

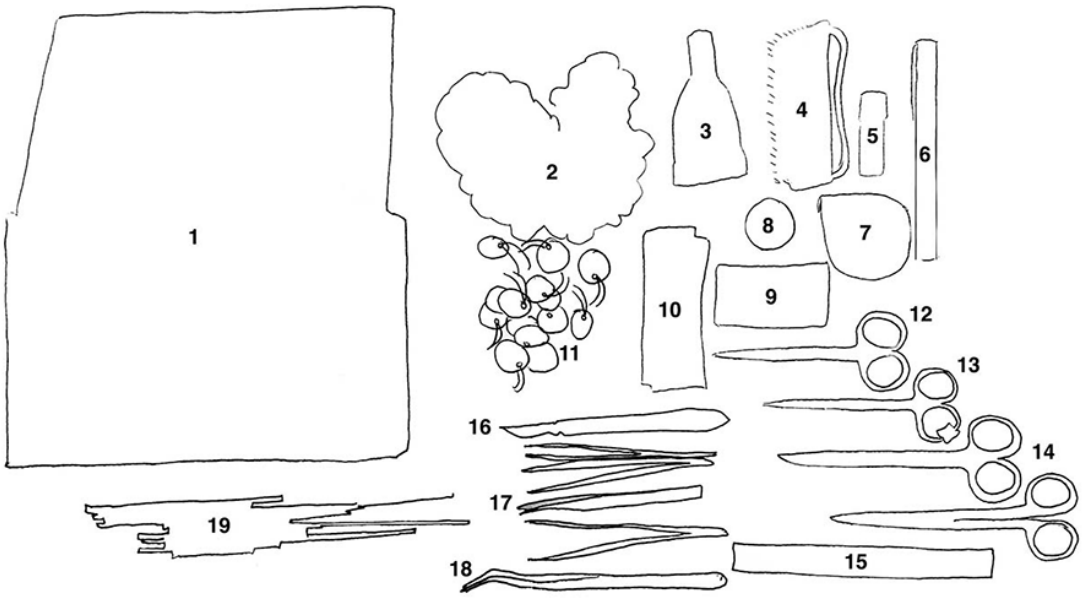


Figure 5-10. Items in the specimen preparation kit: [1] Cigar box; [2] Cotton wool; [3] Superglue, bottle with precision applicator tip; [4] brush for removing corncob “dust’ from feathers; [5] tissue tube; [6] Sharpie for marking tissue tube with collection number; [7] measuring tape; [8] cotton thread; [9] sewing needles; [10] scalpel blades; [11] identification tags, pre-strung with thread; [12] pointed scissors, medium; [13] pointed scissors, small; [14] round-tip scirssors, two pairs; [15] plastic ruler, marked in mm; [16] scalpel; [17] pointed tweezers (one featherweight), four pairs; [18] angled tweezers; [19] wooden dowels and bamboo skewers, to use in wings and as ”backbones” in smaller birds. (Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

It is useful here to think briefly about the material aspects of things being ‘‘in play,’’ that is, constantly generative of new circumstances and resulting consequences—such as collecting tissue samples, and Departments creating new data types to link these samples to the correct voucher specimen. The writings of Deleuze and Guattari (Deleuze and Guattari 1987, 2004) have been an influential example of generativity despite various insightful criticisms from feminist scholars of science (Haraway 2003). In *A Thousand Plateaus* (1987), the authors celebrate the interaction of the technological and the biological in a way that forces a rethink of the generative potential at the intersection of technsocience and the “lively.” Thinking through this “liveliness,” or at least the potential for liveliness as I held the internal organs of the duck in my hand, I extend this into the liveliness of material things. The heart of the matter, in this case, was an actual heart. Or a very small section of a heart, accompanied by slices of muscle tissue and liver, carefully pushed into the bottom of a 2ml plastic vial so they didn’t squeeze out when the top was screwed on (life, once again, at risk of spilling over its frame). This was also a (bird) Body without Organs (Deleuze and Guattari 1987:161), both literally and figuratively—a concept to which I explore further on in the chapter.

An important aspect of generativity is the distinction, made by Deleuze in *Difference and Repetition* (1968:146–148), between depiction of the world, on the one hand, and creating the conditions under which new things come into existence, on the other:

‘‘[I]f our objective is to depict the world, then, no matter how rich the world appears to us, we will only have as tools what already exists or what has already taken place. However, if we are concerned with thinking about the conditions under which new things come into existence, we can actually see ourselves become part of those creative happenings—part of the bringing of ‘something to life’’’ (Deleuze 1968:147).

In re-conceptualizing the boundaries between humans, things and technologies, and further in “troubling” our received knowledge about control, they place animate and inanimate life into what Fujimura and Clarke call a new ‘‘philosophy of becoming’’ (1992:30). This opens up an understanding of social theory by emphasizing not only the play of words, but the ‘‘play of the world’’ and the (bio)materials through which knowledge is produced and negotiated (Deleuze and Guattari 1987:69 cited in Fujimura and Clarke 1992:31).

The generative potential of a tissue sample, then, is balanced uneasily at the border of animate and inanimate. It was, on the one hand, just little bits of meat.

On the other hand, these little bloody fragments held the potential for multiple technological unfoldings in the future—the extracted DNA assessed and amplified, mapped and assembled, and then circulated to databases the world over. *Meat could be turned into meaning*. My bird skin would not fly under its own power ever again, however in one sense its migration paths were far from over—as some parts of it would continue to move in the world, crossing boundaries and borders and being transformed along those "flight paths" in and beyond the museum.

Making a Bird Study Skin: From Meat to Meaning

The process of crafting a bird study skin broke down into roughly eight processes, or more precisely into eight clusters of processes: [1] Measuring; [2] Skinning; [3] Sampling; [4] Washing and [5] Drying (not always needed if the bird skin doesn't have a lot of fat); [6] Stuffing; [7] Sewing; and [8] Pinning. The third of these—sampling —was the most recent addition to the workflow, while most of the process remained little changed from the procedures set out by Spencer Fullteron Baird in 1859 [Figure 5-11; Figure 5-12; Figure 5-13]. The First Secretary of the Smithsonian, Baird was an ornithologist by training and author of numerous works on collecting and preserving museum specimens (Baird 1856). He also designed the original museum catalogs for the collections at the United States National Museum, precursor to the National Museum of National History. The categories laid out in these nineteenth collection records were based on birds, a structure which has carried forward into the museums current categories (Turner and Greene 2014), which I suggest demonstrates the continuing institutional dominance of Vertebrate Zoology.

As I stepped through these processes I felt a certain kind of vertigo on and off as my hands went numb in the frozen duck blood—a visceral reminder of the formerly living thing I was slowly dismembering. Past and future both seemed very present—my hands pinning out feathers looking like a vignette out of one of the historic specimen prep manuals, a deep link to the past and a continuity with histories of collecting. The future seemed immanent as well through the potential future uses for the tissue samples I was taking, as well as the ever-present idea that I was making something that would be kept in perpetuity.

a bare space along the middle, but in ducks and other water birds the feather covering may be practically continuous. If the wings are in the way, break the large bone, the humerus, as near the body as possible, which allows the wings to be pushed aside. With a sharp knife cut the skin on the midline from the end of the breastbone (which you can easily feel) to the vent (fig. 20).

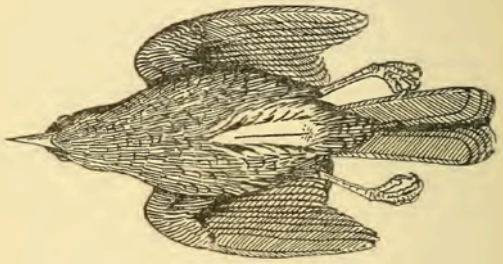


FIG. 20.—Line of opening cut on abdomen.

Try not to cut the abdominal membrane. Sprinkle some absorbent along the cut and, using the handle of the knife or your finger, separate the skin from the end of the breastbone. Continue this loosening as far as possible on either side of the cut down toward the vent, exposing the knees. Holding the foot, push the knee farther into view (fig. 21) and clip the leg at that point. Do this for both legs, thereby severing them from the body.

During the entire process of skinning, sprinkle corn meal or fine hardwood sawdust on the exposed surfaces to absorb blood and other fluids so that these will not soil the feathers. Keep the fingertips dry by dipping them in the absorbent for the same reason. If nothing else is available, fine, dry earth may be used.

Using your fingers rather than a knife, press the skin away from the body on either side of the rump until it is free all around, connected only at the tail. With scissors cut the body loose at

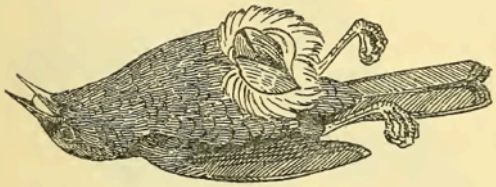


FIG. 21.—Exposing the knee.

the base of the tail (fig. 22) and sprinkle the cut with absorbent. Press the tail and rump skin over and off the body. Do the same with the under side until the skin, inside out, is free up to the wings (fig. 23), using absorbent freely.

Cut off the wings where they join the body, and continue the process of pushing the skin back over the neck. Press the skin carefully over the back and sides of the head. Soon a membranous piece of skin attached to the skull will appear on either side. This is the ear (fig. 24). Carefully pull the ear skin from its

attachment on the skull without tearing it. Press the skin forward until the membrane joining the eyelids with the skin appears. Cut this membrane in such a manner as to avoid injuring the

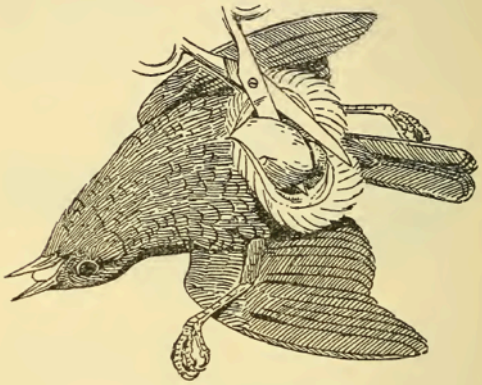


FIG. 22.—Severing the tail.

lids or the skin (fig. 25). Remove the eyes with forceps or knife. Free the skin from the skull clear to the base of the bill. On the lower side cut the membrane below the tongue so that the tongue and the plug of cotton in the throat are free.

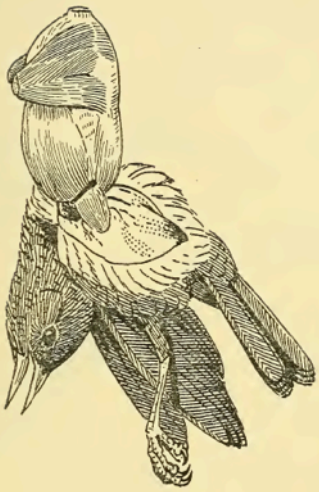


FIG. 23.—Skinning the body.

3

Figure 5-11. Baird's Directions for Collecting, Preserving, and Transporting Specimens of Natural History (1856)

With scissors make a cut across the roof of the mouth, between the branches of the lower jaw below the eye sockets, so that it enters the forepart of the brain cavity (fig. 26). Then make

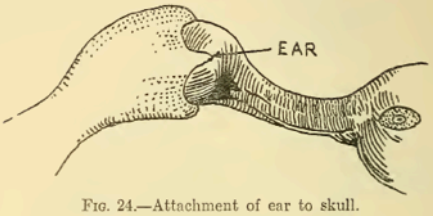


FIG. 24.—Attachment of ear to skull.

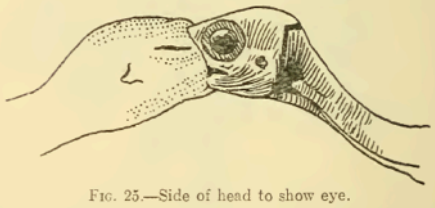


FIG. 25.—Side of head to show eye.

another cut on either side from the end of the first one to the upper base of the skull, and a fourth cut connecting the upper ends of these two. The base of the skull and all of the body,

now free of the skin, may be pulled loose and put to one side. Clean out the brain through the cut end of the skull. If there is much meat on the side of the skull, scrape it away. Dust the skull with the arsenic and alum preservative. Make smooth balls of clean cotton for eyes and put one in each eye socket. Dust the inside of the head and neck skin with arsenic and alum and work it back over the skull.

Large-headed birds like ducks, woodpeckers, and hornbills have heads too big to allow the skin of the neck to be worked

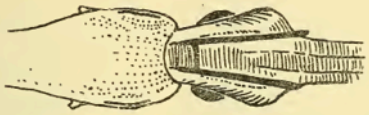
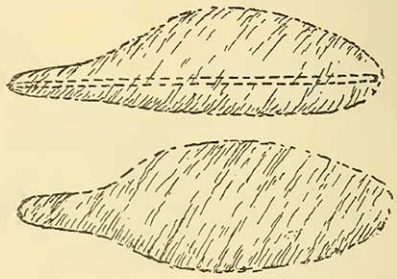


FIG. 26.—Line of cuts on skull.

over them. In such cases, when the base of the skull is reached, cut it loose from the bones and muscles of the neck. When you have finished the rest of the preparation of the skin, poison it and turn it right side out. Then make an incision down the back of the head (fig. 27) and loosen the skin around it until you can skin and prepare the head as directed above for ordinary birds. After the head skin is poisoned and the eyes are in place, sew up the cut in the back of the head with fine stitches.

Free the wing bones as far as the joint and clean off any meat. Skin along the top of the wing to expose the meat on the second joint and remove this also (fig. 28). In sandpipers, goatsuckers,

whitish or blackish, narrow, bean-shaped bodies lying side by side. If it is a female, the ovary, normally on the left side (usually only one, but two present in some birds), will show as a mass or cluster of small round bodies. This is the only certain way of determining the sex of the specimen. The organs are large in the breeding season, very small at other times. If the body



FIGS. 31-32.—Form of body for stuffing.

cavity is bloody so that the organs are not readily seen, wipe it out with a fluff of cotton. Write the sex (male = ♂, female = ♀) on the label and in your catalog.

Cross the feet and tie them together. Tie the label to one of the feet above where it is fastened to its companion (fig. 35).

Arrange the feathers in place and carefully wrap the now completed skin in the cotton sheet to keep its shape while drying,

drawing the cotton from either side toward and over the bird, leaving only the tail feathers protruding. Arrange the tail feathers to insure their drying in place and shape the skin carefully. Large birds may be wrapped in paper or thin, soft cloth. Place wrapped

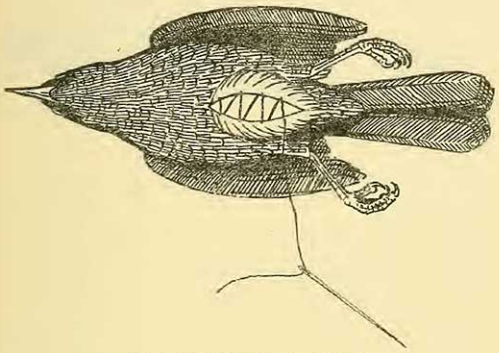
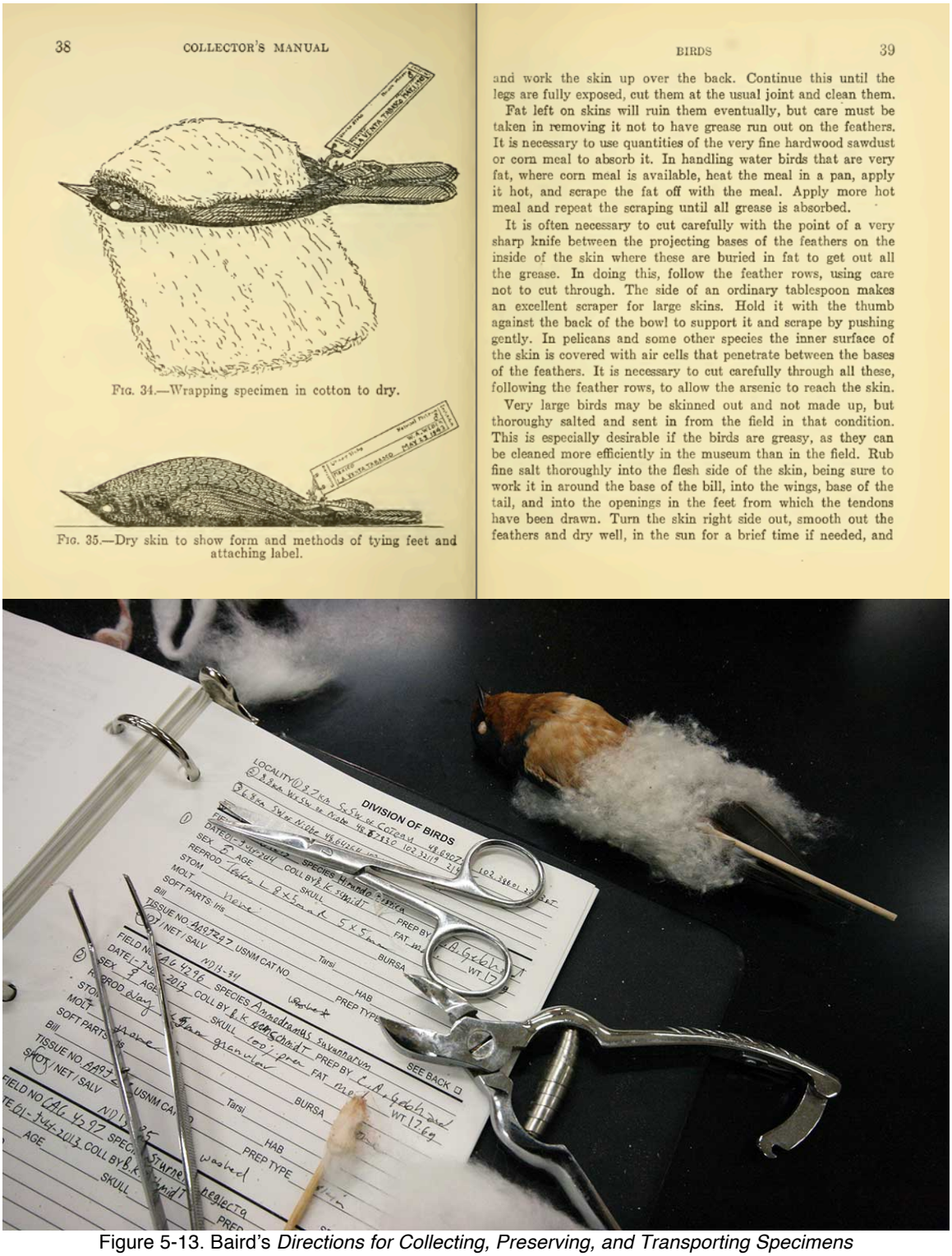


FIG. 33.—Closing the body cut by sewing.

bird skins carefully in a tray or other flat place to dry for a few days. Once dry, they can stand being moved without serious damage.

In skinning hummingbirds, after making the opening cut loosen the skin on the sides of the abdomen, cut off the tail as usual

Figure 5-12. Baird's Directions for Collecting, Preserving, and Transporting Specimens of Natural History (1856)



38 COLLECTOR'S MANUAL

FIG. 34.—Wrapping specimen in cotton to dry.

FIG. 35.—Dry skin to show form and methods of tying feet and attaching label.

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and work the skin up over the back. Continue this until the legs are fully exposed, cut them at the usual joint and clean them.

Fat left on skins will ruin them eventually, but care must be taken in removing it not to have grease run out on the feathers. It is necessary to use quantities of the very fine hardwood sawdust or corn meal to absorb it. In handling water birds that are very fat, where corn meal is available, heat the meal in a pan, apply it hot, and scrape the fat off with the meal. Apply more hot meal and repeat the scraping until all grease is absorbed.

It is often necessary to cut carefully with the point of a very sharp knife between the projecting bases of the feathers on the inside of the skin where these are buried in fat to get out all the grease. In doing this, follow the feather rows, using care not to cut through. The side of an ordinary tablespoon makes an excellent scraper for large skins. Hold it with the thumb against the back of the bowl to support it and scrape by pushing gently. In pelicans and some other species the inner surface of the skin is covered with air cells that penetrate between the bases of the feathers. It is necessary to cut carefully through all these, following the feather rows, to allow the arsenic to reach the skin.

Very large birds may be skinned out and not made up, but thoroughly salted and sent in from the field in that condition. This is especially desirable if the birds are greasy, as they can be cleaned more efficiently in the museum than in the field. Rub fine salt thoroughly into the flesh side of the skin, being sure to work it in around the base of the bill, into the wings, base of the tail, and into the openings in the feet from which the tendons have been drawn. Turn the skin right side out, smooth out the feathers and dry well, in the sun for a brief time if needed, and

Figure 5-13. Baird's *Directions for Collecting, Preserving, and Transporting Specimens of Natural History* (1856) compared to a preparation scene in 2015.
(Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

Continuity with the past then stretched into the future. I kept this sense of long histories and longer futures in mind as I learned to skin, measure, sample, wash, dry, stuff, sew and pin my bird study skin.

Skinning. Focused on the table in front me and the task at hand: transforming dead things into study skins and tissue samples. I rolled up my lab coat sleeves and opened up the prep kit I'd been loaned (a bedraggled cigar box repaired with tape, "volunteer prep kit" written in sharpie across its lid). I'd already filled a black coffee mug with water and a white mug with a half-bleach / half-water solution. A shallow enamel bowl had been filled with "dust," using the proper mixture of course and fine to get just the right "feel" [Figure 5-14]. As I fitted a new blade into my scalpel Christina told me the duck's head skull was too big to fit through its neck (as you do with other birds). So I'd be making two incisions, one on the belly and one along the back of the neck, using tools seemingly identical to those used in the nineteenth century [Figure 5-15; Figure 5-16].

I weighed the bird, noting it in the lab prep book and making sure I wrote down the specimen number. I felt for the bottom of the ribcage (sternum), finding bone under fat and down. Measuring a thumb width down and pushing the feathers aside, I started gently cutting through the skin of the belly using short gentle strokes with the tip of the scalpel to avoid piercing the intestines. I slid my fingers between the skin and the still half-frozen muscle below, pulling the skin away fairly easily [Figure 5-17]. Inside the bird was an indistinguishable mass of lighter and darker red —I couldn't tell what I was looking at.

Christina reached over and sprinkled some cornmeal 'dust' into my bird. "For grip—it'll help you not slip in the blood." The cornmeal turned red instantly, but I was able to hold the edge of the skin. "Find the knees." I felt inside the bird, following the leg bones until I found a joint inside the bird. "Sometimes an illustration can show you what you need to see so much better than a photo," Christina said pointing towards the pages of bird anatomy taped to the front of the fridge. Determining the sex of the bird meant digging in the red for the tiny black dots of gonads, if they were there.[41] I was learning to see, ornithology-style, one small piece of a bird at a time.

[41] Christina told me that they "usually check for bursa [a specialized organ at base of the tail] if it is a young bird or we just cut the backbone near the tail and start skinning the bird down the back . . . I usually sex the bird after I am done skinning and the body is completely detached from the skin."

Figure 5-14. “Dust” and pins (Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

Figure 5-15. Preparators's tools, circa 2015
(Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

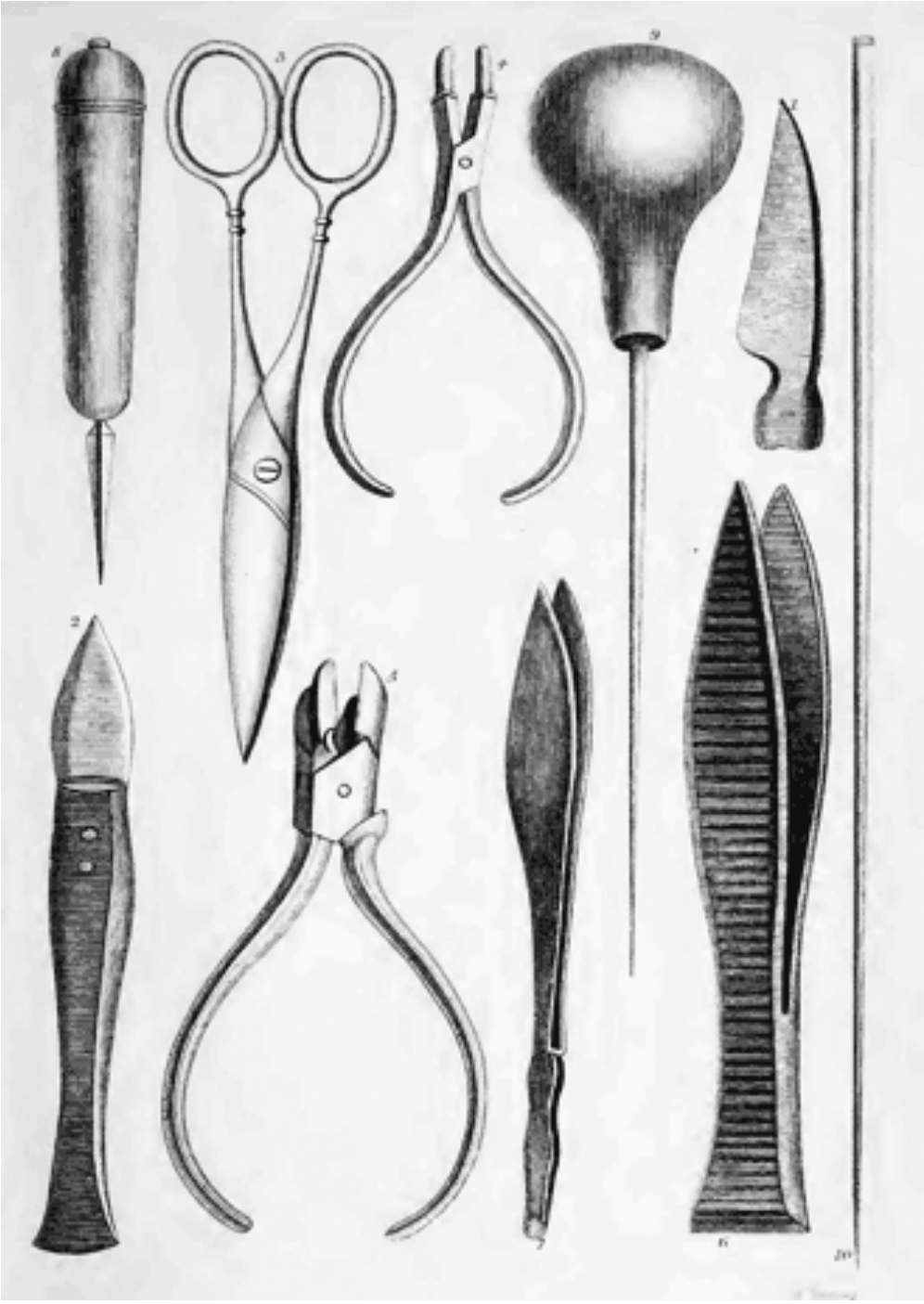

Figure 5-16. Preparators's tools, circa 1853 (T. Brown 1853:27)

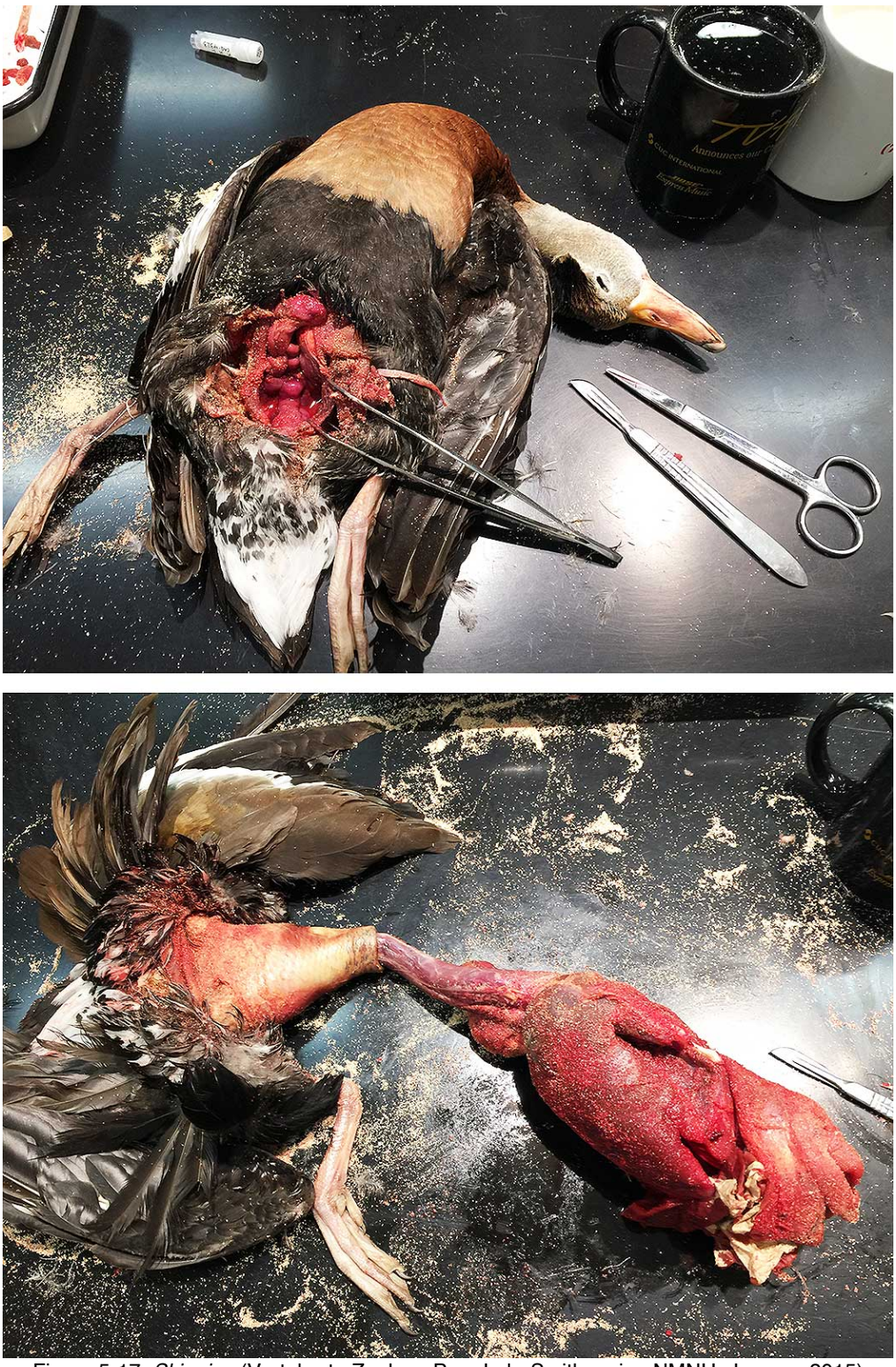

Figure 5-17. *Skinning* (Vertebrate Zoology Prep Lab, Smithsonian NMNH, January 2015)

A bird anatomy picture open on my iPhone and bird knee pinched between my fingers I rooted around in my prep kit and found the scissors. I began to trim away muscle and sinew, excavating the joint to leave a clean leg bone with the skin. “You’ll need good fingernails when you get to the wings,” she tells me. Coming to the bird’s “arms”—its humerus (upper “arm” bone)—I repeated the procedure as for the legs, cutting the bone and cleaning away muscle, and leaving the ulna (lower “arm” bone) in place for tying together later with string.

The larger (primary) feathers, I discovered, were anchored in the “forearm” bone itself, the ulna. “If I know I’m going to be doing a lot of prepping,” Christina tells me, “I grow out the nails on my thumbs . . . Hold the base of the wing in one hand, and then use your thumbnail to scrape down the shaft of the bone.” She demonstrates, her strong hand cleanly separating feather from bone in one swift motion. Sergei, the contractor with his large bag of little birds at the end of the table shakes his head and tells me “use the edge of the forceps.” Christina merely raises an eyebrow and threads a needle to sew up her bird. In the time it has taken me to make the ventral incision and peel the skin back to the knees, Christina has almost completed skinning and stuffing a bright yellow Meadowlark.[42]

I attempt to mimic her action but after several attempts I instead follow Sergei’s advice and use the edge of the forceps to scrape down the length of the bone. Everyone is intently focused on their own bird, many of them having moved onto prepping yet another bird in the time since I started wrestling with the wing bones. When I asked how many study skins each had prepped they all had rough running totals—from just over a thousand to almost ten thousand. “The more you do, the faster you get,” I’m told by one of the preparators. As someone who has not yet acclimated to study skins as “natural,” looking at a row of drawers packed with hundreds of rigid birds in rows is still a deeply unnatural sight. Soon, however, I will be contributing one more bird to the rows.

[42] A final test of skill for preparators used to be preparing five cuckoos, a bird notoriously difficult to work with (“skin like wet tissue paper”) in under an hour, under the watchful eye of their instructor. As this story is recounted in the VZ prep lab people weigh in on their least favorite birds—cuckoos top the list, with doves a close second. The skin rips easily and is so thin that sewing it back together is near impossible, the stitches simply perforate the skin and it rips more. Hummingbirds, on the other hand, which would seem to be incredibly difficult due to their minute size, offer a challenge of meticulous care and dexterity, something to do carefully and be proud of the result. The skinning and de-fleshing is done entirely with tweezers, one of the lab techs tells me, or at least that’s how he does it. “My hands are bear paws,” he says holding up his sizable mitts, “I couldn’t get my fingers in there if I tried.”

The duck skin is finally loose all the way up to the head, still attached around the beak and the eyes. Using the forceps I remove the wad of cotton tucked into the duck's throat. "We put cotton in their mouths to keep them from bleeding all over the feathers," I'm told. I make another incision along the back of the neck, and find a small cluster of snails in the bird's throat—a last meal. The snails are not deemed interesting enough to save, and go into the refuse pile.[43] Snipping through the throat I finally liberate the body mass out of the bird, and set it aside. This feels like a significant moment, as the duck skin collapses flat like a deflated balloon. Yet there is measuring and sampling still to do before the body become biowaste.

On the duck's head, I use the tip of the scalpel to slice along the edge of the eyelid from the inside, gently pulling the skin away from the skull and eyeball. Eyelids can be a diagnostic feature and should be preserved as intact as possible, I'm told. Sliding the forceps in under the eyeball I pop it out, and then cut the back of the skull with scissors—the bones are so delicate it crunches through them easily. I snip away, leaving enough of the skull to keep the shape of the head, but opening it up so I can remove the brain. There are specialized brain spoons, I'm told, and I've seen them listed in historic specimen prep manuals. Forceps do the job just as well, scraping and scooping out the pale pink mass until the skull is clean.

Finally I had two separate objects on the table in front of me: an empty skin and a lump of a body [Figure 5-18]. I set aside the lump of the body for the moment (it was not yet waste, it still had more pieces to extract, weigh, view and record). Picking up the skin I gently turned it inside out, a strange sight with the nubby skin covered in layer of pale yellow fat, and tufts of feathers poking out of the various openings. *Biologies were starting to unbind*, in some very visceral ways as my bloody hands and spattered lab coat could attest.

Getting up from the table I crossed the room to the fat wheel ("Everyone loves the fat wheel," several of the specimen preparators tell me). A plywood box with a

[43] Sometimes interesting things do turn up as birds are turned inside out—a dozen tiny frogs in an ibis, grasshoppers in a stork. Snipping through the throat I finally liberate the body mass out of the bird, and set it aside. This feels like a significant moment, as the duck skin collapses flat like a deflated balloon. Yet there is measuring and sampling still to do before the body become biowaste

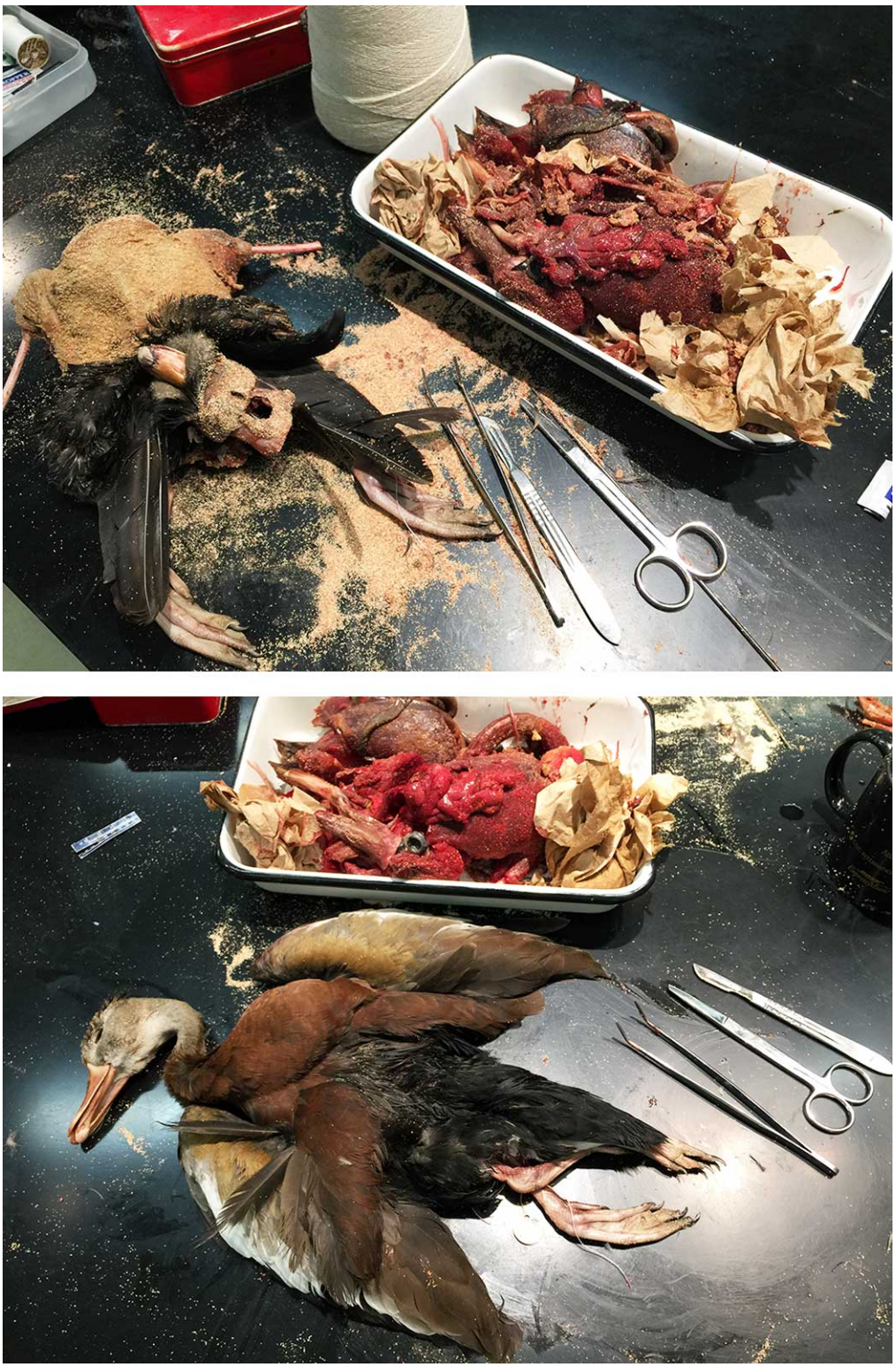

Figure 5-18. *Skinning* (Vertebrate Zoology Prep Lab, Smithsonian NMNH, January 2015)

plexiglass top, it was open on one side. A motor drove a steel wire brush mounted inside the box, a grinding wheel for removing fat. Holding my inverted duck skin to the turning wire brush I carefully move the entire skin back and forth, the fat turning into pink foam that accumulates on the insides of the cabinet, all over my hands, and on the front of my lab coat. “You’re done—stop! Any more than that and you’ll burst through the skin and start loosing feathers.” I take this as compliment, dutifully putting down the skin. Even after a thorough washing my hands still smell pungently of duck fat.

Measuring and Sampling. Setting the skin aside I cut open the lower part of the body. Once again, I don’t know what I’m looking at—it all just seems to be shades of red. Christina comes over and points out the inner topography of the bird with the tips of her forceps. After much searching I finally “sex” the bird, locating two tiny black dots in a sea of blood, adrift in different shades of red bright to almost black. There’s a small plastic ruler in my prep kit, and I measure the tiny gonads—only a few millimeters long on each side. After noting the measurements in the prep log, I root around inside the bird and find the heart and what I think is the liver. A quick dip in the bleach solution (to sterilize it) and then the water (to keep the DNA-degrading bleach out of the bird) and I was ready to cut. I snip pieces from both organs and push them into a clean 2ml cryovial, already labeled with Biorepository stickers bearing barcodes and a unique alphanumeric code, noted in the specimen prep log. I brush the dust off of a duck breast, revealing clean muscle tissue. I add a snippet of this to the cryovial, screw the lid on, and add it to a box in the prep lab freezer [Figure 5-19].

This particular duck was part of a study requiring lots of samples. The standard heart-liver-muscle tissue tube collected, I collect the duck’s stomach in a little ziplock baggie and label it, followed by snippets from feathers on several parts of the wing, each in its own little baggie [Figure 5-20]. My work done with the carcass, I drop it in a large metal tray in the center of the table. At the end of the workday the tray will be emptied into a garbage bag in the prep lab’s chest freezer. Once full, those bags make their way to biohazard disposal. For now, my duck’s body kept company with the insides of a meadowlark, several finches, and part of a heron.

Figure 5-19. Tissue sample (heart, liver, muscle) headed for the Biorepository
(Vertebrate Zoology Prep Lab, Smithsonian NMNH, January 2015)

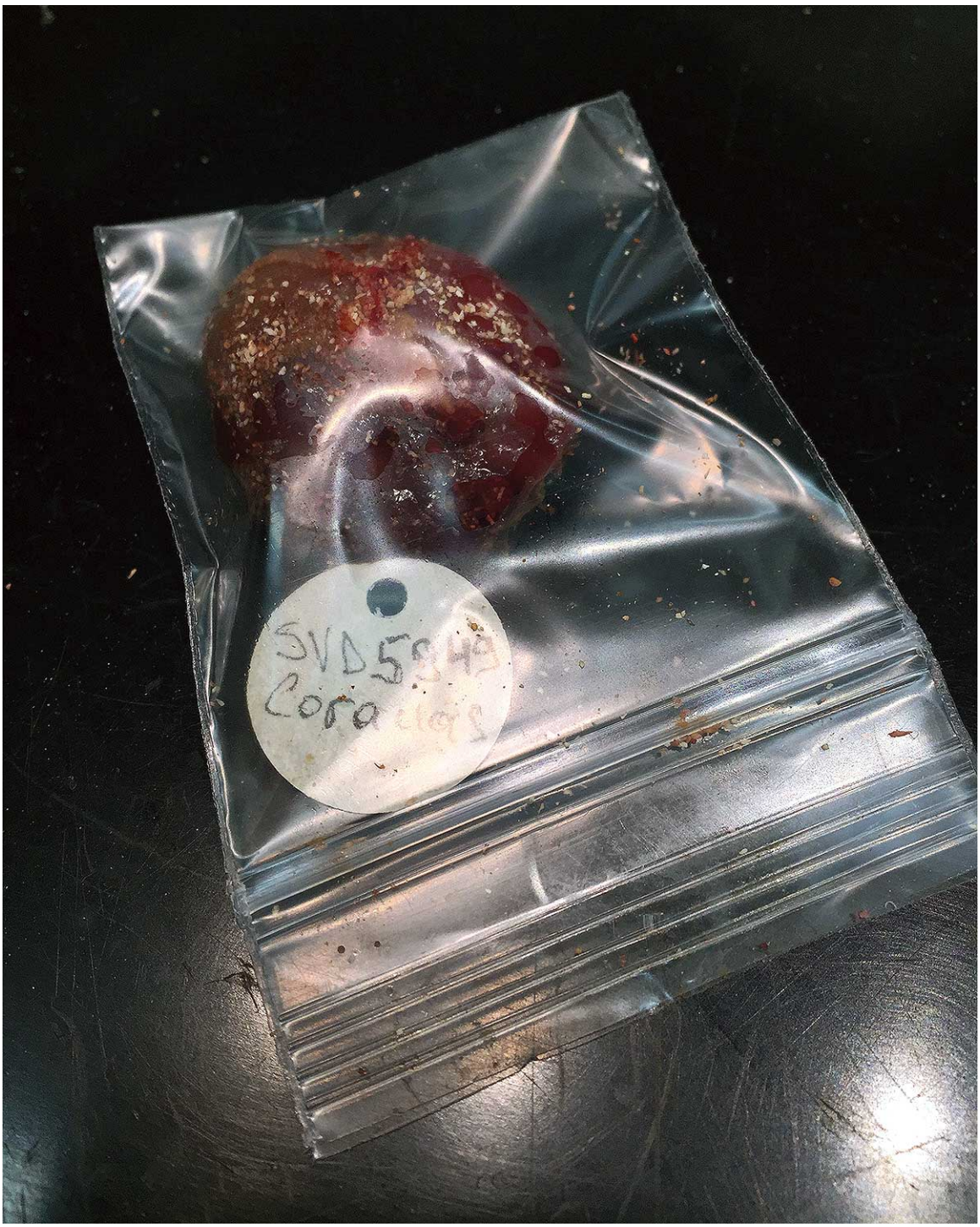

Figure 5-20. Tissue sample (stomach)
(Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

Washing and Drying. Carefully laying my deflated duck skin in a basin of soapy water I agitate it slightly to clean it off, and am surprised by the amount of dirt and filth that float off in the water [Figure 5-21].[44] I lay the washed skin in a towel, gently folding the wings next to the deflated body and then rolling it up and pressing gently to get the water out ("like you're drying a sweater," Christina tells me). Opening up the tumbler next to the chest freezer, I scoop some of the dust inside the bird and cover the outside as well. Latching the lid shut the motor begins to whir and the whole drum turns, gently tossing my duck skin in dust. Twenty minutes later I pull a much improved but very dusty bird skin from the tumbler. A quick shake and a blast with the air hose inside the skin and out results in a clean, fluffy duck skin ready for stuffing.

Stuffing and Sewing. I clean off my section of the worktable—getting blood and dust on the skin now would mean having to wash and dry it all over again. Measuring a length of cotton string the width between the duck's shoulders I tie the wings bones together, and then the leg bones, anchoring them the correct distance apart [Figure 5-22]. Cutting a wooden dowel to serve as a proxy for the spine, I notch the end so it will catch the cotton fibers. Taking a length of white cotton batting, I roll it onto the notched tip of the dowel trying to approximate the size of the duck's head. Folding over two small pieces of cotton I make round balls to fill out the eyes and make the eyerings visible, a diagnostic feature for some birds. it also makes the shape of the head "correct" [Figure 5-23]. The cotton "eyes" go in, followed by the cotton head on the end of the dowel [Figure 5-24].

The other end of the dowel is poked through the duck's cloaca (anus). "It's a useful place to have a pre-made hole in your bird skin," she tells me with a shrug. The dowel in place, I tie the dangling strings from wings and legs around the wooden dowel "spine." This will keep the body more stable for the future, as it is taken in and out of the collection drawer, handled and turned over by researchers. Rolling a square of cotton batting into a cone, I try to approximate the shape of the bird's missing body. "Too fat!" various voices call out,

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[44] "Ever heard the expression 'dirty bird'?," Christina asks me, "That's because birds are absolutely filthy creatures, covered in everything you can imagine." Parasites, dirt, feces (some storks defecate on their legs to keep themselves cool, apparently), and after being shot and skinned add blood, guts and cornmeal dust to that list. I start to think of birds as self-contained ecologies of parasites and dirt with wings.

Figure 5-21. *Washing* (Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

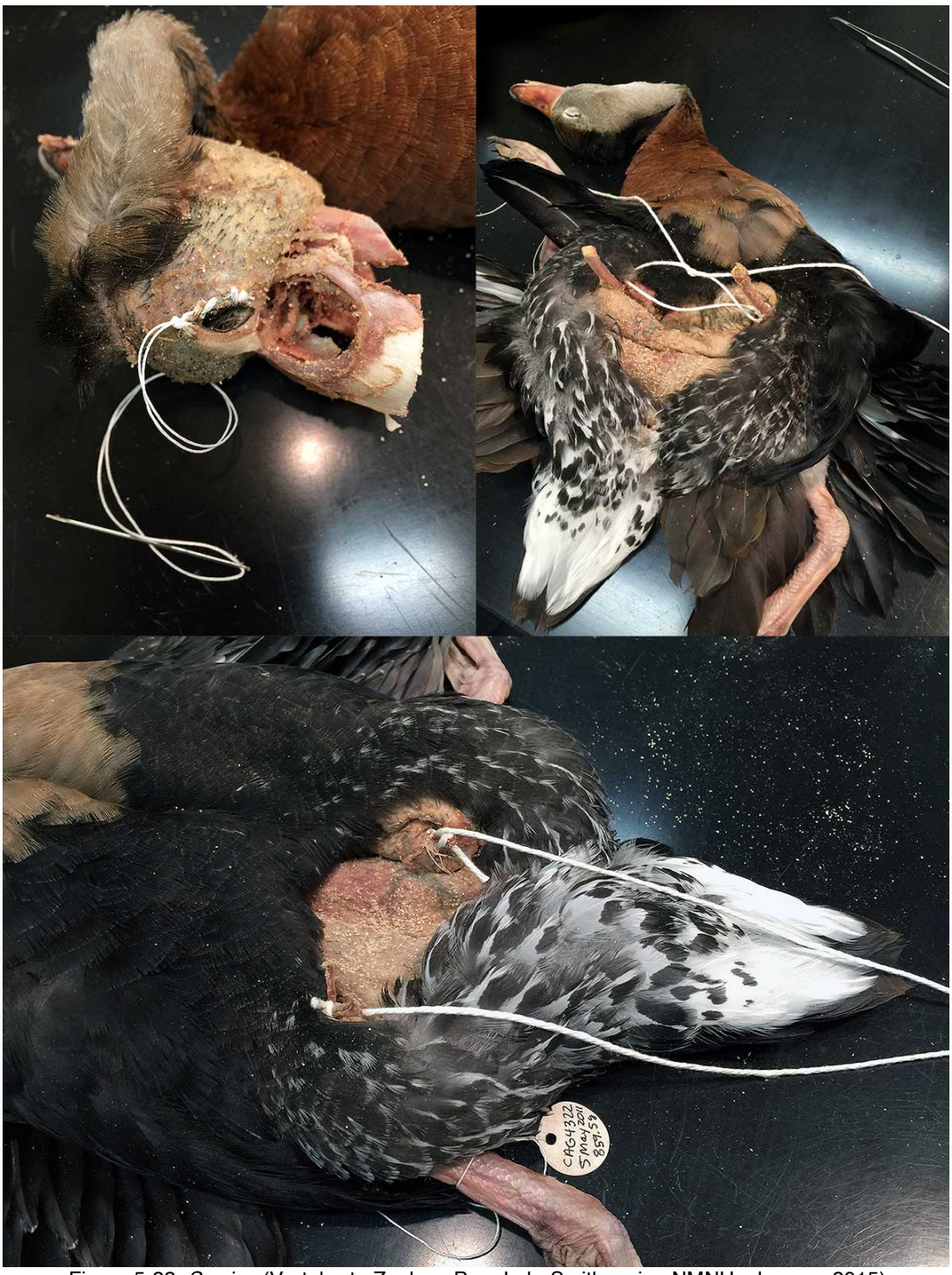


Figure 5-22. *Sewing* (Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

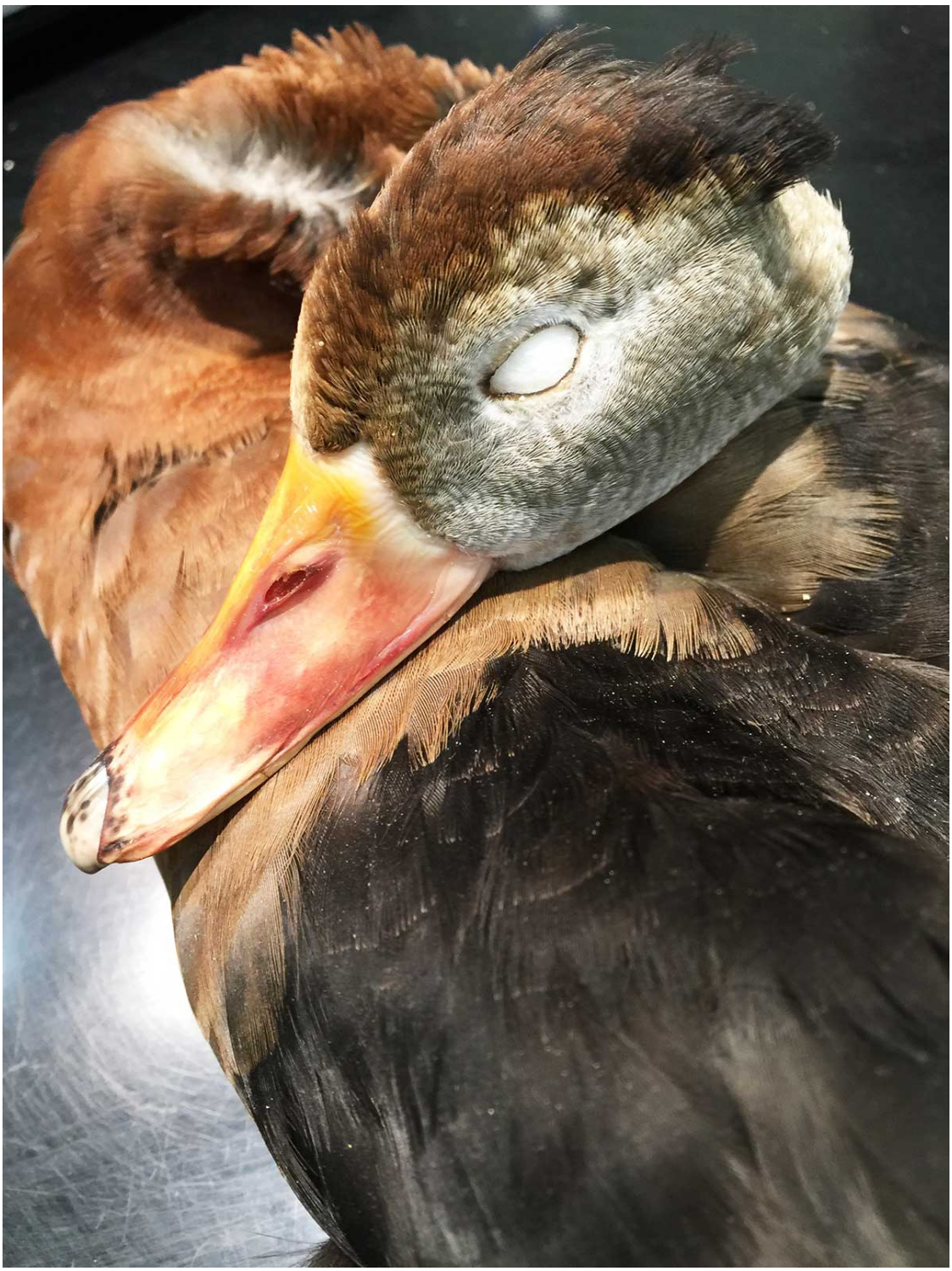


Figure 5-23. *Stuffing* (Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

Figure 5-24. *Stuffing* (Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

looking over as I rolled and rerolled my cotton cone. Finally I used my forceps to guide the tip of the cotton up through the empty body, tucking the cotton into the body cavity as I went.

I find the edges of the skin under the feathers, and sew up from the tail to the throat. My stitches go under and over ("like the cording on a baseball"), to pull the sides together with the thread showing as little as possible. The downy feathers catch in the stitches, so the other way to do it with ducks, I'm told, is to make the incisions on the side under the wings or along the back and prep the skin that way. "That's how I do it," Brian Schmidt tells me, "It leaves the down on the belly pristine. You'll usually see the stitches if you do it down the center if you aren't careful." [Figure 5-25]. Digging in my kit, I pull out the Superglue and put a dab in the tip of the bill, holding it shut while it dries.[45] My bird is now fully sewn up, full of stuffing, with a dowel protruding from its tail.

Sewing up the bird, I think about the other kinds of "conservation" done in the museum with needle and thread, and what kind of truths they create or recreate. How is sewing up a bird skin like conserving other sewn objects in collections? In particular I'm reminded of a description of repairing a seventeenth century Mantuan gown—the huge hoop skirt and tailored bodice modified over generations to fit a series of new owners and styles. Titika Malkogeorgou, a conservationist at the Victoria and Albert Museum in London, asks which version of stitches is the "authentic" one, positing that each series of actions she takes in "conserving" the object is also an ethical choice and construction of a truth made in relation to it (2011:22). She sees each stitch she saves or removes as an ethical choice about how to preserve different "life histories" (2011:22) of the garment and its wearers. I would argue this can be carried over to the study skin and tissue samples in front of me as well, where each decision about producing a specimen—be it morphological or molecular—can be thought of as the same process of ethical choices made in relation to its "authentic" life histories. The choices made determine (and are determined by) contemporary concepts of value and use—what is removed, what is saved, and how what remains is classified. The museum scientists also reflect on the changing values of

[45] Others use a thread through the nostrils and tied around the beak to hold it closed, not wanting to add any chemicals to the specimen which might later prove to be a problem for conservation or genetic sampling. Different styles were present in many of the details of specimen prep—some with long histories and others developed by personal preference.

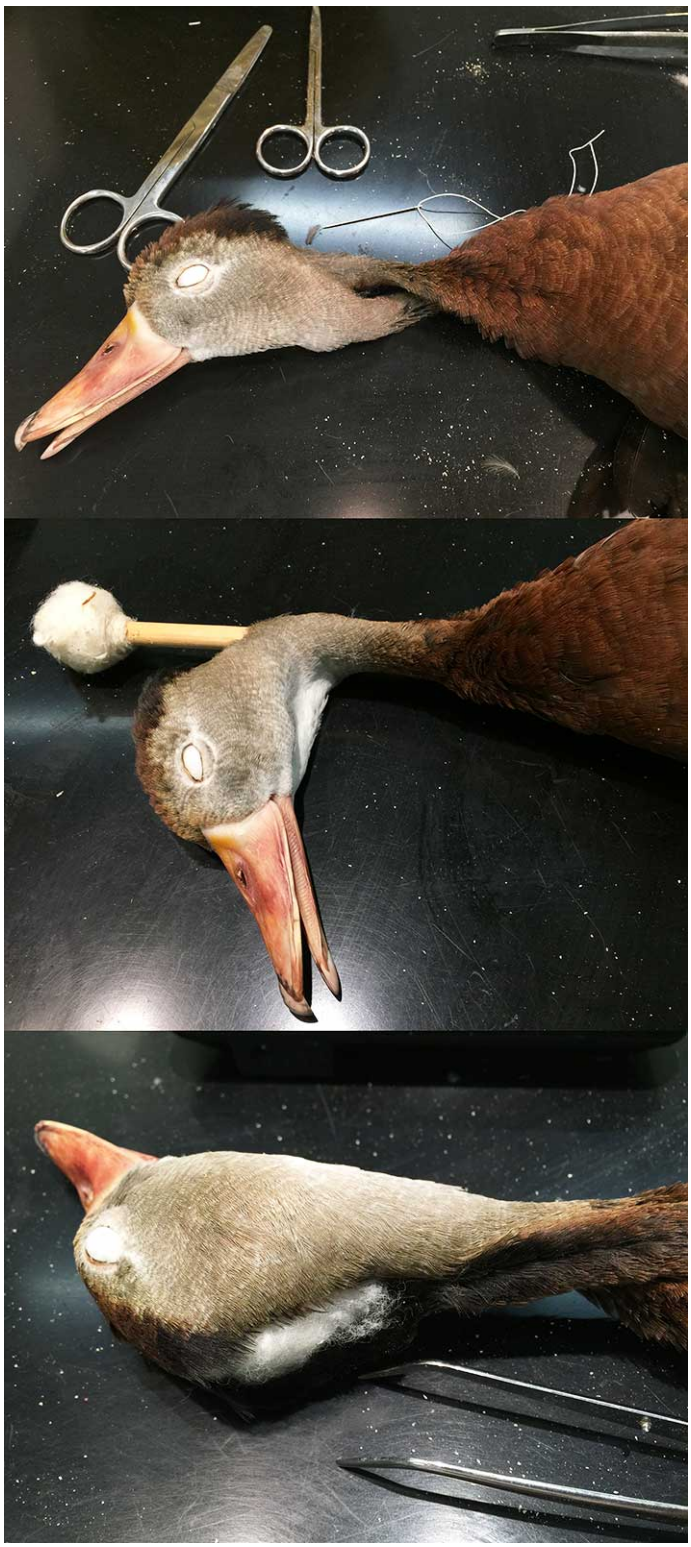


Figure 5-25. *Sewing*
(Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

specimens (as many of the ethnographic episodes in previous sections have attested), where they contemplate that their scientific predecessors could never have imagined what use they would be making of specimens collected a hundred years ago, such as sampling the study skin of an extinct species for DNA.

Pinning. I take my stuffed duck skin over to a side table and place it on a piece of styrofoam covered in brown paper [Figure 5-26]. Feet tied together around the protruding dowel with cotton string, I use a large pin to "anchor" the stuffed bird to the board— pushed straight through just below the breast into the board below. **I** tuck the wings under the body, along the sides of the bird and push its head back to lay flat. Using two more large pins, I make an X over beak to hold it in place. I'm looking for "symmetry," Brian tells me, "a straight line from beak to feet, wings arranged evenly, body even (not tilted) and slightly rounded. These are actually called 'round skins'.""". I tuck and arrange feathers, following Brain's lead, making Xs of pins over the feet, and around the toes. Brian raises an eyebrow as I carefully separate every toe and pin it, pointing out that usually he just lets the feet dry in a "natural" position [Figure 5-27]. Then we stand back, looking at my completed duck and set the board in the drying cabinet. In a few days I can come back and carry it over to the Division of Birds to catalog it, confirm identifiation, and install it into the collection with the correct taxa within the family *Anatidae* (ducks).

Bird Skin: As A Body Without Organs

Sitting at the table disassembling my bird into various parts and pieces (variously valuable as they turn into study skin, genetic samples, feather clippings), I think about what exactly it is I'm making. It is clear that value can be created in multiple ways through multiple intersections of materials, concepts, people and places. For example, the concept of a Body without Organs (BwO) in the work of Deleuze and Guattari (1987, 2004) resonates with both the material practices of preparing a bird study skin—literally a body from which I remove the organs—and as a figurative body, or body of knowledge that functions in a complex negotiation of misplaced desire, authority, and agency. For Deleuze and Guattari, every actual body has a limited set of traits, habits, movements, affects, etc. But every actual body also has a virtual dimension: a reservoir of potential traits, connections, affects, or movements.

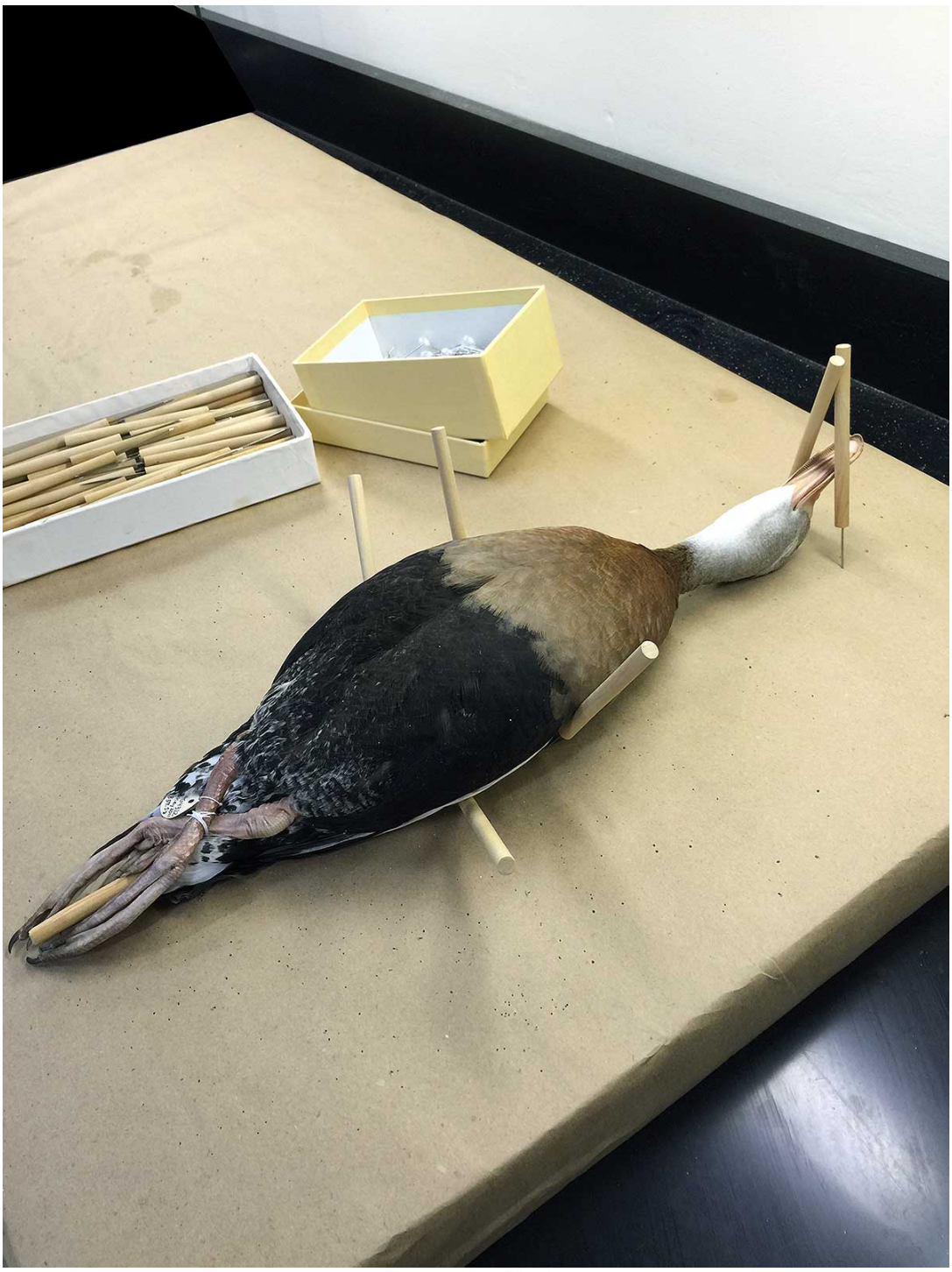


Figure 5-26. *Pinning*
(Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

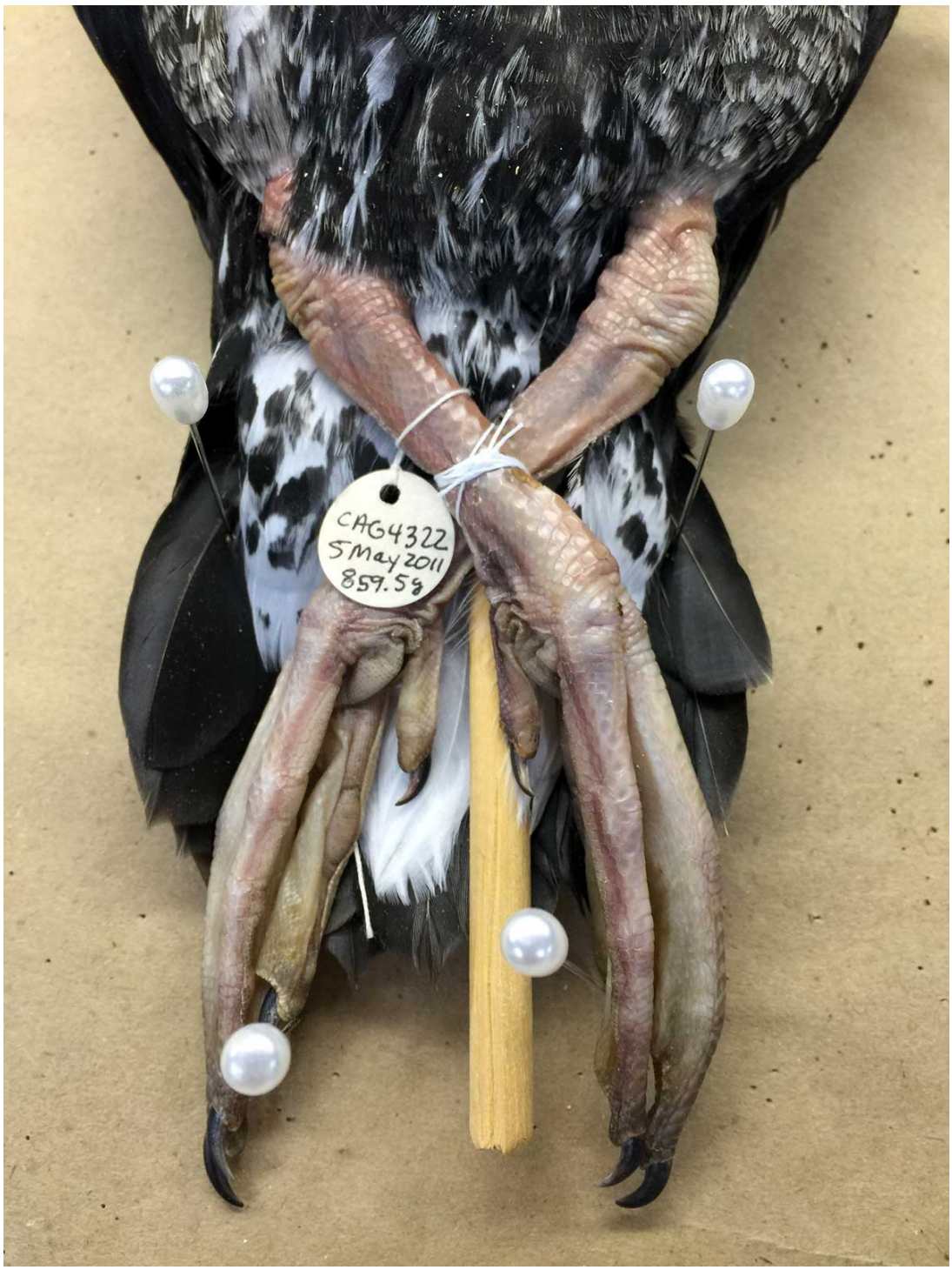


Figure 5-27. Pinned toes
(Vertebrate Zoology Prep Lab, Smithsonian NMNH , January 2015)

This collection of potential traits is what Deleuze calls the Body without Organs (BwO), and appropriately enough it begins with the image of an egg: “The body without organs is an egg: it is crisscrossed with axes and thresholds, with latitudes and longitudes and geodesic lines, traversed by gradients marking the transitions and the becomings, the destinations of the subject developing along these particular vectors” (2004:19). To "make oneself a body without organs," then, is to actively experiment with oneself to draw out and activate these “virtual potentials” (2004:19). These potentials are activated through conjunctions with other bodies (or BwOs) that Deleuze calls "becomings."

Deleuze and Guattari use the term Body without Organs (BwO) in an extended sense, to refer to the virtual dimension of reality in general (which they more often call "plane of consistency" or "plane of immanence"). In this sense, they speak of a BwO of "the earth." "The Earth," they write, "is a body without organs. This body without organs is permeated by unformed, unstable matters, by flows in all directions, by free intensities or nomadic singularities, by mad or transitory particles" (1987:40). That is, we usually think of the world as composed of relatively stable entities ("bodies," beings). But these bodies are really composed of sets of flows moving at various speeds, for example glaciers as slow-moving flows, living things as flows of biological material through developmental systems, or language as flows of words. In *A Thousand Plateaus*, Deleuze and Guattari give a somewhat abstracted protocol for building yourself a healthy BwO[46]:

“Lodge yourself on a stratum, experiment with the opportunities it offers, find an advantageous place on it, find potential movements of deterritorialization, *possible lines of flight*, experience them, produce flow conjunctions here and there, try out continua of intensities segment by segment, have a small plot of new land at all times. It is through a meticulous relation with the strata that one succeeds in freeing *lines of flight*, causing conjugated flows to pass and escape and bringing forth continuous intensities for a BwO “ (Deleuze and Guattari 1987:161 emphasis added)

In drawing attention to Deleuze and Guiatarri’s phrase “possible lines of flight,” I use this to think through the trajectories and connections between (bird) bodies,

[46] Deleuze and Guattari eventually differentiate between three kinds of BwO: cancerous, empty, and full. Roughly, the empty BwO is the BwO of Anti-Oedipus. This BwO is also described as "catatonic" because it is rendered as parts, eviscerated of its organs; all flows pass through it freely, with no stopping, and no directing. Even though any form of desire can be produced on it, the empty BwO is non-productive. The full BwO is the healthy BwO; it is productive, but not petrified in its organization, that is, on the static arrangement of its organs. The cancerous BwO is caught in a pattern of endless reproduction of the same pattern, a replication ad-infinitum (1987:40, 161).

materials and what I have called flight paths in the museum—that is, that the circulation routes of biomaterials in various forms and transformations across and beyond the museum change in value as they move across boundaries. Further, other kinds of things travel along with them, changing "in flight": concepts of valuing these assemblages of objects (and subjects) of specimen-tissue-data, and also the kinds of labor involved in rendering them "natural."

This leads me to ask: What kinds of bodies, and bodies of knowledge, are in transit in these circulations? What are the possible lines of flight for a Body without Organs, be it hominid or avian? Shifting from the scale of the disciplinary and institutional, I move down to the scale of a specific organ-less bird body. Though Deleuze and Guattari suggest that an empty BwO is non-productive, I suggest that the productive potential of a specimen BwO is precisely in its dismembered, eviscerated parts and pieces—as both *value- and meaning-producing* study skins, tissue samples, feathers, tope pads, bone fragments, and sites for parasite extraction. Lynda Birke (1994, 1999) strongly criticizes conceptions of the postmodern body-without-organs (Deleuze and Guattari 1987) as merely "extended surface," available to be written upon by culture—essentially a passive form to be inscribed (Birke 1999:31–35). This recourse to "exteriority without depth" (Braidotti 1989, cited in Birke 1994), Birke argues, abandons the responsibility to theorize embodied agency and resistance, leaving the body "uncannily empty" (1999:32). However, in following the work of Karan Barad and the entanglement of Deleuze and Guattari's "materials and forces" in a different way—that of discourse as always already about materials—I move towards a use of the BwO that looks at, in the words of Barad, "how matter comes to matter" (2003). Barad's work on matter examines the creation of meaning through the performative force of materials and discourse—the tangled meaning we make through things and words—or in this context, the tangle of bodies, (bio)matter, and the ways they come to matter.

Barbara Noske (1989), Lynda Birke (1994) and Donna Haraway (1985, 1989, 2003, 2013, 2015) have each explored the status of non-human animals as "objects-to-think-with" in constructing the boundaries of the "human." Into this conversation, Haraway offers a useful perspective into the struggle for defining "life" and "nature," and also the value of these concepts as they move between environments of all kinds, be they biotech labs (1997), museum exhibits (1985), dog kennels (2003), or a multispecies Anthropocene (2015).

With the weight of the duck organs in my hand as I transfer them to the metal "discard" tray in the center of the table, I have a slightly different take on a Body without Organs, and its location in a negotiation for defining and archiving life—one distinctly more avian than human (Birke 1994; Noske 1989), and one far more immediately visceral than particle physics (Barad 2003). I follow Birke halfway in her criticism of a BwO as an empty slate ready for cultural inscription, instead thinking through the potential of the disassembled body, and the power of proliferating parts. As bodies come apart—specifically, are actively taken apart in specific ways for specific ends—I look to Haraway's observations about the increasing intimacy and exchange between what counts as "nature'" and what counts as "culture" (1997:56).

The Biological tropes of "species" as distinct and separate embodiments of "nature order" are being refigured in a world where human nature can be "embodied" in a genetic database. This happens —as part of the nature-crafting practices of bioinformatics and their material counterpart, biodiversity biobanks. Haraway's cyborgs and their companion species inhabit a "nature-of-no-nature" (1997:269), and through the figure of the "modest witness" who is accountable for their own scientific representations she suggests a path towards the interventions that can refigure *knowledge* projects as *multispecies* projects. In this world in which nature and culture have imploded, Haraway claims that staking out a new common space is now inescapable (1997:269–70), with the struggle for control of the genome as a struggle for control of "life itself" (1997:150). My own modest intervention at this juncture is through reconfiguring a duck into multiple re-valued parts—but doing so reflexively, and with an attention not only to how meat becomes meaning, but with genuine curiosity about the human and non-human animals in this museum assemblage.

How to Build a Bird, Part II:

On the Uses of Feathers and Bones: Shifting Values at Interdisciplinary Boundaries

From the disassembly of a bird and its transformation into a study skin, tissue samples and a carcass, I now follow several of these parts and pieces across the museum. I note the shifting value at these border crossings (Giroux 2007), as feathers, bone fragments and discarded carcasses become valuable resources

for producing knowledge about extinction events, bird strikes, parasites and the food webs of the deep sea.

February 2016. I'm in the Division of Birds at the National Museum of Natural History, on the top floor of the East wing. Long corridors lined with white metal cases stretch out into a labyrinth, row after row, stacked three cases high. Metal rolling ladders are scattered throughout the collection, providing access to even the tallest cabinets. The drawers within the cabinets are little more than shallow wooden trays, with bird skins, nests, eggs and wings neatly arranged in rows, packed as densely as possible. Space is an ongoing issue. An arrangement of slots along the insides of the cabinets allow the drawers to be slid in with different amounts amount of space between them—a tall bird like a whole bundled pelican is much taller, taking up more vertical space than a drawer of small and relatively flat plovers, for instance [Figure 5-28]. An ostrich skin shot by former President Theodore Roosevelt on his 1909 African safari takes up an entire drawer—legs folded back over the body and the Nairobi newspaper originally used to stuff the head still legible through the eyes [Figure 5-29]. Learning how tightly you can slot in the drawers is a skill one quickly learns "pulling birds" from the collections.

More than 640,000 bird specimens are housed here—the third largest bird collection in the world—and a mere fraction of them are accessible via the public version of the online collections catalog (Smithsonian NMNH, Division of Birds 2014). If you want to find something, you have to ask. The alcohol collections of pickled birds in glass jars and larger birds folded into metal cases are stored out at the Museum Support Center (MSC) in Suitland, Maryland. Also stored at MSC are the flocks of taxidermied birds that migrated out of the Smithsonian's Hall of Birds, which closed to make way for a newly designed Ocean Hall that opened in 2007. The Hall of Birds contained multiple curiosities: dioramas of ostriches being hunted, an Arctic scene of penguins (a reject of which I encountered at the Smithsonian Castle for the SIBG launch), a display case of the now-extinct passenger pigeon clustered by the dozens on a fake oak branch, and a case devoted entirely to extinct birds: passenger pigeons, Carolina parakeets, an auk with "Extinct" spelled out in mid-century modern script across the back of the case. Though the large dioramas have been dismantled, some of the birds remain in the museum, in glass-fronted mahogany cases lining the hallways outside the Baird Auditorium on the bottom floor. A case is still devoted to extinct birds, with a pair of passenger pigeons, a Carolina parakeet and a replica auk egg on display for the public who wander down these back corridors.

Figure 5-28. A standard drawer full of study skins, packed in neat rows. A a separate box holds chicks that have more delicate plumage, and more space is given to a specimen with a spread wing.
(Smithsonian NMNH, Division of Birds, March 2015)

Figure 5-29. An ostrich collected by Theodore Roosevelt during a 1909 African safari.
Note the newspaper still visible through the eye.
(Smithsonian NMNH, Division of Birds, March 2015)

85-30. Taxidermy that has been “relaxed” into a drawer in the collections
(Smithsonian NMNH, Division of Birds, March 2015)

On this February afternoon I am in another set of back corridors full of stuffed birds, however these are not accessible to a wandering public. The cabinets are filled with study skins instead of taxidermy, although the occasional taxidermy mount will be retrofitted to lie flat in a drawer if it's deemed valuable enough. The effect is somewhat unnerving—as I look down the rows of round study skins with cotton eyes suddenly there is a little face staring back at me with shiny glass eyes and contorted wings [Figure 5-30]. These interlopers have been bent flat to fit in a drawer, or as flat as possible given their original positions, mostly posed and mounted to perch on a branch.

My guide is Jacob Saucier, one of the technicians in the Division of Birds. I've asked him to show me all the different preparation types in the collection, from the standard round study skin to flat skins, skeletons, "pickles" (alcohol preserved specimens), and anything else he can think of. There are many more kinds of preparation, and subtleties between them than I ever imagined. Looking through the drawers of study skins, I ask Jacob if he can tell who prepped the skin just by looking at it. He takes me to a drawer of what look like perfectly identical birds and says he knows instantly when he sees some preparators work—they have immediately recognizable "style" that can be "read" across the drawers. Nature is variable, but so are the techniques of those who craft it.

We talk as we move between the cabinets, opening drawers and handing birds' skins, nests, dried wings and cleaned bones back and forth. He shows me what he's working on at the moment—a synoptic collection of bones. He pulls out a drawer lined with white foam, which he has cut precisely to fit the individual bones: skulls of different birds arranged by type [Figure 5-31; Figure 5-32]. "It's very satisfying to get the bone to fit just right," Jacob tells me, "I'm probably spending too much time on this, but I know it's going to be here a long, long time so I want it to be perfect." He pauses and smiles, "Or as perfect as I can make it." The similarities and differences between the bones are immediately clear just by looking across the drawer contents—the long thin beaks of herons for spearing fish versus the short rounded bills of ducks for grabbing snails, for instance.

In a drawer of thighbones a huge bone the size of a baguette takes up the left side of the drawer. An ostrich, I'm told. In the lower right-hand corner of the same drawer I notice a tiny rectangular acrylic box. I pick it up and see a miniature version of a thighbone, no bigger than the end of a toothpick, its catalog number neatly labeled in Lilliputian script down its side. A hummingbird femur, so small it

had to be enclosed in a pillbox so it wouldn't get lost in the fray. Jacob also shows me the collections he made on the recent trip to Djibouti. Still in "hold-up" cases, waiting to be sorted into the collections, there are bird nests wrapped in paper, stored in cardboard boxes, bird skins, spread wings and also bird songs he recorded on the expedition. Jacob told me he "place[s] a high emphasis on song recording" as part of collecting and understanding biodiversity and he "plans to publish some analysis of song data in the near future."

I repeat these guided visits through the collection with multiple staff members in the Division of Birds, asking each of them how they've seen the uses of collections change during their time at the museum, and then to show me different preparation methods that relate to those histories. Where these narratives intersected and where they diverged provided a view into how within a disciplinary "culture" subtly different practices (and their associated value systems) were in the process of changing -- from how changes in the materials used for specimen preparation impacts their later use to changes in collecting methods in the field and in the collections themselves.

March 2015. I heard about changing collecting practices: mist nets strung between trees, shooting with different gauge bullets sized to the bird, how to compress the chest of small birds between thumb and forefinger to quickly euthanize them—all things that could have come directly out of collecting manuals from the 1860s. Chris Milensky, a Museum Specialist, told me about trying to carry liquid nitrogen dewers through the forest, how the time to prep a study skin in the field had quadrupled with all the tissue sampling that now needed doing, and the immense amount of labor required once back at the museum to keep all the proliferating parts and pieces correctly connected in the collection databases (as discussed in Chapters 3 and 4).

July 2015. In the type collection, kept in a separate locked room with red labels on the cabinets and red labels on their feet, Helen James, a Curator in Birds, shows me the most recent type that had been collected a few years ago. It was tucked in next to specimens from the 1890s and 1920s. Helen also showed me the collection of seabirds she's doing research on, tracking historic food webs through isotope analysis of bone fragments taken from the legs bones of the Hawaiian petrel (Pterodroma sandwichensis), Newell's shearwater (*Puffinus auricularis newellii)*, and the Laysan albatross (*Phoebastria immutabilis*).

5-31. The synoptic bird bone collection (Smithsonian NMNH, Division of Birds, February 2015)

Figure 5-32. Each bone fitted precisely into place
(Smithsonian NMNH, Division of Birds, February 2015)

As top predators who spend much of their lives out in the deep ocean, these birds condense histories of the ecosystem into their bones—what fish they ate, when they ate it, where they migrated (Ostrom et al. 2014). These histories can be extracted from tiny chips of bone taken from the broken end of the bird knee inside the study skin. Recalling my own experience skinning and breaking of the duck knees, I could imagine this as a good place to take a sample. “With a few snips of thread, we can get easy access to the leg bone, break off a bit and then sew it back up. Destructive Sampling Request committees in museums like these kinds of requests better than other kinds,” Helen tells me, “since they do little visible damage. We aren’t asking for a toe pad, for example.”

February 2015. The seam on a seagull study skin (collected at the turn of the century) was starting to come undone. Brian Schmidt, a Museum Specialist, gently pulled apart the two halves of the belly to point out the wood wool or “excelsior” (wood wool) used to stuff the bird, a precursor to the cotton now used [Figure 5-33]. This answered a question I’d had while working in the Vertebrate Zoology Prep Lab. Three large metal trash cans held bulk materials for specimen prep, one of which was labeled “Excelsior.” Peering inside the bin it was indeed full of thin strips of wood in a tangle like dried noodles. Brian also showed me some of the first specimens that had been sampled for genetic projects, their collection of toe tags multiplying with each sampling event [Figure 5-34; Figure 5-35]. “We try to keep one side intact, for future morphological work,” he tells me, “So you have one foot, one leg, one wing to work with. There are some specimens of extinct specimens where there aren’t any toe pads left. And that’s it for that bird.” The toe-pad-slicing procedures of Rob Fleischer come to mind. Slicing isn’t the hard part, it’s getting permission to do so.

August 2015. On a tour of the “bird hospital,” a cabinet in the back corner of the collections where damaged specimens are temporarily housed while they await repair, Christina tells me that detached heads are a common problem, as are broken feet. Designing solutions to reassemble the birds, or at least keep the parts together, is part of Christina’s purview. If birds are small enough all the pieces can go into an acrylic tube, for larger birds there’s usually enough “material” to sew or glue pieces back together. Renowned in the department for her meticulous arrangement of feathers, particularly on spread wing preparations, sometimes the collecting event itself doesn’t leave much to work with. She shows me what she considers her worst specimen, a tiny bird head mounted on a stick.

Figure 5-33. Excelsior, or wood wool, inside a historic study skin of a Laughing gull (*Larus atricilla*, USNM 212809) (Smithsonian NMNH, Division of Birds, February 2015)

Figure 5-34. A drawer of study skins of Micronesian kingfishers (*Halcyon cinnamomina cinnamomina*) (Smithsonian NMNH, Division of Birds, February 2015)

Figure 5-35. Bird study skins of Micronesian kingfishers (*Halcyon cinnamomina cinnamomina*) sampled for DNA, their life histories documented in labels (Smithsonian NMNH, Division of Birds, February 2015)

The bullet had obliterated the rest of the body. She had dutifully prepared the head, and the stick protruding from the bottom meant it could be used with minimal damage— - at least the head has a handle. “Every time you take out a study skin, it gets damaged. Maybe just a little, but there’s always wear and tear,” Christina tells me. “And some researchers are more careful than others.” This tension between preserving the specimens in pristine condition for perpetuity and the function of the collection as a collection of objects for use was not new to me. I had heard these frictions recounted in every part of the museum, as well as in the reports from the Division of Birds and Mammals from the 1880s—the story was the same: collection managers try to preserve, while researchers want to make use of whatever they can. As one (contemporary) anthropologist put it: “It’s their job [the collections managers] to keep things perfect, for us [researchers] we need to take things apart . . . What they think of as doing damage we just think of as looking closely.”

July 2015. “They’re even getting DNA out these nowadays,” Carla Dove, Director of the Feather Identification Lab in the Division of Birds tells me as we look at a drawer full of eggs [Figure 5-36]. “Pipette a little ethanol in there, swirl it around to pick up some of the albumin still on the inside of the shell and sequence that. . . So amazing what uses people are coming up with for collections.” Carla’s lab is certainly among those with new uses for old collections. The Feather ID lab is the leading identification facility for bird strikes—mid-air collisions between aircraft and birds that result in damage and death for the birds (and possibly humans) involved. Carla’s mentor Roxie Layborne founded the Smithsonian’s forensic ornithology program in the 1960’s, pioneering many of the methods used in feather identification, and refining the process of identifying what bird had struck a plane through using tiny fragments of feather [Figure 5-37]. Washing the fragments of feathers sent to her by the Federal Aviation Administration (FAA), the US Navy and US Air Force, Layborne would then mount a tiny section on a microscope slide. Different birds have different structures on the barbules of their feathers, clearly visible under a high-power microscope. More intact feathers would then be compared to study skins, matching the shape and color of the plumage [Figure 5-38].

Figure 5-36. The Oology collection, now a site for DNA extraction (Smithsonian NMNH, Division of Birds, July 2015)

Figure 5-37. Roxie Layborne and staff in the NMNH Division of Birds
(Photo: Smithsonian Institution)

Figure 5-38. Bird study skin of a Laughing gull (*Larus atricilla*, USNM 212809), its plumage used to identify birdstrike remains (Smithsonian NMNH, Division of Birds, July 2015)

Building up a library of feather slides [Figure 5-39; Figure 5-40], the Feather ID lab now incorporates DNA barcoding[47] into its analysis procedures as well. Ziplock baggies with smears of tissue and feather inside now arrive at the Smithsonian for the Feather ID Lab, which the lab calls "snarge."

The DNA barcoding is just another tool, I'm told, with its pros and cons. "Its very different now than when Roxie first trained me," Carla tells me, "It used to be all about training your eye to pick up the different patterns in the barbules, to become a pattern library of birds, but the move to genetics means things are more abstract . . . You have to rely on what it [the technology] is telling you . . . Of course if something seems off we always check it, but it's gotten pretty cheap and reliable. Training someone to recognize the shape of twenty different owl feathers under high magnification is very different than teaching them to barcode DNA."

"[The Division of Birds] has saved feathers from every skeleton prep for at least the last ten years," Jim Whatton, a Research Assistant in the Feather ID lab tells me. These feathers come from specimens catalogued in the Division of Birds, separate from the collections of the Feather ID lab. I'd met Jim while he was in the VZ prep lab making study skins as references for the feather microscope slides and "snarge" DNA sequences. He's now being trained to do DNA barcoding by Nor Faridah Dahlan, the senior lab tech in the Feather ID lab. There's just so much to do, I'm told, that they need more people doing both molecular and morphological work. "We still need the study skins, but there's a lot of work in DNA barcoding too," Jim tells me.

The feather library that has accumulated, it turns out, has been used as a resource not just for ornithologists. Visiting scholars have found their way into the collection, such as a parsitologist hunting for mites. "[The Division of Birds] had a parasitologist come in and go through our feathers," Jim tells me, "She would hold each plastic bag up to the light and see if there were any little black dots,

[47] "In 2003, Paul Hebert, researcher at the University of Guelph in Ontario, Canada, proposed "DNA barcoding" as a way to identify species. Barcoding uses a very short genetic sequence from a standard part of the genome. . . The gene region that is being used as the standard barcode for almost all animal groups is a 648 base-pair region in the mitochondrial cytochrome c oxidase 1 gene ("CO1"). COI is proving highly effective in identifying birds, butterflies, fish, flies and many other animal groups. COI is not an effective barcode region in plants because it evolves too slowly, but two gene regions in the chloroplast, matK and rbcL, have been approved as the barcode regions for plants" (Barcode of Life 2016). See Waterton et al. 2013 for a social science critique of DNA barcoding.

Figure 5-39. Feather Lab slide library
(Smithsonian NMNH, Division of Birds, July 2015)

Figure 5-40. Microscope slides of feathers, Feather Identification Lab
(Smithsonian NMNH, Division of Birds, July 2015)

which meant there were mites . . . She went through the whole collections and got a lot of specimens." The Division of Birds was happy to give up the mites (through a destructive sampling request)—they were after all, not what they had intended to collect, but it proved a valuable resource for another scientist. More uses of the collection, in effect, validate the existence (and expense) of the lab, and help ensure its future. This orientation to the future shifted across multiple scales, articulating multiple types of time in the museum. These "types of time" (a concept I explore further in Chapter 7) included the future of the Division of Birds and its ability to meet the expectations placed on it by curators, researchers and the administration. It also included a long view into the future, negotiating the incorporation of new types of objects, such as tissue collections, into the on-going care and maintenance of their own collections.

Bird Parts as Boundary Objects

On the one hand it is important—at a time when genomic collecting is still relatively new and its future uncertain—to document the co-emergence of the value(s) of genomic samples and their biological specimens with the hopes and expectations of how nature can and should be known. On the other hand, as Hans-Jorg Rheinberger (1997) and Karin Knorr-Cetina (1999) remind us, scientific-epistemic objects are best characterized by their state of continual (re)emergence.

The standardization of specimens, tissues and data might suggest that they speak for an atemporal natural order. However, it is important to remain attentive to the historically rich natural orders revealed by an alternative reading of (genomic) collecting (Leonelli 2012b; Leonelli and Ankeny 2012; Star and Griesemer 1989). The different disciplinary histories between Birds and Fishes, Botany and Invertebrate Zoology, for example, contribute to the emergent value(s) of museomics and its specimens as scientific objects. "The growing recognition of the microbial richness of even the most humble bit of tissue," writes Joanna Radin, "complicates the effort to render flesh as data" (Radin 2012:310). The very *materials* of tissues are in a state of becoming—becoming ever more microbial, epistemic, and valuable in different ways (Leonelli 2012a; Star 2010). The complicated translations needed to make shifting scientific objects coherent across these boundaries was explored in a case study of the Museum of Vertebrate Zoology at U.C. Berkeley (Star and Griesemer 1989). Star and

Griesemer's analysis of the different communities intersecting in the museum (scientists, administrators, researchers—all very familiar figures for my own research) revealed how:
"[O]bjects of scientific inquiry inhabit multiple social worlds, since all science requires intersectional work . . . The fact that the objects originate in, and continue to inhabit, different worlds reflects the fundamental tension of science: how can findings which incorporate radically different meanings become coherent?" (1989:392).

Star and Griesemer's answer to this question of coherence across domains was to introduce the concept of the boundary object, "a many-to-many mapping, where several obligatory points of passage are negotiated with several kinds of allies" (1989:390), objects which are "both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual site use. These objects may be abstract or concrete" (1989:393). My duck and its parts, I would argue, function as boundary objects between practices, knowledges and disciplines at the museum. As a type of many-to-many mappings, the study skin, its tissues and parasite-ridden carcass all work to *produce difference* between these now-discrete pieces as they are each sorted and classified in new contexts—from frozen bird tissue in the Biorepository, to a bird skin in a drawer in the Division of Birds, to a nematode for the Parasite Collection. Yet they are all rendered (semi)legible across these boundaries by the thin threads of (increasingly standardized) data, as I discussed in Chapter 3 on standardizing data and Chapter 4 on networks of tissues.

This production of difference in material practice happens on the local level, yet particularly in the return to encyclopedic collecting of the natural world with new genomic tools I see an assembling of the global, and its complex connections, in a very specific and local frame. "Capitalism, science, and politics all depend on global connections . . . Yet this is a particular kind of universality: It can only be charged and enacted in the *sticky materiality of practical encounters*" (Tsing 2005:3 emphasis added). This "sticky materiality of practical encounters" helps to articulate how these "frictions" come into being in the museum context, and indeed the literal stickiness of the practical encounters I engaged in were the stickiness of blood, fat and feathers. In the next chapter I encounter more stickiness and slippages – of the slippery alcohol-soaked beetles and of my

sweaty hands inside latex gloves pipetting DNA suspended in buffer, and of specimens reclassified to move across borders. This idea of "slipperiness" extends Tsing's concept of "stickiness," providing another way of accessing the friction—or its counterpart, a lack of friction—that shape objects, concepts and pathways in the museum.

Bird Body as "Fieldsite" for Collecting Parasites

From the border-crossings of feathers, toe pads, and bone fragments I now turn to another part of the disassembled bird: the intestines. This discarded piece of byproduct created by the bird study skinning process is, it turns out, a lively site for parasite wrangling. Parasites exist in an interesting space in the taxonomy of the museum, having been extracted from a host organism which lives in some other Department or Division—a lion and its blood-filled ticks, a bird and its tapeworms or a fish and its mouth parasites are separated and sorted, circulating across boundaries to Mammals, Birds, Fish or Invertebrate Zoology. There are the pieces the parasites are divided into as well, from the traditional microscope slides of either whole organisms or stained and sliced sections, to the frozen tissue samples, to the complex data sets linking host to parasite. The "unbound biology" of parasites happens in an even more layered and interconnected way than other creatures I have examined thus far.

August 2015. I'm in the Department of Invertebrate Zoology [Figure 5-41], holding a rounded piece of watch glass about eight inches square mounted in a black square frame. It bulges out in front to create a dome, full of alcohol. Floating in this is a preserved white mouse completely covered in parasites, black dots buried in the fur. I gently set the object into a niche in the cabinet, with a light directly behind it. The silhouette of the mouse pops into focus, fine hairs and black parasites both waving softly in the alcohol [Figure 5-42].

"Amazing," says Anna Phillips, Curator of the National Parasite Collection. She leans in to get a closer look. "You can really see the details when they're lit up like this, the way they used to be. Too bad that now it's considered a fire hazard." She digs in a blue plastic crate behind her and pulls out another watch glass frame, this one full of a section of pig intestine with tapeworm. Set in the case next to the mouse, the strip of intestine glows a rich coral red. The tapeworm is visible as a long ribbon running along the tissue section, like a tear in a stocking.

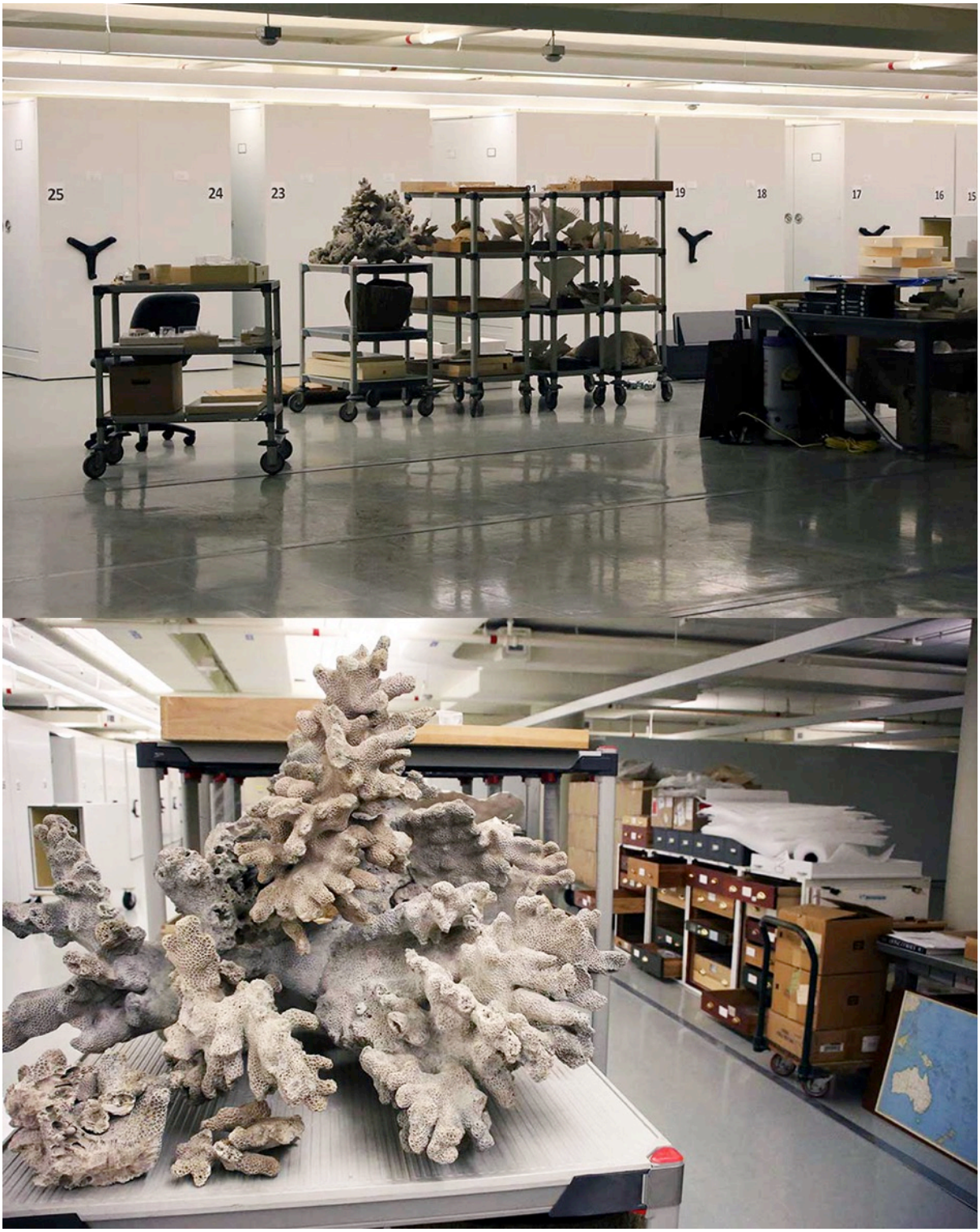


Figure 5-41. The Invertebrate Zoology collections being reorganized (Smithsonian NMNH, August 2015)

Figure 5-42. Mouse and its parasites in a watchglass filled with alcohol
(National Parasite Collection, Invertebrate Zoology, Smithsonian NMNH, August 2015)

Figure 5-43. Display cases from the National Parasite Collection reassembled
(National Parasite Collection, Invertebrate Zoology, Smithsonian NMNH, August 2015)

Anna and I met earlier that day to reassemble the original cabinets of specimens that were on display in the old location. Put into storage when the collection was moved, they no longer meet safety requirements, as the alcohol used to preserve the parasitical specimens and their hosts—besides looking very beautiful lit up from behind—is also very flammable. The original wood and glass cases have shallow shelves painted white, with little light bulbs lined up along the back. We unwrap specimen after specimen, setting them into the case [Figure 5-43]. I shuffle the specimens around, "curating" them according to shape and color, using my photographer's eye to create compositions out of the creatures. Anna comes back to the case with another watch glass-encased specimen in hand, and starts to re-shuffle my compositions of tissues organized into color-spectrums, instead organizing by species. We are amused by the different patterns each of us had chosen, and I noticed she organizes by parasite taxa, not the host. "It's the *parasite* collection after all," she says with a smile.

The National Parasite collection had recently moved to the Smithsonian, transferred from the U.S. Department of Agriculture Animal Research Service in Beltsville, MD. Anna, the curator, is a specialist in tapeworms and leeches. In her office, I notice a coffee mug that reads "I heart leeches," in case there was any doubt. She speaks about parasites with an enthusiasm that is infectious. We pull a large glass jar out of one of the blue storage crates, and a cat head, completely encrusted with scabies, slowly rotates in the alcohol to look at us through eyes almost squeezed shut by the parasites [Figure 5-44]. "Look at that!," she exclaimed. "I love this one, it's just so over-the-top infested. I wanted to display this during the Board of Trustees show-and-tell, but the Director of Collections said no. . . I think it just grossed her out too much. But it's so cool! I'm glad you're taking photos of it. . . . Parasites are just such an amazing part of life webs, they connect all the different parts. I don't think people realize." Another curator in Invertebrate Zoology had likened parasites on animals to insects on fruit—"It's just a part of things—it's not *contamination*, its just being *alive*."

Anna and I talk as we pull one object after the other out of the wall of blue crates filled with the recently transferred National Parasite Collection: a carved wood model of a worm that comes apart into 3 pieces so you can see its insides, boxes of microscope slides of thinly sliced, stained and mounted parasites [Figure 5-45], jars of pickled specimens (besides the cat head) that include a paratype and extra pieces of watch glass and leatherette-covered cardboard to repair or make new specimens for the illuminated parasite display case.

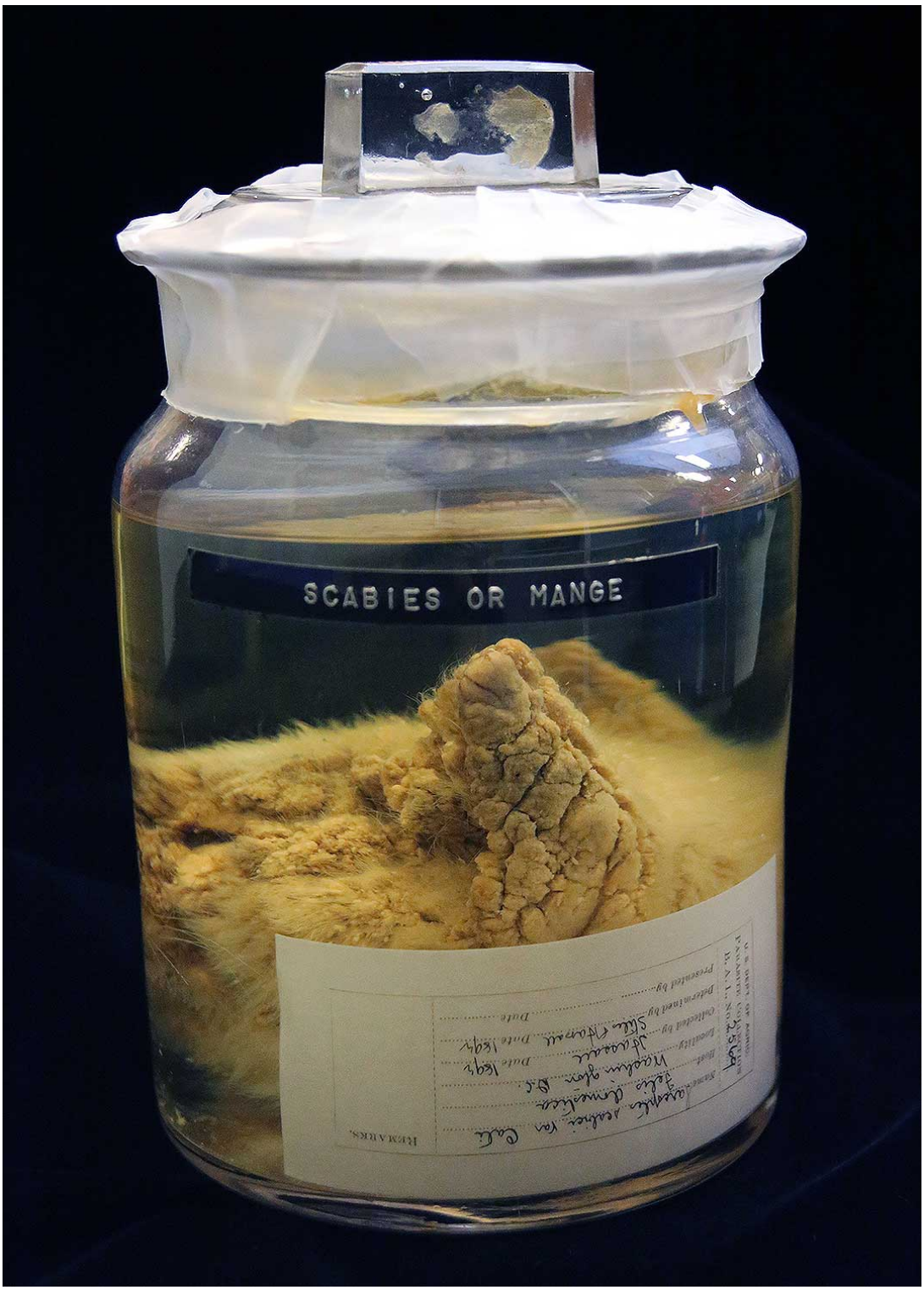


Figure 5-44. Cat head encrusted with scabies or mange
(National Parasite Collection, Invertebrate Zoology, Smithsonian NMNH, August 2015)

Figure 5-45. Parasite slides and slide cases
(National Parasite Collection, Invertebrate Zoology, Smithsonian NMNH, August 2015)

She tells me about going on collecting expeditions, usually accompanying Bird people, she tells me, since her specific area of research is on tapeworms that live in bird intestines. “You’re waiting for the bird collectors to come back from the field so you can get to work ,” she tells me, “. . .You have to be so delicate, and so patient. . . It turns into a waiting game, getting the parasite out of the bird. . . .you sit there with two needles, usually looking through a microscope, and tease it out, trying not to rip it . . . using just the tips of the needles, trying to get it out whole. Then you identify it as best you can, put a sample of it into [liquid] nitrogen, and then put the rest of it [the parasite] in a vial of ethanol for the collection. When the collection gets back to the museum the IZ [Invertebrate Zoology] preparator makes histology or whole mount slides for identification.”

Anna’s “fieldsite” for collecting her specimens is the bird’s intestines, and as it passes across the boundary from “bird” to “invertebrate zoology’s parasite collection” it crosses from being waste to being a valuable specimen in its own right. One curator’s biohazard, as I had seen before, is another curator’s voucher specimen. Or, “waste not, want not,” as another Invertebrate Zoology curator said with a wry grin.

I was curious about the process of making histology slides, so Anna introduces me to Freya Goetz, a museum specialist for IZ. Originally trained in molecular biology, Freya decided to shift her focus from the biolab to the more hands-on processes of histology slide mounting and scientific illustration. Reminding me that “molecular work is also hands-on,” Freya told me that she “wanted to look at the animals instead of pipetting clear liquid.” She walks me through the process of making specimen slides. For some preparations she stains the creature (from the size of a piece of linguine to about the size of a grain of rice)—with red dye to a “rose pink”—“Anna asked for rose pink and I asked what that was, exactly. So I printed out a Pantone color chart [gestures to wall] and she circled the one she wanted. So, yeah, that’s rose pink” [she points to the circled color block on the page]. It is one of perhaps five color blocks on the page I myself could classify as “rose pink,” but my photographer’s eye is clearly differently trained than an IZ Curator’s eye. After the parasite is stained rose pink and “cleared”—passing it through multiple chemical baths to fix the dye and remove the excess—these “whole mounts” of tapeworms are mounted onto microscope slides using Canada balsam, a type of tree sap.

Another type of preparation is the traditional histology slide, where the specimen is cast into a solid block of paraffin wax and hardened ten days in the oven at fifty degrees Celsius. This little block is then sliced hair-thin using a metal blade, the resulting sections mounted on a slide in a row to make a "serial-section" slide. Alternatively the specimen is embedded in epoxy resin and then sliced by a special machine that has settings in micrometers, with a blade made from either a diamond knife or a precisely broken piece of glass. "It takes a lot of practice to get the blade just right," Freya tells me, and shows me the box of discards next to the machine. "Over time, you get good at it though," she says smiling. Freya strikes me as a very meticulous and optimistically patient individual, traits, I'm coming to learn, necessary for the tasks at hand.

Sitting on top of the machine is perhaps my favorite tool in the entire museum (thus far): a small homemade instrument for guiding the specimen slices off the glass blade so they don't crinkle or fold back on themselves. It is a little hook-like tool made from a curator's eyelash glued to a stick [Figure 5-46]. I laugh as I pick it up, delighted by the quirkiness and ingenuity of the thing. Freya seems amused. "He made another one with his dog's hair," she tells me, "but I think the eyelash works better." I smile and put the tool back, imagining its maker hunched over the machine gently teasing the ribbon of slices off of the broken edge of glass with his eyelash tool. Back in her lab, Freya shows me how she mounts some of these thin ribbons of specimen-in-paraffin wax on a microscope slide, arranging them so that the slices reform the organism: "So you can 'read' it from head to tail." This makes me think of the slices like pages of a miniscule book, laid out sequentially making the organism once again "legible," its life (or afterlife) an open book.

Para-sites

The word "parasite" comes from the Greek *parásītos "*one who eats at another's table."[48] This reading makes parasites on a host creature those who have invited themselves to dinner, and, like all unwelcome guests, have refused to leave. Marcus has described a para-site as "a field site where anthropologists and their interlocutors come together to discuss matters of concern" (Marcus 2000:5).

[48] Online Etymology Dictionary (http://www.etymonline.com/index.php?term=parasite)

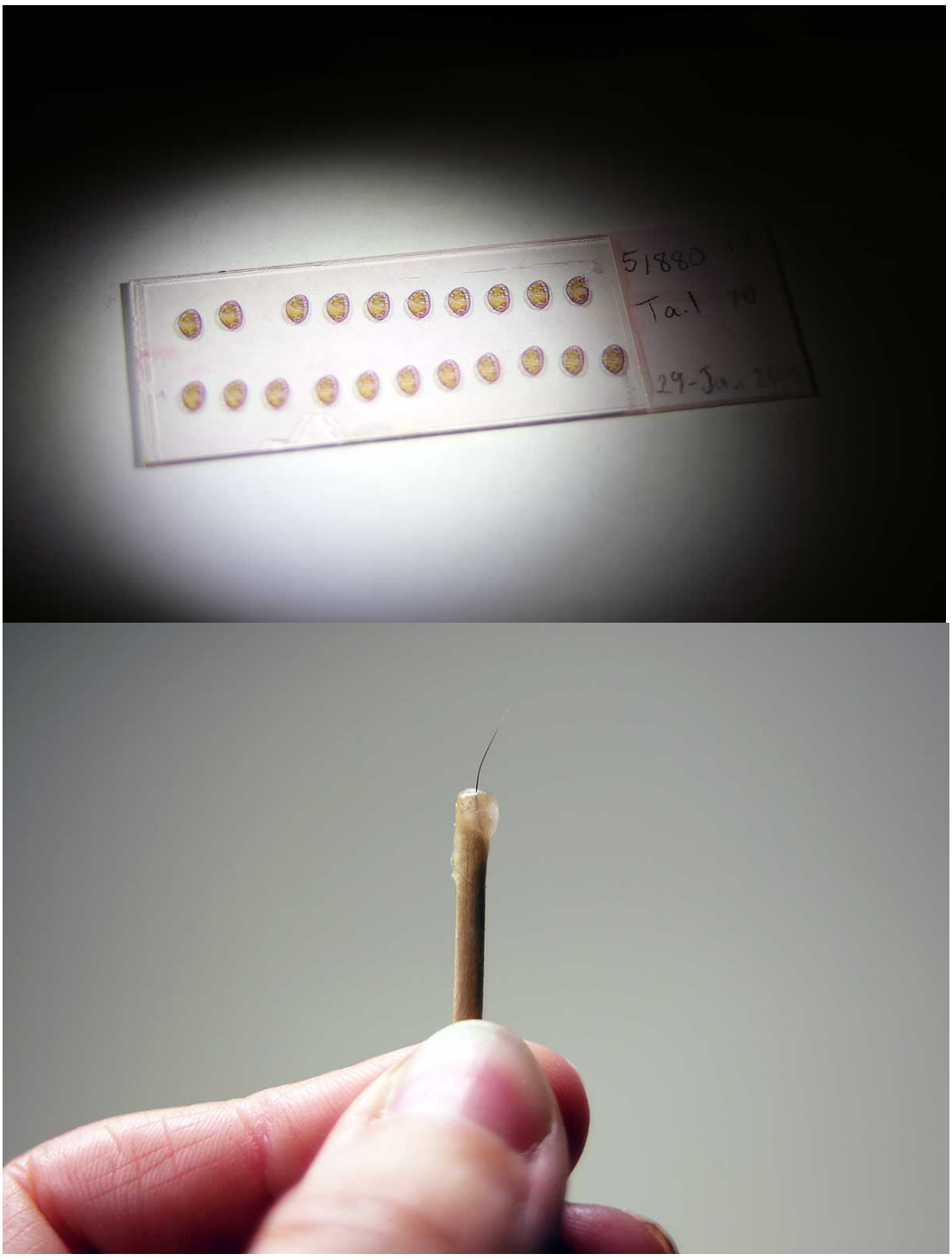


Figure 5-46. Eyelash tool in Histology Slide prep lab (bottom image), used to pull micrometer-thin slices off the machine, so they can be mounted on a slide (top image).
(Invertebrate Zoology, Smithsonian NMNH, August 2015)

Using the term to acknowledge the extent to which anthropologists were increasingly venturing into terrain where they encountered individuals who possessed critical, reflexive tools that complemented or even challenged their own, Marcus distinguishes the para-site from the traditional anthropological field site. What I find to be its greatest value as a mode of undertaking engagement with expert communities is its use as a generative space—"a space of various uses and ethical inflections" " (Marcus 2000:5).

The word parasite in French has an additional meaning not present in English: *interruption*. Michael Serres' (2007) acknowledges the "para-site" as an interruption point that has been productively used by various scholars engaging communities from an adjacent position. Joanna Radin's ethnographic and historical analysis of frozen collections of human blood sees a "para-site" as a way of "re-choreographing the forces necessary to produce knowledge in ways that seek to rectify the parasitic and increasingly politicized nature of knowledge making that relies on cold blood" (Radin 2012:315). For my own research, it is a possibility for reconfiguring the system of relations in the museum between species, that is—human and non-humans, between specimens and their makers. This means looking to the spaces *in-between*, at the borders where disciplines and ideas are interrupted and open up to different potential, such as a bird carcass becoming a "fieldsite," or a natural history collection becoming a site for genetic exploration and extraction. In her book *When Species Meet* (2008), Donna Haraway implicitly adds to Serres' commentary of the consequences of consumption. To eat together in ways that promote flourishing:

> "[O]ne must actively cast oneself with some ways of life and not others without making any of three tempting moves: 1) being self-certain; 2) relegating those who eat differently to a subclass of vermin, the underprivileged or the unenlightened; 3) giving up on knowing more, including scientifically, and feeling more, including scientifically, about how to eat well together" (2008:287).

What this requires is a para-site that involves not only scientists and anthropologists, but integrating an attention to the multispecies relations involved in the practices of nature-making in the museum. This shift in perspective requires, as the IZ curator states above, looking at parasites (as well as para-sites) not as "contamination," but as a way of "just being alive."

Conclusion

Thus far I have argued that the process of making specimens is a process of manufacturing difference—making parts of the natural world discrete in specific ways to do specific work. Examining the techniques, technologies, interests and differently valued forms of labor that go into making and remaking collections are, from this perspective, essential. This focus on material practices is key to understanding how people, places, interests and values are assembled into specimens and the cargo of future visions they carry with them along their "flight paths" across borders and boundaries.

In this chapter I have examined building a bird in three ways: from preparing a bird study skin and taking tissue samples I learned how specimen preparation in Vertebrate Zoology creates different kinds of bodies without organs (and organs without bodies (Braidotti 1989)) that are potential vehicles for types of natural order. Through following bone fragments, feathers, and the remains of bird strikes to different parts of the museum and beyond, I examined their function as "boundary objects" negotiating meaning between disciplinary borders. Finally I turned to the "entangled specimens" of discarded bird carcasses and the parasites extracted from them for the National Parasite Collection, a different kind of transformation as biohazard became a "field site" for collecting valuable specimens.[49]

These border crossings between collected and collecting nations, in the global biodiversity they curate and process, involve many types of slippage and stickiness. "Friction," in Tsing's terms, "inflects historical trajectories, enabling, excluding, and particularizing" (2005:6). Sometimes this takes on the form of translations into familiar categories at these thresholds—enabling or excluding, where the traffic in exotic seafood is common, and the transportation of scientific specimens is not. In other cases it means assessing the "life history" of specimens, be it transported in the body of another snake or kept distinct as two

[49] Waste becomes a precious specimen–a frozen tube in the biorepository. More radically the whole mammal can be pickled (as they have been doing in Fishes and Reptiles for decades) preserving all internal structures for micro-CT scanning at some future date. Formalin destroys the DNA, so a small tissue sample is taken before pickling in an inconspicuous spot not key to diagnostic characteristics—the inside of the thigh of a bird, mammal or lizard, or on the "non-display" side of a fish, for instance. This can be interpreted as preservation techniques "leaking" between disciplines – and as Ingold (2010) reminds us "things leak" in multiple ways between multiple kinds of "things"–as different kinds of information from specimens and types of data become valuable over time and in different contexts.

snake specimens. If new practices in scientific knowledge production such as microbiome sampling from specimens (i.e., the microscopic ecology that persists in and on the specimen from its original habitat) that are tangled together, either literally or figuratively, start to become commonplace, it follows that quite different, and possibly more complex validation procedures would have to be set in place, again carrying relevant implications for the valorization of museum specimens.

Where difference is produced in these moments, where specimens can be discerned as slowing unwinding biologies that tangle in their wake the social and biological interactions that materialized them—these allow me to ". . . grasp the productive moments of misunderstanding" (Tsing 2005:4). These moments, and my analysis of them, have been the focus of the preceding chapters as I turn from collections as data sources, the expanding global networks of tissues and vouchers, and the boundary crossings of birds. I now turn to the "articulations" involved in sharing techniques to craft beetle specimens both morphological and molecular--how knowledge is reproduced, moving sideways down the lab bench.

Chapter 6

ARTICULATIONS/BEETLES

Sharing Techniques and the Value of Parts

articulate—of hearing, thought, intelligence: Clearly distinct or meaningful, indicating clear understanding. Of anatomy: Attached or united by a joint; Having the parts discretely recognizable and constructed. From the Latin *articulatus*, past participle of *articulare* "to separate into joints"[50]
beetle—insects of the order Coleoptera, having biting mouthparts and forewings modified to form shell-like protective cover for membranous flightwings; from the Old English *bitela*, literally "little biter" [51]

The minuscule, a narrow gate, opens up an entire world.
— Gaston Bachelard (1964:155)

This chapter focuses on how new practices in transforming living things into museum specimens are created, shared and become naturalized into daily routine. Viewing museum collections as global assemblages that travel different networks (as explored in the Chapter 4 on Tissues/Networks), and how specimens shift the value they carry at each boundary crossing (as explored in the previous chapter on Birds/Boundaries), I now take up the processes of making various types of artifacts labeled "beetle."

A beetle, it became very clear over the course of my fieldwork, was not a bird—especially when it came to genomic collecting. Exploring the values created as insect bodies are disassembled and dispatched to different parts of the museum for different purposes, I examine the ways skills and techniques are developed and shared. In this chapter I examine different methods for producing scientific knowledge through insect bodies: pinned in a drawer as a voucher specimen, pickled in a bottle for parasite research, frozen in a tank for posterity, or dissolved for DNA extraction. These practices, it will become clear, are distinct from those in the Division of Birds, existing in an entirely different "culture" within the same museum. In learning to prepare beetles in these different ways, I mapped some

[50] Online Etymology Dictionary (http://www.etymonline.com/index.php?term=articulate)
[51] Online Etymology Dictionary (http://www.etymonline.com/index.php?term=beetle)

of the shifts taking place as Entomology negotiated the standardization of its distinctive collecting, cataloging and extraction processes.

To do this I learned to make beetles in three ways, from the most abstracted and molecular to the most intact and recognizable: I begin by running gels in the Laboratories of Analytical Biology (L.A.B.) to assess the potential genomic quality of alcohol preserved and pinned specimens (*How To Make A Beetle: Part I*); then pulling legs from pinned beetles for genomic analysis during a GGI-funded workshop (*How To Make A Beetle: Part II*); and finally learning to pin and point mount beetles in the Department of Coleoptera–a process little changed for over a hundred years (*How To Make A Beetle: Part III*).

Through learning the series of practices required to both create and to genetically sample an insect specimen (albeit in reverse order), I trace the forms of value that accumulate during these transformations, and the kinds of "articulations" (Deleuze and Guattari 1988; Fujimura 1996) between past, present, and projected future that unfold in these encounters. As much as a beetle leg is articulated in a ball and socket joint, the disarticulation of legs from the beetle's body for genetic assessment is yet another kind of articulation: one that speaks to the intersection of people, place, materials and interests in the crafting of "natural order." Insect bodies, I suggest, "articulate" genomics differently than vertebrate bodies such as birds. The structure of the creatures in question either lend themselves or resist genomics protocols based on human beings and model organisms used for (human) biomedical research. Birds and their vertebrate kin adapt more easily than invertebrates such as the parasites pulled from the bird carcass at the end of the previous chapter, or the beetles I take up in this chapter. For instance, different sense of scale in the different Divisions and Departments (a microscopic wasp versus a pelican versus a stand of trees) can conflict with the models for genomics that originated in human biomedical research. A vertebrate, such as a pelican, can be sampled for viable "genome-quality" tissue, however entomologists may need to combine multiple individuals of small insects (like ants or micro wasps) to get enough tissue to reach the same goal, while botanists often collect samples of populations—the "voucher" still standing in the forest.

Learning to craft different forms of nature in the museum was a key method I used for gaining access to the kinds of craft practices in the collections and the labs, tracing continuities with past ways of making. Learning to make specimens

also highlighted for me the ruptures as new ways of making emerged and were integrated, such as genomic techniques becoming part of museum life. The previous chapters took up the re-evaluation of natural history collections for genetic projects, framing this move in a longer history of standardizing life into parts and pieces that were discrete, mobile and "interoperable" in the language of data—be it the data of "paper museums " cataloguing early modern museum collections of the sixteenth century, or the databases of the contemporary DarwinCORE. Museums have long histories of assembling discrete pieces of the global into a naturalized order, organized in miniature—arrayed in drawers and cabinets or stacked in tubes floating in liquid nitrogen. The kinds of meaning and value assigned to these collections are far from stable, as is the value assigned to the kinds of labor and interests that produce them. From analyzing the on-going debates at NMNH over the re-valuing of collections, the standardization of relationships between vouchers and tissues, and the methods for "capturing genomes," I now turn to look closely at the hands-on methods for making the collections themselves—one beetle, tissue sample and genome at a time.

The beetles I “craft” in this chapter move from the most abstract in a dissolved tube of DNA, to the most embodied in a beetle mounted on a pin, with an intermediary stage of pulled beetle legs. This trio of perspectives on crafting (beetle) nature offer an interesting view into the flow of entomology specimens into the Smithsonian collections, where biowealth is typically accumulated and assessed for threat or use through by the many embedded government agencies: the US Department of Agriculture, the US Army and the US Biological Survey. Collections, I argue, “articulate” nature in specific ways based on the materiality of the life they utilize in the context of their distinct disciplinary histories. Further, in doing so collections demonstrate the contingent and constructed nature of specimens as human artifacts.

On Articulations

In the following sections I use the notion of "articulation" to outline the different dimensions of scientific work. This notion was first developed to identify all the forms of "tinkering" implemented by researchers to construct do-able problems while complying with various levels of engagement including experimentation, the laboratory and the social world, as well as contact with distant colleagues and financial backers (Fujimura 1987). "Articulating,” writes Joan Fujimura, “consists

in creating strategies by which researchers juggle, balance and meet multiple, simultaneous demands at many levels of work organization" (1987:275).

The concept of articulation has then been further developed to underline the absence of conceptual determinism in the definition and pursuit of research problems; it highlights the fact that problem definition requires a contingent co-construction and “alignment” of instrumental and conceptual aspects (Griesemer 1992). I show here that, as part of their work, scientists also articulate concepts of natural order and distinct disciplinary histories in the material processes of making specimens, be they abstracted in an electrophoresis gel or stuck on the end of an entomology pin.

Using the notion of “articulation work,” I want to highlight the intersection of multiple fields in the minute space of a beetle body, as it is taken apart and put back together. The notion of articulation, as defined by previous work, also stresses that scholars do not always follow well-defined strategies serving generic plans and theoretical purposes (Barad 1996; Clarke and Fujimura 1992; Fujimura 1996; Latour and Woolgar 1979; Rabinow 1997; Smith 2004). In other words, the notion of articulation is a particularly productive concept here because it is closely related to the notion of “tinkering,” which suggests that scientists’ activities do not follow directly from theoretical programs: instead, scientists progressively construct their work by tinkering between different aspects in contingent and unpredictable ways, that is, in a *bricolage* (Levi-Strauss 1966:16–17) of materials and practices.

Things, as any scientist will tell you, don't always work out quite as planned. Mistakes can also prove to be profitable, however. Scientific knowledge is created in unforeseeable and open ways that were described by Pickering (2010) as a "mangle" of theories, experiments, machines and social organization. I would add to this that the (bio)materials that are being transformed are central to the process of creating these articulations between people, places, materials and interests—in their assemblage and circulation–that are at the core of this dissertation. As much as the different disciplines within the museum are struggling to integrate standardized genomic collecting protocols into their ways of doing things, including the wide-ranging implications for how collections are cared for, used, linked and catalogued, each discipline also continues to “tinker” with practices. These include small changes in how labels are made, from materials for entomolgy pins, to techniques for extracting DNA from specimens.

These small changes accumulate over time and become integrated into the normalized practices, that is, just the “ways things are done.” In the following three episodes I pay particular attention to the ways changes happen—how tinkering happens, how it is articulated and shared, and how it becomes naturalized. To begin, I examine how to extract DNA from disarticulated beetle legs, examining the ways material culture moves across conceptual and physical boundaries–that is, how "things leak" (Ingold 2010).

How to Build a Beetle, Part I:

Extracting Beetle DNA and the Leakiness of Things

November 2015. I'm walking through the central rotunda of the National Museum of Natural History (NMNH), surrounded by three stories of balconies and marble columns, capped with a large dome. At the center of the rotunda stands its iconic inhabitant "Henry," a taxidermy mount of a large African bull elephant first displayed in 1955. Several months from now he will undergo yet another restoration, being vacuumed for dust, cracks patched and painted with colored wax, and the bottle of whiskey stashed in his foot by a quirky taxidermist retrieved. His terra-formed plinth of dirt and thorn trees, birds, dung beetles and a tin can will also be stripped away and replaced with a modernist cube of marble—a window on nature transformed into an elephant-artifact on display. This maintenance on the elephant mount is one small moment where the museum-visiting publics get a glimpse of the efforts to preserve and conserve the exhibits (or, in this case, transform them).

The vast majority of visitors, and indeed the public at large, do not realize the extent or even the existence of the vast collections behind the scenes, currently numbering at approximately 138 million objects across the various Smithsonian museums. Behind the scenes the scientists and staff use these collections for on-going research, working in what I came to think of as the peripheral vision of the NMNH. Projects such as the Global Genome Initiative keep the museum "competitive," to quote one museum administrator, a vital means for integrating genomics research and collections into the trajectory of the museum. This kind of return to encyclopedic collecting with genomic tools, as well as the mining of the existing collections for data (as detailed in the previous chapter) ensure the

relevance of the collections, and the museum's continuing contribution to contemporary scientific debates.

Leaving the rotunda I walk past the giant squid in its tank, under the blue whale model (blowhole remodeled on several occasions as research revealed more accurate data on cetacean anatomy) and down the marble staircase wrapped around a Tlingit totem pole (displayed in the 1876 Philadelphia World's Fair). Cutting through the recently opened hands-on education center, Q?rius, I pause briefly to look at the different sort of "diorama" on display here. It is an interpretive replica of the collections–the drawers and cabinets of specimens behind the scenes–built to withstand the hands-on attention of school groups. Each division and department is represented: tiny beaded moccasins and a batik scarf picturing Obama in the Anthropology drawers; a freeze-dried slug mounted on a pin in Invertebrate Zoology; drawers of (replica) monkey skulls and (authentic) stuffed owl skins in Mammals and Birds. Various projects within the museum try to render visible the scientific work going on behind the scenes. How that research is rendered visible, and what is left invisible–such as the other types of work by collections staff, preparators and lab techs that make the research possible–is an on-going source of friction in the museum. Skirting a group of adults anxiously watching a young child wielding a gorilla skull, I scan my badge and slip through a pair of beige doors next to the cabinets.

I'm now in the "back of the house" part of the museum, with narrow hallways and minimal signage to guide one's path. Getting lost is in fact part of the initiation ritual of joining the museum, and I frequently encountered small groups of new interns or fellows in the hallways debating which direction to go. By this time I had successfully mapped my way across the museum (by using the GPS on my phone to create hand-drawn maps during my first months there), and I followed the hallway through a set of doors marked "Alarm Will Sound" (which did not) into an addition built in the 1960s to house the museum's growing research and collections.

Now in the West Wing, I make my way to the first floor. Completely refurbished several years earlier, the entire floor had been gutted and transformed into a genetics laboratory, ringed by conference rooms and offices: The Laboratories for Analytic Biology (L.A.B.). A great "fishbowl" of a space (as it had been nicknamed), the open-plan lab occupied the center of the floor plan, completely encircled by waist-high windows looking in. From the corridor that encircled the

L.A.B., you could see across the expanse of workbenches, sinks, fridges, and equipment all the way to the hallway on the other side. The person I'm here to meet is at a lab bench to my right, already busy setting up the day's work. I scan my badge again and go in, sorting through the white lab coats on pegs by the door until I find one small enough for me. Experience had taught me that a too-large lab coat not only looked ridiculous, but that the rolled up sleeves also proved problematic for the work—dragging across the lab bench, getting in the way of the pipette, etc. I was relieved to find a lab coat my size and I pulled it on as I walked over to Dan Mulcahy at his workbench.

Dan, a specialist in desert snakes, had been hired several months earlier by the GGI as their lab technician, along with several others: a bioinformatics person to help with assembling and processing genomic data (Vanessa Gonzalez); a "tube wrangler" (Steve Thornton), and a "data wrangler" (Amanda Devine) to handle the influx of cryotubes into the biorepository from GGI-funded projects. Dan's extensive experience on collecting expeditions as a herpetologist–catching and preparing snakes, lizards, toads, turtles and anything else "interesting and cold-blooded"–was useful for the GGI, particularly combined with his experience doing genetic work on the specimens once back in the lab. As he explained:

"I'm the lab guy and also the field guy, at least for herps [herpetology] . . . There's something of a generational split now though, with the younger people going through their whole [PhD] program doing Next-Gen [next-generation genetic sequencing] for everything. But in a museum you also have curators who've been there for decades doing morphological and systematics work. Some have adopted genetic ways of doing things, others not really . . . Depends on what they're interested in, what their questions are."

Having been in weekly GGI staff meetings with me for several months Dan had seen the photos I had taken for other projects. Currently he was writing up a lab protocol for GGI-funded projects, and thought some photos of the process might be useful to illustrate the details. My purpose in the lab was twofold: First to photograph key steps as Dan assessed the genomic quality of specimens already in the collection, focused on a sample set of pinned and alcohol preserved beetles. Second, I wanted to get hands-on experience in the lab, learning the process myself. I had taken the lab safety training course, learning how to not inadvertently cross-contaminate parts of the lab, to wear the correctly colored lab coat in each section (white for the main lab, gray for the pre-PCR room, and navy blue for the post-PCR or DNA extraction lab) and how not to accidentally kill myself while dispensing liquid nitrogen from the vat. I slung my

camera over my shoulder, checking I had a lab notebook and a pair of small latex gloves. I was ready to assess extracted beetle DNA.

Things Leak

According to scholarship in molecular biology, DNA is a relatively stable molecule that can survive intact for extremely long time spans under the right conditions, as demonstrated by the reassembly of a Neanderthal genome from sampled bones and teeth (Green et al. 2006; Paabo 1989; Rohland et al. 2010). Extracting the DNA from museum specimens has typically required grinding up all or part of the source specimens, resulting in the destruction of all or much of the specimen. First, they are frozen in liquid nitrogen to make them brittle and then finely crushed with a mortar and pestle. The resulting powder is then mixed with a "buffer," one of several types of acid that break down the protein bonds, separating (in this particular case) the hard outer casing of the beetles from the DNA-rich muscle tissue and organs inside.

This type of destructive sampling was a source of much debate within the museum and scientific communities–what gets saved, what gets destroyed, how much to sample, what not to sample, and how capable is the scientist using the sample anyway? Will it lead to a new lab technique, a significant reordering of the Tree of Life, or a paper in *Science* or *Nature*? These questions were the topic of on-going debates I overheard at the monthly NMNH Genomics meetings, in hallways, at lab benches and at the weekly staff social event on Friday nights. Many strong opinions circulated, as technicians, collection managers and curators vocalized their beliefs on the use and abuse of genetic sampling in collections they had created and cared for.

However, several new techniques had just filtered into the conversations, filtering out from a series of job talks for a new Entomology curator. Beetles and other arthropods in particular were very promising, as the hard outer shell (exoskeleton), the casings for the legs and the antennae are chitinous (a semitransparent horny substance related to cellulose) and won't dissolve in buffer, whereas the inner muscle tissue and organs will. By piercing the sides of the beetles with a tiny pin and soaking the beetle overnight in buffer, useful DNA will infuse into the buffer–which can then be processed. The damp and slightly perforated beetle is left (mostly) intact, and can be dried off and returned to the

collections, serving as a voucher specimen for the DNA sample. I am reminded of Tim Ingold's assertion about the ways material culture moves across conceptual and physical boundaries, that "things leak:"

> “If we think of every participant as following a particular way of life, threading a line through the world, then perhaps we could define the thing . . . as a ‘parliament of lines’ . . . Thus conceived, the thing has the character not of an externally bounded entity, set over and against the world, but of a knot whose constituent threads, far from being contained within it, trail beyond, only to become caught with other threads in other knots. Or in a word, *things leak*, forever discharging through the surfaces that form temporarily around them” (Ingold 2010:6, emphasis added)

Things, in the context of museum genomics, are leaking in multiple ways and in multiple directions. For today's experiment in assessing the (hopefully) genome-quality extraction from our beetle specimens, Dan had frozen and ground the beetle legs, letting them sit in buffer overnight.

The Materials and Forces of the Lab Bench

The lab bench was a neatly ordered array: Trays of tubes, racks of extracts, pipettes of different sizes, pipette tips lined up ready for each mixture, and a very worn lab notebook with various "recipes” [Figure 6-1]. Hand-written notes covered the printed page, noting modifications in times, temperatures, different mixtures [Figure 6-2]. "We're using a lep [Lepidoptera=butterfly] primer for these," Dan tells me. "They were developed awhile ago and they're pretty solid, they are used for lots of things that aren't actually leps. Must be some conserved genes in there that cut across families. I'm used to working with vertebrates–much better DNA" [Figure 6-3]. Bundled into this conversation is a long and tangled history of the flow of biotechnology. From human-centered medical research, where a great deal of social and financial capital concentrated, emerged a number of technologies and techniques for extracting, sampling, sequencing and banking biological materials.

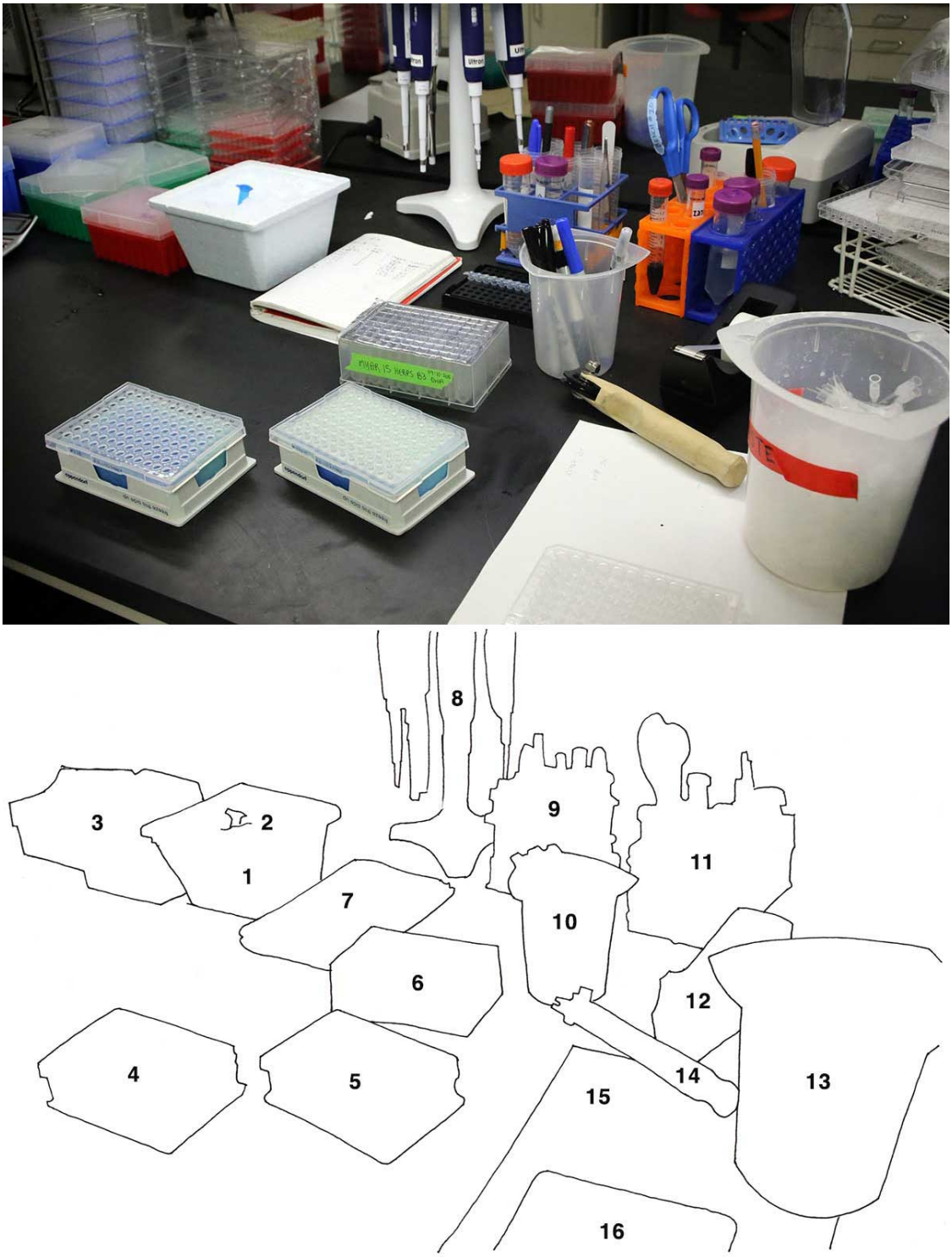


Figure 6-1. Anatomy of a biolab workbench: [1] Tub of ice; [2] tube of extracted DNA; [3] pipette tips; [4,5] pipette tip racks; [6] plate of DNAs; [7] lab notebook with recipes; [8] pipette holder; [9, 10, 11] pens, scissors and random leftover tubes; [12] tape; [13] container for used tips; [14] handmade wheel tool for securing tops on plates; [15] piece of white paper so the DNA, buffer, etc. are visible in the bottom of the wells; [16] plate to pipette into. (Laboratories of Analytical Biology, Smithsonian NMNH, November 2015)

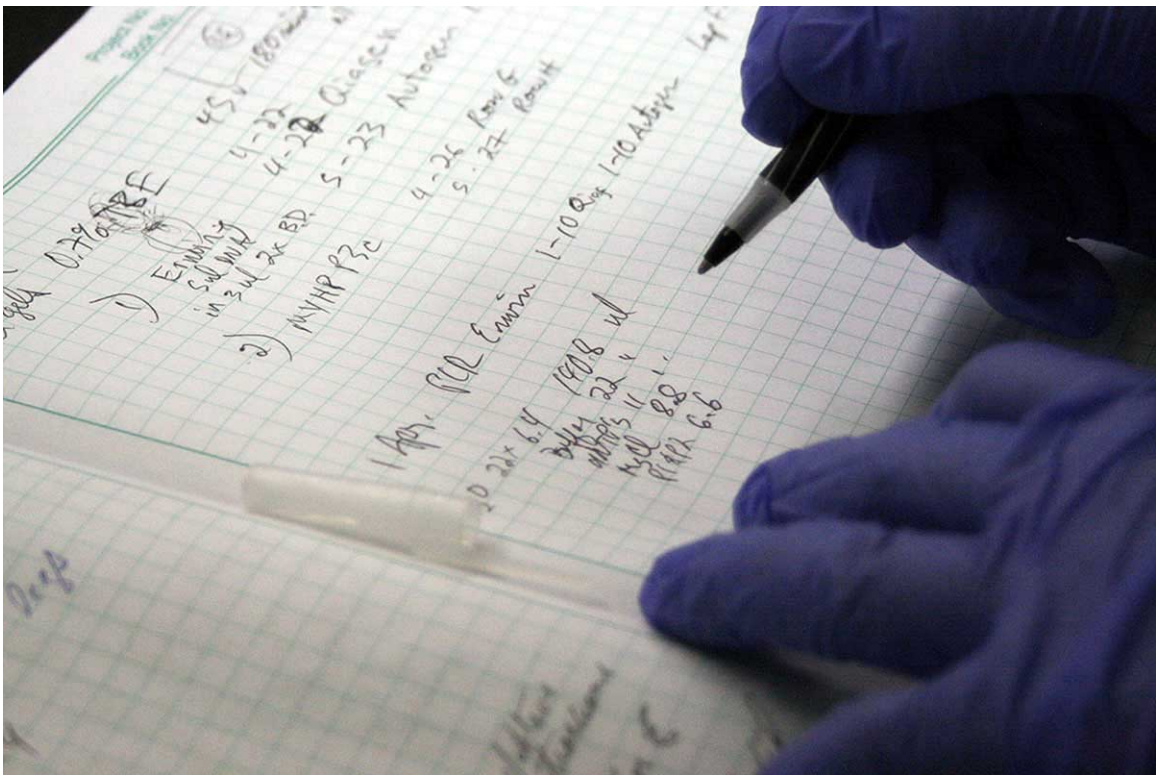


Figure 6-2. Noting time and temperature in the lab book
(Laboratories of Analytical Biology, Smithsonian NMNH, November 2015)

Figure 6-3. “Lep” primers (Laboratories of Analytical Biology, Smithsonian NMNH, November 2015)

The Human Genome Project was in effect a single-species mammal project, which then slowly spread to other contexts (such as museums and zoos) and to other species, such as mammals, then to other warm-blooded vertebrates such as birds, then to vertebrates in general including snakes, reptiles, and fish, and then to invertebrate zoology with hard-bodied insects and soft-bodied worms, snails, etc. And finally, to plants, so very different from us and yet so useful to the beginning of the cycle—useful as raw material for medical biotechnology for our own mammalian species and our many ailments. Gilles Deleuze and Félix Guattari argue that the essential relation, in a world of life, is not between matter and form, or between substance and attributes, but between *materials* and *forces* (Deleuze and Guattari 1987:377).

The materials and forces at work on the lab bench in front of Dan and me are these entangled histories of ways of knowing the world, of reassembling frames of knowledge, of amplifying the DNA of a beetle through that of a butterfly, of then assessing the "quality" of that beetle (vis-à-vis butterfly) DNA to deem it valuable enough to be part of the GGI's collection. Dan and I carefully follow the protocol scribbled in his lab notebook, pipetting 2 microliters (µL) of material from here, then 7µL from there, adding liquids from one tube to another over and over until we had distributed the extracted beetle DNA and the requisite buffers and stains into a 96 well plate [Figure 6-4, Figure 6-5]. Putting a rubber matt on top of the plate, we used a tool fashioned from a wood dowel and a wheel to secure it to the top of the plate. The lab manager had made a batch of these tools in his garage one weekend, as no lab supply company had something just right (or at the right price) [Figure 6-6]. "Sometimes you just have to make the thing you need," he had told me. We "spun down" the plate in the centrifuge, balancing its weight with a pile of empty plates on the other side. After twenty minutes at maximum speed we had "pelleted" the nucleic acids–a little white blob visible at the bottom. More pipetting out of liquids, washing our pellets in ice-cold 85% ethanol, and then "re-suspension" in new buffer. A final spin in the centrifuge, and we had our extracted, amplified stained DNA at the bottom of each well ready to pipette into our waiting gel.

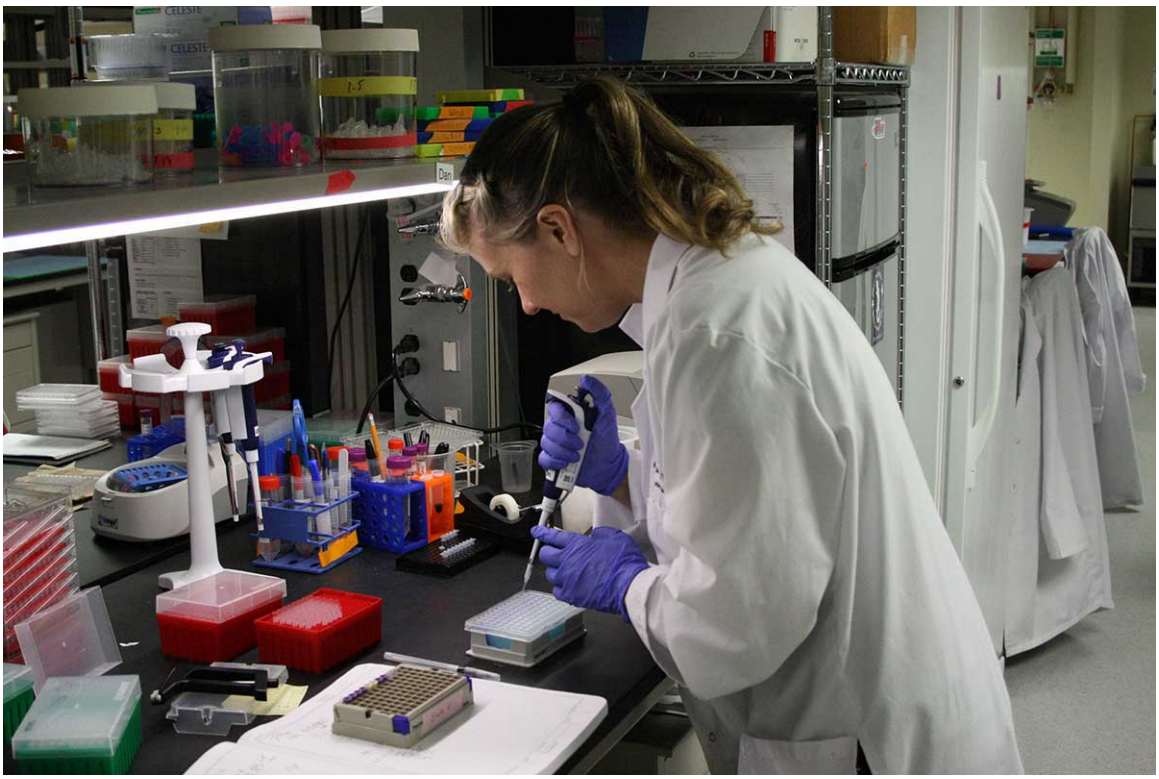


Figure 6-4. Author learning the pipetting technique of stabilizing the tip with a carefully poised fingertip (Laboratories of Analytical Biology, Smithsonian NMNH, November 2015)(Photo: Dan Mulcahy)

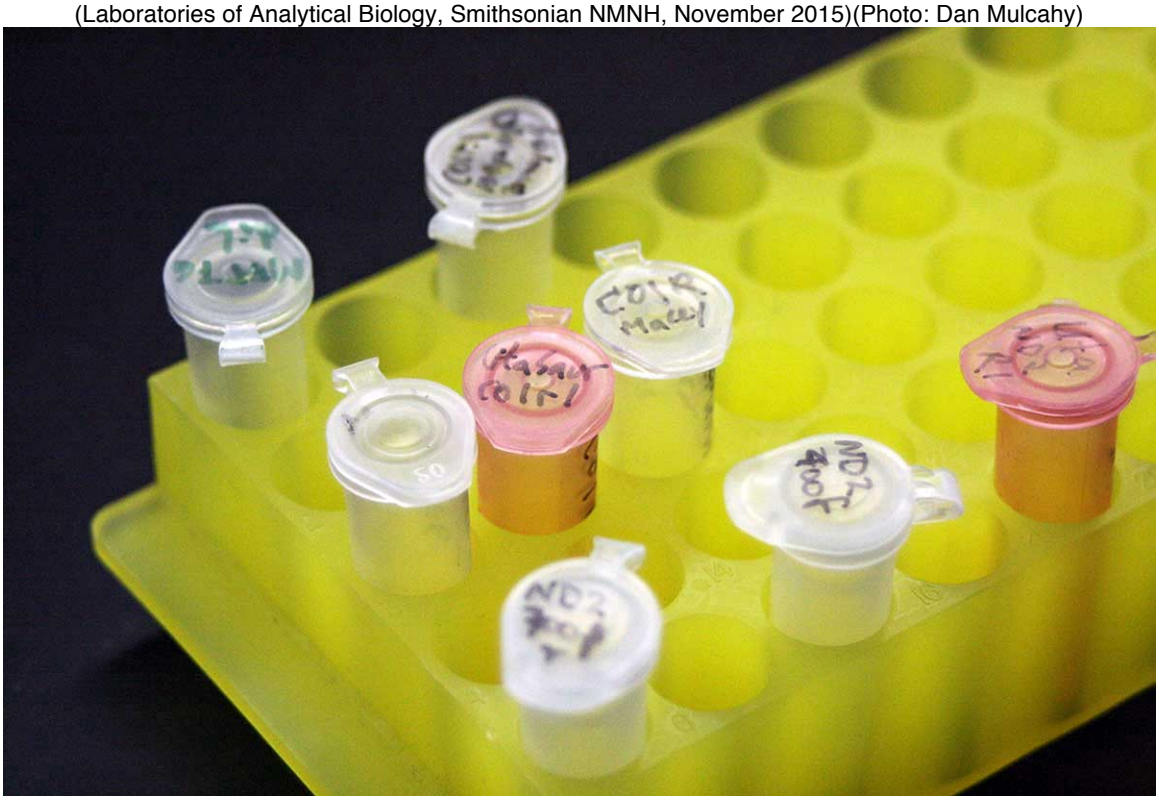


Figure 6-5. Beetles, unbound (Laboratories of Analytical Biology, Smithsonian NMNH, November 2015)

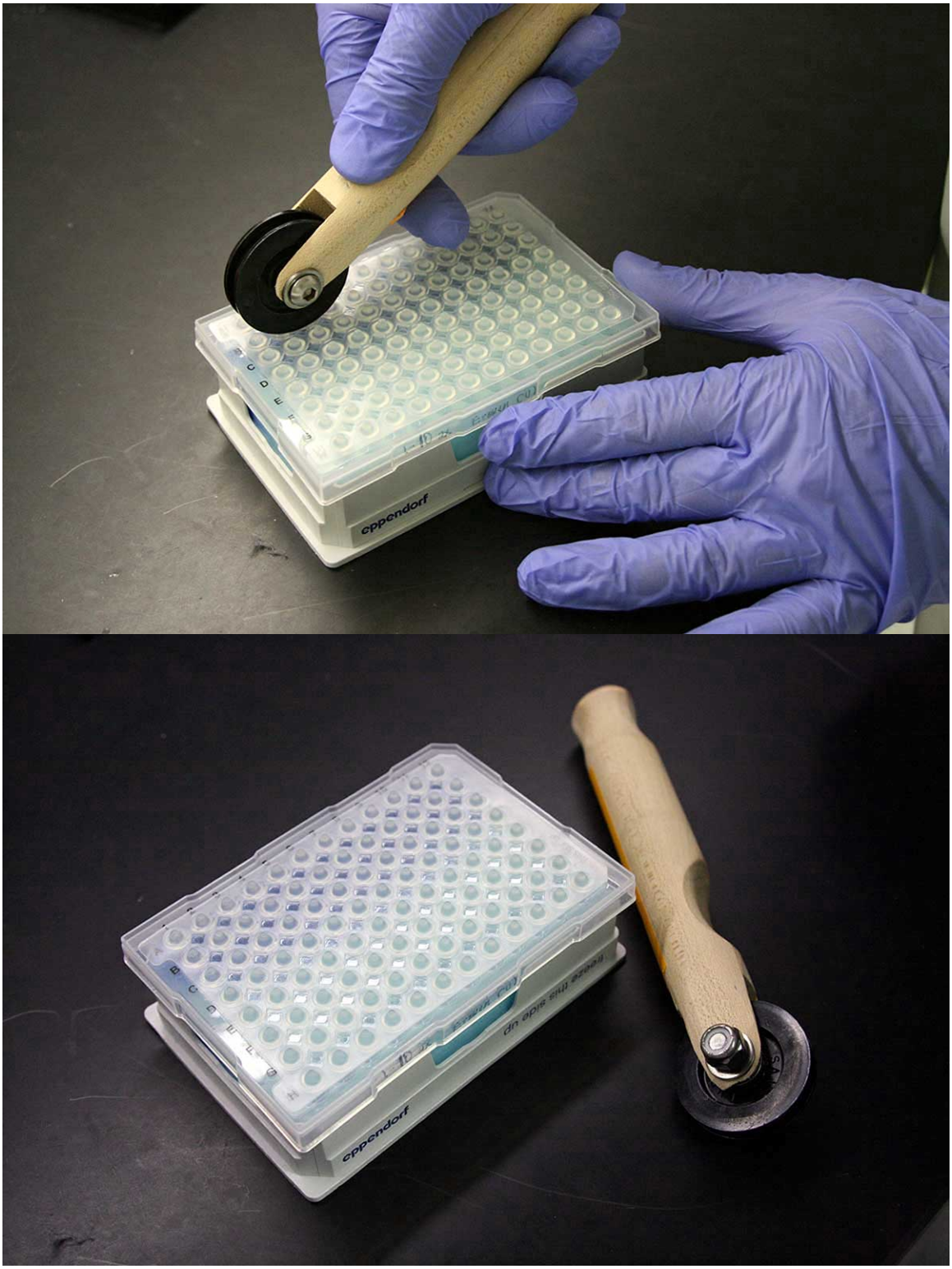


Figure 6-6. “Sometimes you make the tools you need” Hand-made wheel tool for sticking rubber mat onto 96-well plate of DNA extracts (Laboratories of Analytical Biology, Smithsonian NMNH, November 2015)

Pipetting DNA and Learning to See in Microliters

Ten microliters is a miniscule amount of liquid [Figure 6-7]. A regular drop of water is about 50μL, so I was squinting as I tried to deposit one-fifth of a water droplet into a small indentation at the bottom of the electrophoresis gel. Many hours of work in the lab, not to mention the effort to collect, curate and preserve the specimen in the first place, were concentrated in the tiny tubes next to me. The possibility of wasting all that condensed effort weighed on me as I picked up the pipette. Stained dark blue with dye, it was easy to see when the DNA didn't go exactly where it was supposed to in the clear soft gel, leaking out slightly sideways and underscoring the leakiness of things [Figure 6-8]. This time, I guided the pipette with my latex-gloved finger, positioning the tip of it at the front edge of the plate's next "lane." Each extraction went into its own "lane," lining up in columns with a negative control in the first and last lanes. Once we applied electricity, the current would pull the DNA through the gel from negative at the top to positive at the bottom, unwinding it along the lanes. Measuring these unfurled DNA "ladders," we'd be able to see how much DNA we'd managed to extract and whether it was patchy and ghostly or opaque and good. However, first I had to get the extracts into the tiny indentations in the gel—about the size of a grain of rice—that had been formed by the hot liquid gel flowing around a comb when it was poured.

With the tip of my pipette balanced on the front ledge of the indentation, I gently pushed my thumb down on the release button, trying to "pour" it in as Dan had instructed. This one went in perfectly, but I had left a tiny bubble in the gel. Dan grunted, and I tried again. Pausing, we repositioned a clamp light so it raked across the gel, and suddenly the little gel landscape in front of me jumped into perspective. What had been a murky greyish-white space became more clearly defined with the comb indentations casting tiny shadows. I had to tilt my head back and forth to see it, but I now had a space I could (almost) see. The rest of the extracts went in smoothly. Plugging in the cables to the gel plate, we set the timer and waited, the forces of electricity pulling our DNAs out along their paths. An hour and a half later, we carefully disassembled the sides of the plate and slid our gel into a plastic tray. Gently covered with a stain that interacted with the stain we'd put in with the DNA extract, our gel sat in a darkened cabinet in its tray for another half hour. Finally we removed it, washed it off and carefully slid our gel into the UV camera box. With the white light turned on, we gently nudged it

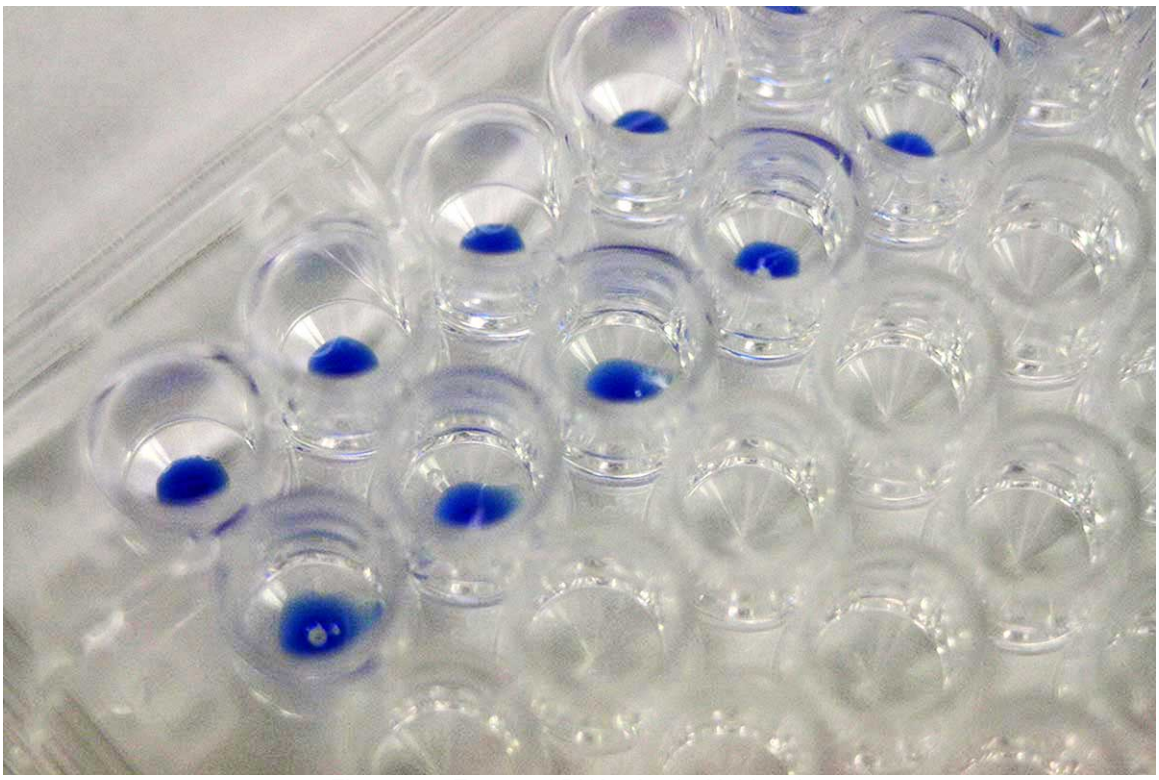


Figure 6-7. Extracted DNA mixed with blue dye
(Laboratories of Analytical Biology, Smithsonian NMNH, November 2015)

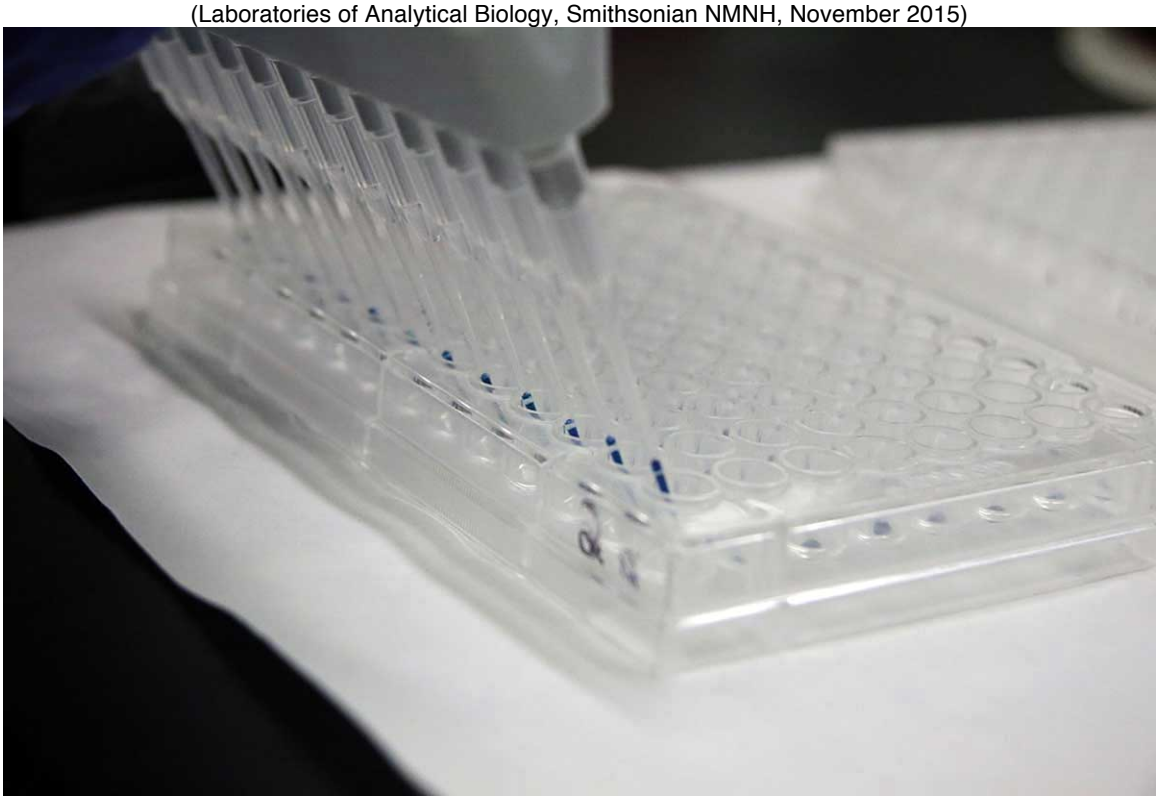


Figure 6-8. Multi-tip pipette (Laboratories of Analytical Biology, Smithsonian NMNH, November 2015)

back and forth until it fit in the preview window visible on the connected computer. Closing the door of the camera box, we switched the light from white to UV and took a picture. "Moment of truth," Dan said. An image popped up on the screen, rows of blurry black rectangles lined up in a wavering grid. Inverting the image, we adjusted its contrast slightly and now saw our beetles transformed into "ladders" of white to grey bars lined up in the lanes against a black background. Not as much opaque white blocks as hoped, but it could be worse. Printing out hard copies we taped them in our respective lab notebooks, my ethnographic notes about process, materials and forces in contrast to Dan's lab notes on time, temperature, and ratios of extraction buffer to stain.

Standing in the Laboratories of Analytical Biology (L.A.B.), contemplating the pile of discarded electrophoresis gels left to crinkle up and dry out for easier disposal, I thought about the networks of people, places, things and interests embedded in those gels. Each row in the gel represented a different creature, part of a global menagerie, with an origin in some ocean, tree canopy or leaf litter somewhere in the world at some point in the past. Assembled at the museum, extracted processed and assessed, these markings of abstracted life articulate a part of "the makeshift links across distance and difference that shape global futures—and ensure their uncertain status" (Tsing 2005:2). Although Tsing is speaking of the problematic nature of claims to universality in the context of her project of an ethnography of global connections, her insight into the linkages in those encounters resonates with what I encountered in the museum and its labs, both its global ambitions and uncertainties. Those uncertainties become highlighted in moments of what Tsing calls frictions:

> "A study of global connections shows the grip of encounter: friction. A wheel turns because of its encounter with the surface of the road; spinning in the air it goes nowhere. Rubbing two sticks together produces heat and light; one stick alone is just a stick. As a metaphorical image, friction reminds us that heterogeneous and unequal encounters can lead to new arrangements of culture and power" (2005:5).

Her work shifts the scale of inquiry down to the narratives and "frictions" of individual encounter and from there she tracks their amplification outwards to global networks–a useful perspective for tracing the "individual encounters" of assembling museum specimens and their circulation as part of these global networks. Indeed, I argue that Tsing's articulation of the "makeshift links across distance and difference" serve to highlight the global assemblage *within* the

museum, to the collectors and collections bound up with the accumulated time, places, histories and interests from which they are created.

By looking "sideways" across the assemblages of human and nonhuman animals in the collections—a raking glance across the museum drawers and the hands that hold them open—we can see that the collections create a global map of social histories and their projected futures. Tsing's links across distance and difference amplify outwards across these domains of past and present, and also across the domains of where to *collect* biodiversity versus where to *preserve* it, bringing into relief both colonial histories of collecting and current power relations of conserving biodiversity: "Cultures are continually co-produced in the interactions I call 'friction': the awkward, unequal, unstable, and creative qualities of interconnection across difference" (2005:4).

These interactions across difference happen not only across cultures but within cultures as well. Particularly at the micro-scale of daily encounters, they render visible longer histories of creating and organizing difference and then naturalizing it. In the museum, the ranked positions within the museum hierarchy–from administrators to curators to technicians to janitors–are re-inscribed daily in small encounters from the color of one's badge to who speaks in a meeting to who cares for the differently valued parts of a collection (precious type specimen or replicable DNA extracts). Each of these occurrences is a product of naturalized difference, or in other words they are "aspects of contingent encounters" embedded in a distinct "genealogy of commitments and claims" (Tsing 2005:4). To understand the frictions at work in the integration of genomics into the museum, I argue that it is crucial to carefully attend to the ways these frictions erupt from materials and material practices—looking to the matter itself, and the differences that are made from it. This attention to the "sticky materiality of practical encounters" (Tsing 2005:1) can be seen in the museum as the sticky materiality of *practices of making*, in crafting difference through the production of specimens.

In this research I examine the material production of scientific knowledge and how the narratives of order, difference, and value are materialized in those practices. Looking to specimen production opens up the possibility of difference produced on multiple scales, articulated across those scales by the materials themselves–by learning what parts or pieces are saved, extracted, discarded, or replicated. Preparing a traditional bird study skin, according to several curators in

the Division of Birds, is like "keeping the wrapping paper and throwing away the present." That is, the most valuable "body" of information is the actual bird's body, which is removed from the skin and discarded. The hollowed out skin is then stuffed with cotton wool and sewn shut, the spine replaced with a wooden dowel (more on this in Chapter 6). Some bones remain, such as the skull and, some partial wing and leg bones, but what is considered most valuable at this present moment of zoological science–fresh heart, liver and muscle tissue samples–were traditionally discarded.

In current emerging practices, tissue samples are taken after which the majority of the body is still discarded. However various curators, collection managers and technicians in vertebrate zoology are going, as one curator called it, "the way of the fishes." The Division of Fish and Reptiles have traditionally "pickled" their specimens, that is "fixed" them in formalin and then preserved them in sealed jars of either 70% or 90% ethanol. This has the advantage of preserving the entire organism, including its digestive tract and the organism's last meal. The organism then becomes a tiny microcosm of its environment, preserved as a moment in time.

"Time capsules, that's what collections are," one curator told me, "A window back in time, if you know how to get what you need out of them. And of course if you can get the permission to get it out in the first place." The pickled specimen can be x-rayed, micro CT scanned or genetically sampled later—though the DNA may be quite fragmented by the formalin and requires ancient DNA techniques to stitch the sequences back together and produce "meaningful" data (as mentioned in Chapter 2). While these practices in different zoological disciplines have long histories–which have shaped their ways of making and ways of knowing–they each concentrate global biodiversity into a local museum setting where order and value are negotiated.

In thinking through how to look “sideways” across these collections, I look at not only the specimens, but also at the hands that create them and the ways that voices carry sideways down the lab bench as techniques are shared and become embedded into the “ways of doing things.” I now turn to examine the craft of pulling legs from beetles for genetic analysis, examining the different materials and forces at work in disarticulating—and “articulating”—insect specimens.

How to Build a Beetle, Part II:

Pulling Beetle Legs, Sharing Techniques and the (Continuing) Stickiness of Practical Encounter

March 2015. I'm making my through the Division of Mammals, past the rows of white metal cabinets: *Ursus arctos* (brown bear); *Ursus americanus* (black bear); *Castor canadensis* (North American beaver); *Ornithorhynchus anatinus* (Platypus). The cabinets with red labels, I've been told, demarcate the type specimens. Locks are fitted on these cabinets and the ones on more well-traveled routes through the collections. I pass by a glass-fronted case full of the taxidermy cast-offs from exhibits: a sloth hanging from a preserved branch, a tiny antelope called a dik-dik the size of a small terrier, an elephant shrew with its dangling nose. I swipe my badge and go straight through a door and continue down the corridor, through the Physical Anthropology section where a group of FBI cadets with navy blue suits and wide eyes were attentively studying rows of skulls on a long table. On the other side of the table a curator was pointing out various indentations on the skulls with his latex-gloved hand. They're probably learning forensics. Blunt force trauma, maybe? Turning the corner I almost bumped into an intern wheeling a cart of skulls and bones, neatly arranged in shallow wooden boxes. I apologized, helped steady the cart and hurried down the hall towards the Division of Birds. I was running late and the beetles were waiting.

Down another hallway, through another door and I was in the Department of Entomology. At least I was on one floor of the expansive Department of Entomology, which though their subjects are tiny comprise the majority of specimens in the natural history collection–hundreds of thousands of bees, beetles, flies, spiders, butterflies, wasps etc. collected at every stage of development from pupae to adult. The collections also include as their nests, cocoons, their food sources from other insects to leaves, flowers, and tree sections. To be able to do their research, entomologists collect not a few individuals but hundreds or thousands of the same species and pin them, pickle them or freeze them, depending on their intended use. "You can smell the wax and honey on the floor with the bees," one bioinformatics staff member told me, "I change my route so I can go through the bees in the Spring . . . " Thinking about the smell of collections as "data," I popped into the elevator and went up.

The elevator doors open onto a hallway of cubbies filled with canvas sacks. In the sacks are piles of small white cardboard boxes, each filled with pinned insects, ready to be shipped around the world on loan to other researchers at other museums. A statue of a rhinoceros beetle watches over the mail cubbies. Shiny and polychrome it's the size of a football helmet. I'm not among the honey-scented bee cabinets this time, but surrounded by a faint odor of mothballs from the naphthalene originally used for pest control. I'm in so-called "Beetle Heaven," Department of Coleoptera on the top floor of the building where the arthropods go for their final resting place. Or, as I learn to dissect beetles today, some parts of them go for their final resting place while other parts circulate further afield.

The group piles into a small workroom—grad students, the GGI lab tech Dan and me. In the center of the room is a narrow table, where Terry Irwin a beetle curator, sets down drawers of beetles, each covered with a glass lid. I notice the table is exactly the same width as the drawers, designed to hold the drawers precisely in neat rows. Several slender wooden trays holding glass vials of alcohol-pickled beetles are already on the table. One has a handwritten note tucked into it: "DNA" with an arrow pointing towards the glass vials [6-9]. We're here to learn how to take a genetic sample from a preserved beetle, both those pinned in the drawers and the ones pickled in the vials [Figure 6-10]. A GGI-funded workshop, the sampling workflows we test out today will inform the first version of the GGI Collecting Training Module.

Besides learning to take genetic samples, I'm also photographing the events of the day, documenting the process for myself, for the GGI and for the entomologists. "Nobody has pictures of this," one of the grad students tells me, "Its so small and fiddly its hard to see what's really going on." Learning to see "what's really going on"—from identifying bird gonads to selecting which leaf veins to display—has been part of every specimen preparation process I'd learned so far at the museum; Figuring out how to document those moments of "seeing" had been an on-going challenge. Today would not be any easier.

The room is lined with narrow workbenches with microscopes, forceps of various sizes, and small ceramic dishes to empty the alcohol vials into [Figure 6-11, Figure 6-12]. Each of the grad students sets up their station, carefully arranging their notebooks, gridded worksheet for each "plate" they'll be populating with samples and their smart phones displaying illustrations of beetle anatomy.

Figure 6-9. Beetles in alcohol selected for DNA extraction
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, March 2015)

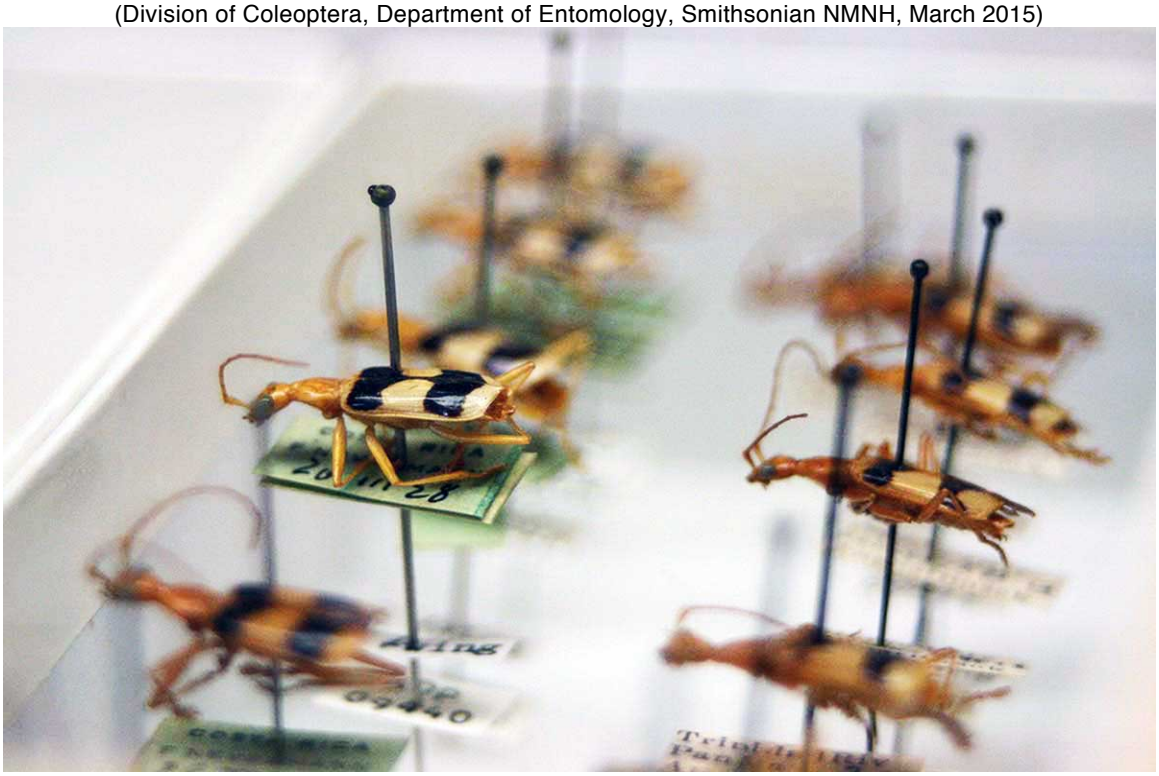


Figure 6-10. Pinned carabid beetles
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, March 2015)

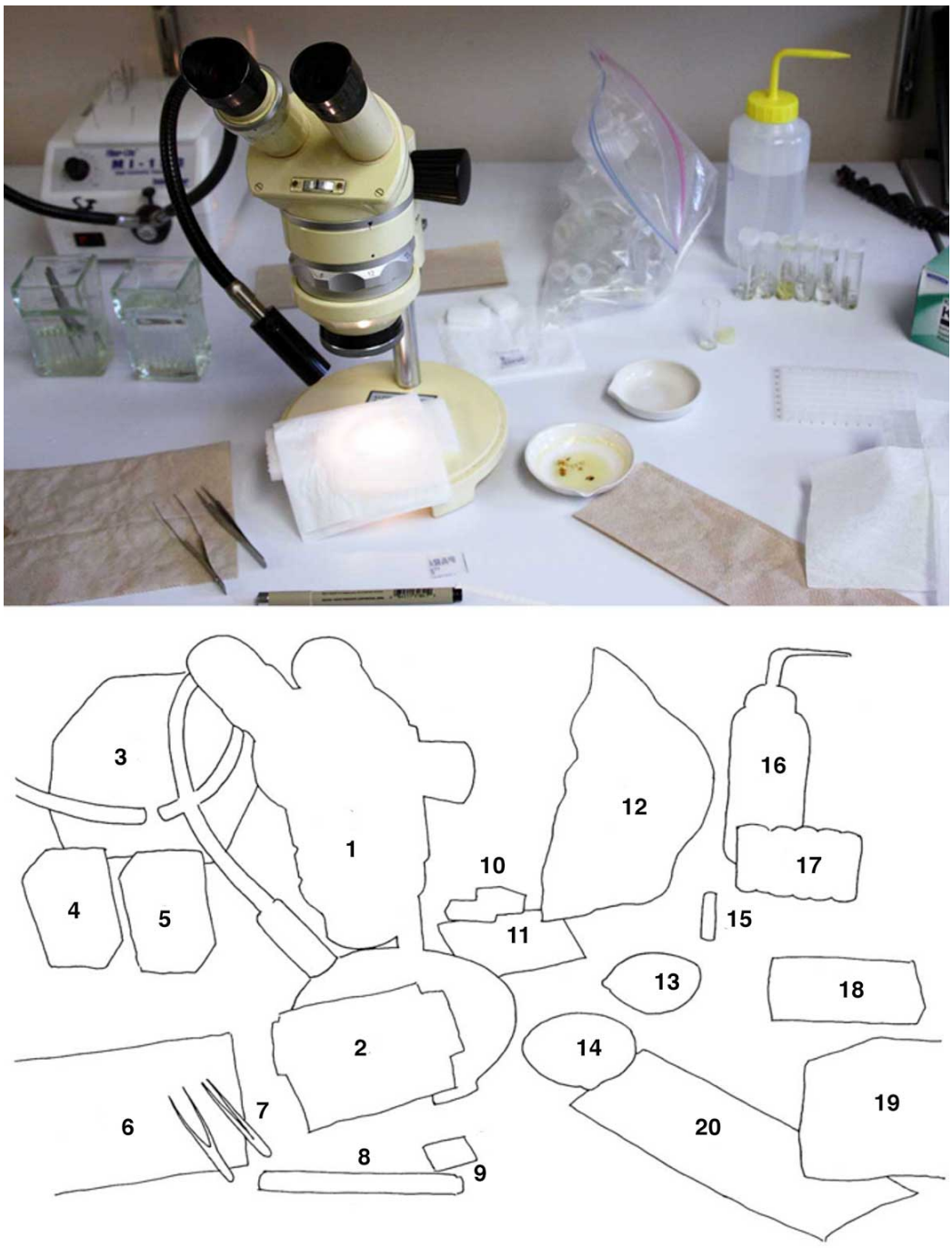
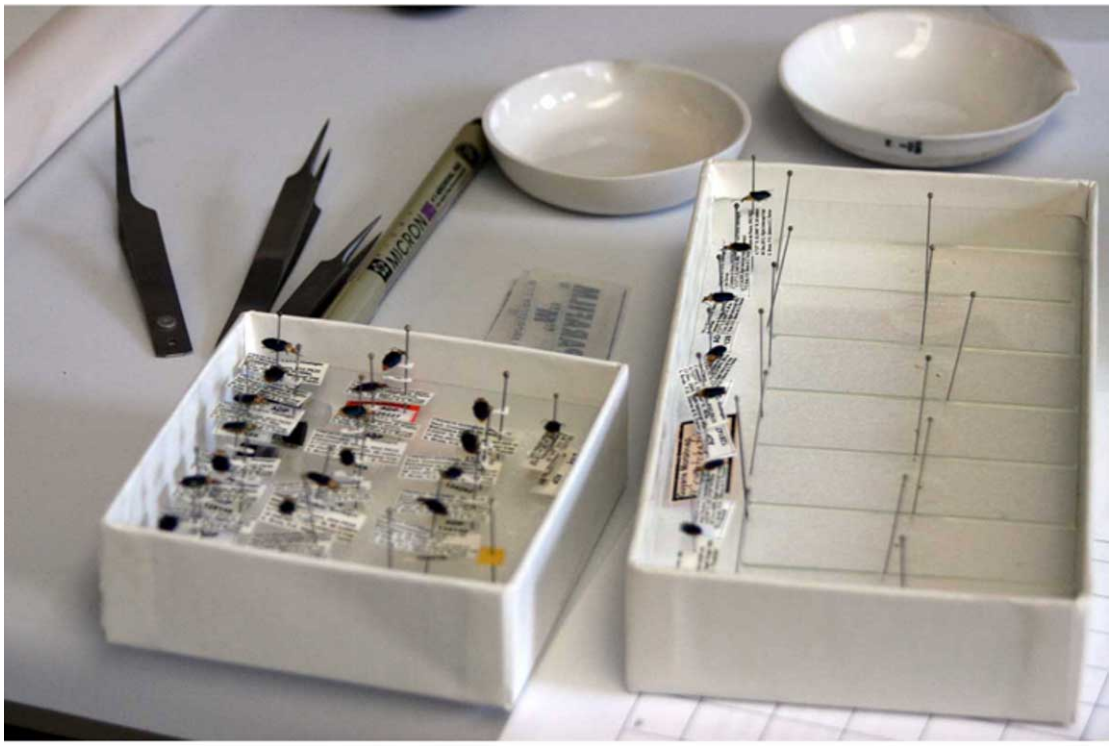


Figure 6-11. Anatomy of a beetle sub-sampling workstation, Part I: [1,2] Microscope and stage with tissue for alcohol-soaked beetles; [3] Adjustable light; [4] Bleach to sterilize forceps; [5] Water to clean off the bleach; [6] Paper towel; [7] Feather-weight and pointed forceps for beetle leg-pulling; [8] Archival ink pen for labels; [9] Label; [10] Tiny styrofoam blocks to hold pinned insects; [11] Tissues; [12] Bag of vials to put specimens in (in alcohol) once separated and sampled; [13,14] Dishes for sorting; [15] Vial ready for selected beetle; [16] Alcohol bottle with dispensing tip; [17] Sorted specimens; [18] Lid for plate; [19] Plate for extracted legs, with tissue draped over top to mark which row is being filled– – this helps to keep the specimen info correct while filling in the data sheet to accompany the plate; [20] Paper towel for leaky beetles.
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, March 2015)



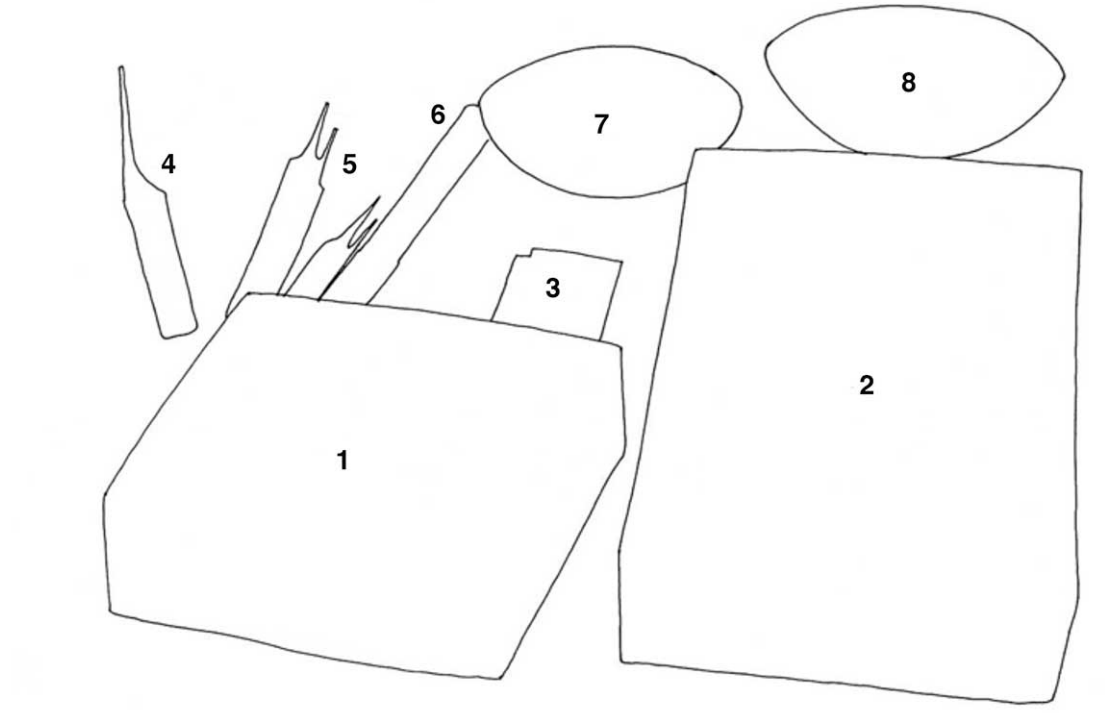


Figure 6-12. Anatomy of a beetle sub-sampling workstation, Part II: [1] Specimen box with pinned beetles; [2] Specimen box with pinned and slide-mounted beetles parts; [3] Sterile squares of waxy paper for pulled legs; [4,5] Forceps with different pointed tips; [6] Archival ink pen for labels; [7,8] Dishes to sort alcohol-preserved specimens.
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, March 2015)

The object is to select a variety of specimens preserved at different times (from last year to 20 years ago), by different methods (pinned or pickled) and then to carefully remove the left hind leg. This is easier than it sounds—the carabid beetles that are our subjects today are small and slender, about the size of a lentil [Figure 6-13]. The tools laid out in the workstations are very similar to the tools I would later use when I learned to pin and point-mount beetles—putting together and taking apart required, to my surprise, the same set of tools but a very different set of concepts and skills.

We gather around the glass-topped trays and begin our selection process—a slow process of learning to dis-articulate the beetle's limbs [Figure 6-14]. More precisely, how to remove the left hind leg from a pinned specimen without crushing or mangling it, destroying the tiny paper labels also on the pin, and meanwhile making sure some part of the muscle tissue holding the leg to the beetle body comes off with the leg [Figure 6-15]. All while looking down a microscope so you can see what you're doing. At least part of the beetle comes into focus if you move your head in the right way and squint [Figure 6-16].

The task of getting the legs off cleanly proved difficult for all present, and as the day wore on and the beetles stubbornly refused to give up their legs I noticed the conversations moving across the small room. The group of young women grad students were helping each other figure out techniques. Without looking up from their microscopes they offered up advice on leg-pulling and beetle-wrangling: "don't just pull, but instead pin it down and then twist with the forceps"; "brace the point of the pin on a square of foam on the [microscope] stage so you can balance it that way"; "turn the pin upside down–you can see the joint easier."

The pinned beetle with its stack of labels slowly spun like a miniature shish kabob under the microscope lens as I try to find a "point of access"—a way to get the tweezers into the joint of the leg at the right angle. I need to be able to carefully wiggle the leg off. With the alcohol preserved beetles, they were poured into a shallow ceramic dish next to the scope. Using the end of a pin or the tip of a paintbrush, a selected beetle individual was slid up the edge of the dish and onto the tip of the brush. Deposited gently onto a piece of tissue on the microscope's stage, a careful procedure of bracing, wiggling and bending proceeded.

Figure 6-13. A point-mounted carabid beetle
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, March 2015)

Figure 6-14. Selecting beetles
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, March 2015)

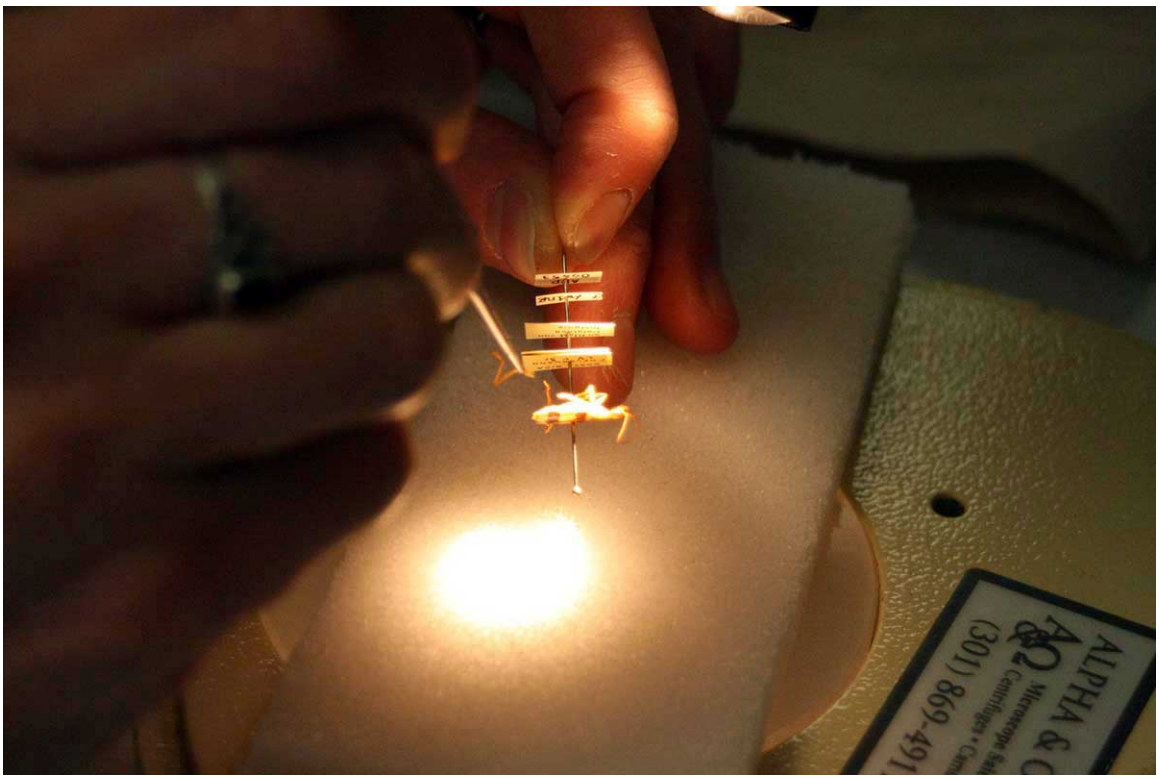


Figure 6-15. Breaking off the left hind leg
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, March 2015)

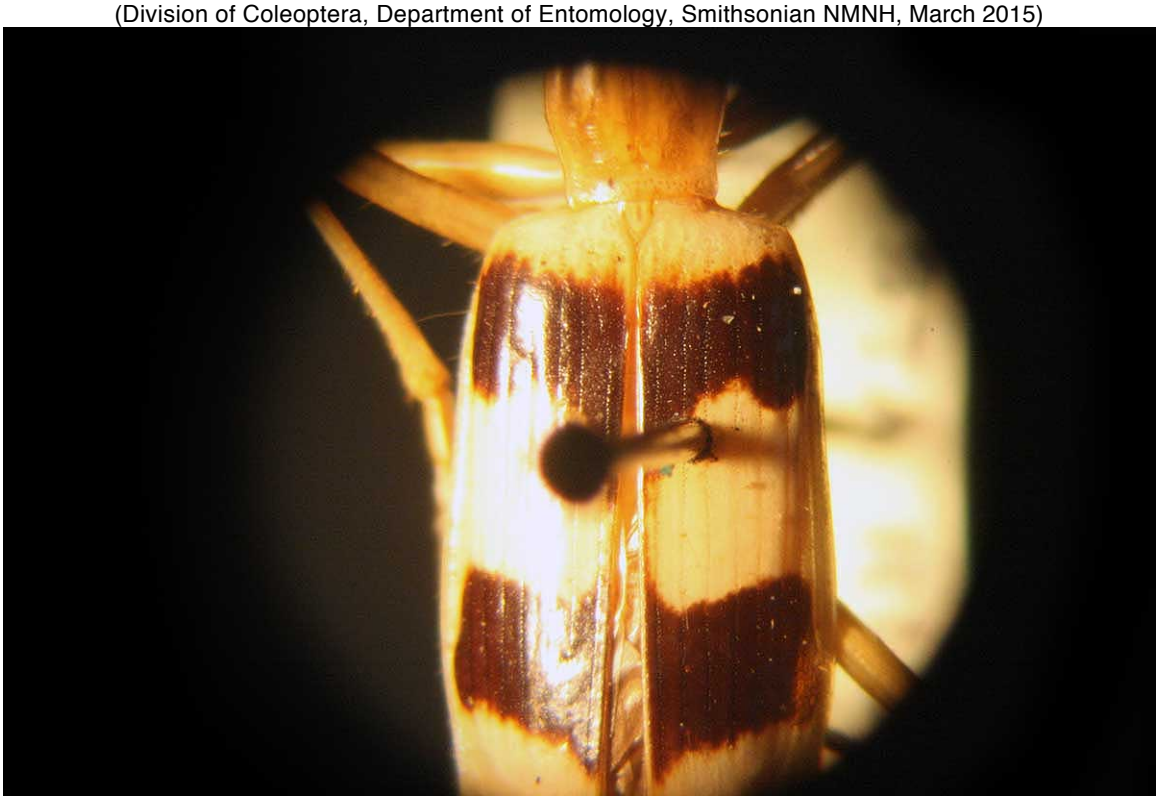


Figure 6-16. View of a beetle through the microscope
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, March 201

Focused on unfolding and removing the left hind leg, the chatter back and forth mixed with the click of the steel pins against glass vials and the squeak of the desk chairs as people adjusted to get just the right view. "If you brace the thorax with a pin or the side of the tweezers–like this," the speaker leaned away from the scope so her neighbor could look down the microscope lens, "then you can come in from the other side with tweezers and pull the leg from that direction. At least that seems to be working for me..." Her voice trailed off, and she looked up for validation or confirmation. I had heard this tone of self-deprecation repeatedly from female staff and researchers in the museum.

Ways of knowing extended from how techniques were transferred and shared among researchers, but following lines of the existing power relations within the museum (Bennett 2005; Foucault 1966; Fujimura 1996). *Ways of knowing were also ways of disciplining knowledge*—what techniques filtered forward into official documents (such as the GGI collecting training module) or those that were shared "sideways" through unofficial channels such as word of mouth in the prep labs.

Learning to See a Beetle Body as Parts

I had to learn how to see again, squinting down the objective of a microscope. I was trying to see the beetle body *as* its parts, to locate where the junctions were, and therefore where it would break. Hopefully, at that point, it wouldn't just break apart and be destroyed. Destroying the beetles under the watchful gaze of the man who had spent his time, energy and funds collecting them added to the pressure. Tiny valuable objects that we were all pulling apart to create different forms of value—but only if we didn't mess up and pull them apart into useless pieces. Destruction had its useful limits. Our goal was to keep the rest of the beetle body as pristine as possible, so that it could serve as an acceptable reference–that is, a voucher specimen–for the genetic sample(s) produced from the legs.

The creature looms into focus; the once indistinguishable dot at the end of a pin now seems to contemplate me back from round black eyes staring back through the microscope eyepieces. This encounter reminds me of a response to *Micrographia* by Robert Hooke published in 1665, the first published work illustrating the view through a microscope [Figure 6-17]. The common flea was

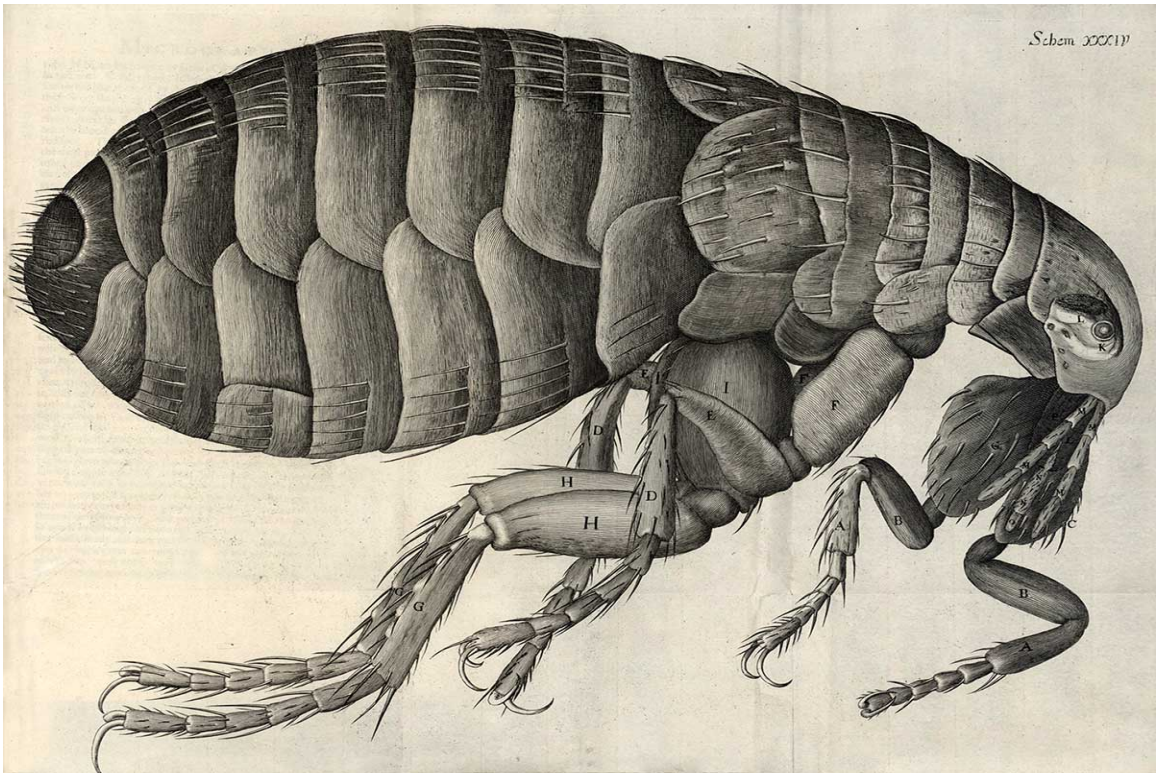


Figure 6-17. The Common House Flea. Robert Hooke, *Micrographia* (1665)

Figure 6-18. Dust on the bees
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, March 2015)

enlarged into grotesque and shocking detail, a "horrible prospect" as it was transformed by becoming visible at a different scale, opening up unseen, invisible worlds that exist around us. To make the familiar horrible and wondrous—in effect, unfamiliar.

The view through my camera achieved a similar but different perspective–the wide angle lens pulls everyone into the same frame, capturing multiple mini-scenes at once: those in conversations at the center of the room over the beetle drawers, and those at the edges immersed in their own worlds at the end of their microscopes.

The macro lens, on the other hand, gives me the microscopic view of the entire room, but one small piece at a time, bit by bit. The macro lens in practical terms functions like a microscope, enlarging whatever is in frame beyond the scale that it exists in the world. This view allows hyper-detailed focus—one minuscule microcosm at a time. Switching from the microscope to my camera (with its macro lens) I can see the details of the room with a new eye, (almost) as detailed as the microscope but mobile. With the light pouring in from the windows, I can see the hairs on the beetle legs in the alcohol-filled vials, the dust settled on a pinned bee forgotten on a shelf [Figure 6-18], the impressions of the pen into the paper of the specimen labels [Figure 6-19], the shadow the dis-articulated beetle legs make in the bottom of the DNA sample plate [Figure 6-20].

Staying within this zoomed-in view, focused on the beetle and its parts in hyper-detail, I move from dis/articulating beetle legs to learning to pin and point mount whole beetles. I move from creating new kinds of value through “unbinding” the biology of a beetle, to instead transforming a jar of alcohol-preserved beetles into specimens neatly ordered on the ends of pins—their legs articulated into “natural” poses. In contrast with the genetic projects the mounted insects are now used for, the practice of insect mounting, particularly beetles I will come to learn, has changed very little for over a hundred years.

Figure 6-19. Detail of pinned beetles
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, March 2015)

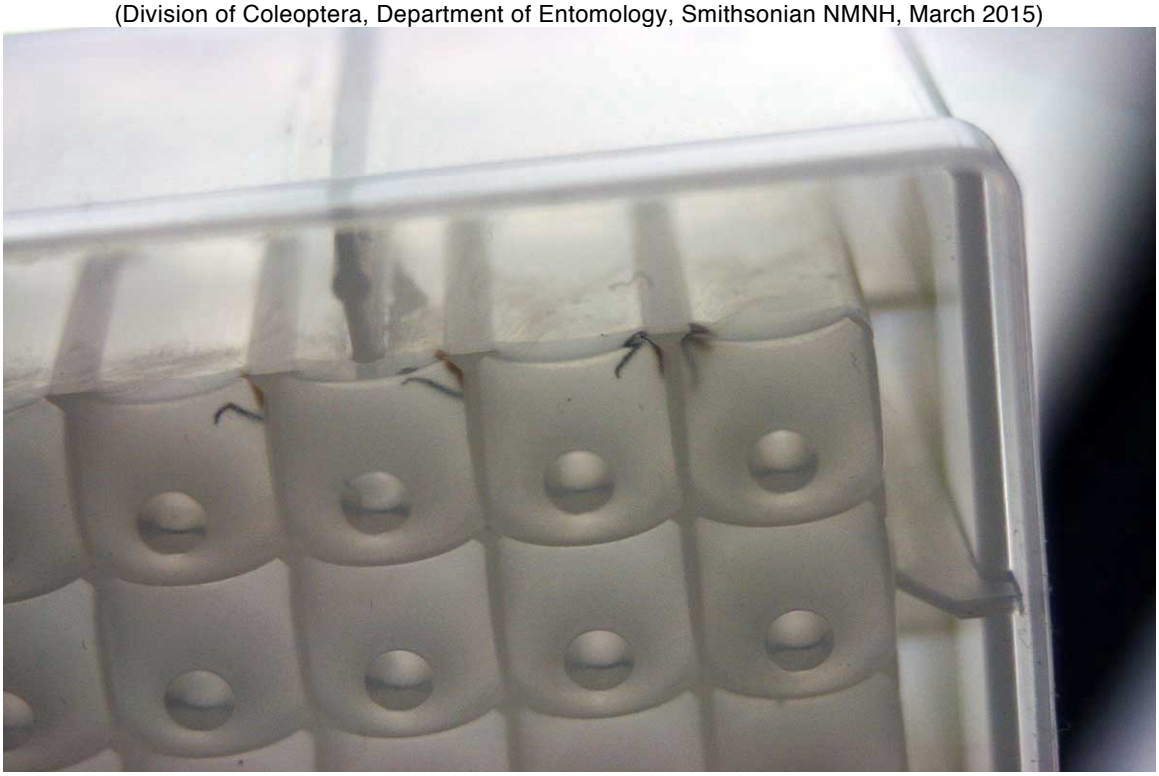


Figure 6-20. Pulled legs, visible in the bottom of the extraction plate
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, March 2015)

How to Build a Beetle, Part III:

Biology Unbound and the Value of Parts: Pinning and Point-Mounting Beetles

June 2015. I'm walking down the back hallways of the Natural History building with two entomologists, Torsten Dikow (Flies) and Warren Steiner (Beetles). We've just come from Warren's talk about the Djibouti expedition, a return to the biological survey expedition but with a contemporary global political turn. The expedition, partially funded by the GGI, has sent preparators from Birds, Mammals, Botany, Entomology and, Herpetology to Camp Lemonnier, a U.S. Navy base in Djibouti, to do a biodiversity survey of the local flora and fauna, under the auspices of the Smithsonian's Feather Identification Lab and their agreement with the U.S. Navy. The biodiversity survey provided specimens (filling gaps in the desired families of life for GGI's goals) from a difficult to access part of the world for the Smithsonian on the one hand, and on the other hand the Smithsonian's analysis of the survey would provide the Navy with recommendations on how to deal with the various wildlife that might collide with their planes.

Recently, bird strikes had become less of a concern than preventing their drones from being taken down by birds, I learned, and the Navy was particularly interested in how to track flocking birds and maneuver drones around their flight paths. The soldiers had an ammo case in the freezer filled with all the creatures they'd collected and saved to show to the Smithsonian team when they arrived—pinned insects, along with a bag of trapped rodents and birds. The variety of "beasties" (as several of the Smithsonian Djibouti team called them) in the frozen ammo case and bag were much more varied than what the Smithsonian team collected, leading them to conclude that the ebb and flow of biodiversity in that area was very seasonal and perhaps they hadn't gone at the right time.

The Smithsonian had passed through the area now occupied by Camp Lemmonier during the Roosevelt Africa Expedition in 1909 [Figure 6-21], returning with thousands of specimens, a few for display in dioramas and many for the research collections [Figure 6-22]. Edgar Mearns, a Smithsonian ornithologist and botanist, had collected a number of birds from the area, which he noted he prepared in the blistering heat using the saddle of his horse as an

Figure 6-21.Theodore Roosevelt and other members of his expedition party from the Smithsonian Roosevelt African Expedition, 1909. Edgar Mearns is center with crossed arms and moustache. [Photo: Smithsonian Institution Archives SIA2009-1584]

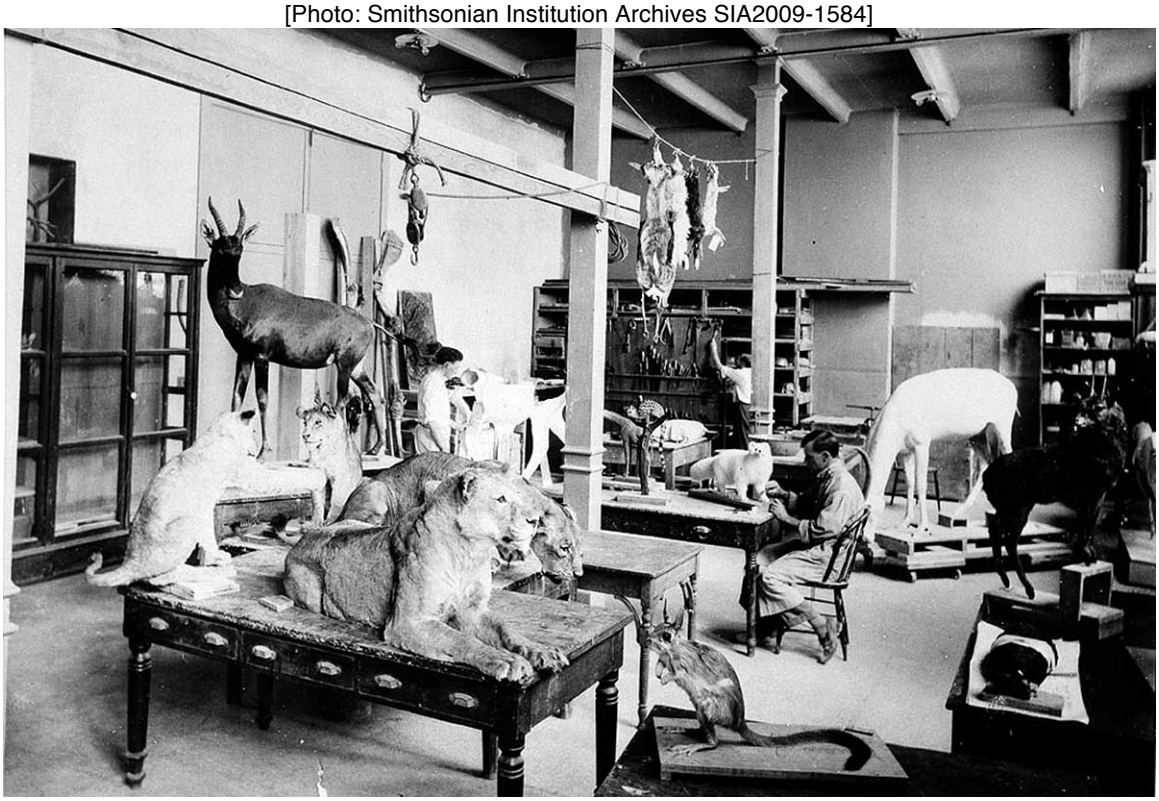


Figure 6-22. Taxidermist at work on Smithsonian-Roosevelt African Expedition Specimens, with the East African Lions in the foreground, 1911. [Photo: Smithsonian Institution Archives SIA2009-1371]

impromptu specimen preparation station (Mearns and Mearns 1998; Smithsonian Institution Archives, RU7083 1909). It was, Mearns wrote, less than ideal. He also noted that he couldn't find any insects in the area. The 2014 Smithsonian expedition team were able to prepare at tables in air-conditioned Quonset huts (decorated with skulls on the front), setting traps in the scrubland desert surrounding the base's runway, collecting insects under lights at night, trapping mammals and shooting birds.

The GGI was partially funding the trip for the genome-quality tissue samples the expedition could provide, a process which took more time–"twice as long to fill all those little vials, make all the labels and then add them to the spreadsheet," Warren told me. The trip was "an old fashioned multidisciplinary collecting trip–where I was picking the lice off birds and sticking them in vials right next to the Bird prep folks. . . One cattle egret came in with a crop full of grasshoppers - I've pinned versions of that kind before . . . I also got some fleas and ticks off of the desert fox, gerbils, bats and other rodents collected by Mammals . . . " Warren collected along with the herpetologist (reptiles and amphibians), which provided "a good symbiosis," as they found specimens for each other—looking for insects in the sparse underbrush one would find a lizard while the other found a grasshopper, which they'd capture and then swap. The botanist would sometimes come along, but was annoyed that most things were either dead or not in flower–the moment in the life cycle of a plant when some of its most diagnostic characteristics are visible and therefore the moment to collect it.

At the end of the trip the Smithsonian team did a show and tell for the troops on the base, "we got to show off our catch–but also show them what the stuff means." In all, the team collected 20 genera, divvied up among 25 species of Darkling Beetles (Warren's specialty)—though many of those were "singletons," single specimens representing that species. The summary for the export permit detailed the collections made: birds—225; herpetology—113; mammals—90; botany—51; insects—2400 (which actually proved to be 5147 once the jars of ethanol and insect "soup" were emptied and counted back at the Smithsonian)[Figure 6-23, Figure 6-24]. The authorization permits were gone over carefully on exit from the country, and the collections were gone through "they poked at the prepped *pectinators* [study skins of small rodents] seeing if they were still alive, as our permit was just to transport dead things. Just one of those things."

Figure 6-23. Warren's desk
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

Figure 6-24. Insects from the Djibouti expedition
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

Wasps versus Beetles versus Butterflies: *Ways of Knowing*

June 2015. "It is just such a joy to work with flies prepared by a beetle person," Torsten says as we walk past the cabinets that line the hallway, "They are beautifully prepared–so symmetrical, the legs are arranged very nicely." Warren smiles. Some specimens, like most moths and butterflies (Lepidoptera) can look like "drowned rats" if they're preserved in ethanol, with all the scales on their wings falling off and getting all over any other insects caught in the same alcohol trap. I heard non-lepidopterists (dipterists and hymenopterists—fly and wasp people), tasked with collecting butterflies or moths while on GGI-funded genomic-collecting expeditions, curse them as "being like damn birds you have to shove into a tissue tube." The specializations *within* departments–Wasps versus Beetles versus Butterflies–went beyond the differences between departments and divisions, as the functional need to collaborate increased due to harder-to-fund expeditions, harder-to-obtain permits, and more-complicated and standardized data management plans.

To get the specimens you wanted and needed for your own research, I heard repeatedly from biologists across the museum, meant you had to learn to collaborate in new and unexpected ways–from sourcing liquid nitrogen in less industrial parts of the world (South and Central America was somewhat easier, I was told, due to the high traffic in frozen bull sperm for cattle husbandry) to learning the collecting methods for other disciplines and modifying them to fit the new requirements of genomic-tissue collecting (as I detailed in Chapter 3 on tissues and networks).

Warren retired some years ago after more than three decades of preparing insects in the Department of Entomology, but he still comes in most days to pin or point mount the seemingly endless waves of insects that come back from collecting expeditions–either preserved in alcohol (hard shelled insects) or folded in paper envelopes (moths, butterflies, dragonflies) or now frozen in tubes in liquid nitrogen (those go to the department freezers and then the Biorepository). Warren tells me it isn't uncommon for a single collecting expedition in Entomology to bring back more than 5,000 specimens; the gallon jars packed full of ethanol and insects are carted back from the field, and are affectionately referred to as "soup."

June 2015. I'm standing in Warren's small office [Figure 6-25], the walls stacked with worn wooden specimen boxes ("I wish these boxes could talk about all the things that have passed through them"), cigar boxes ("a cheap shipping option"), stacks of beetle books, and Warren's own densely packed work station [Figure 6-26, Figure 6-27]. There's a jar of insect "soup" in front of me on the table and I'm going to learn how to pin a beetle. Or twenty.

I gathered my equipment on the small visitor's workbench under the window, noting the nice diffuse light that came in. We rummaged around in drawers and came up with several extra sets of small forceps of different kinds, entomology pins in different thicknesses, a magnifying lens clamped to the table top, a block of foam, a small ceramic dish and paintbrush, paper towels [Figure 6-28]. I watch Warren go through the process several times, moving around to get different angles and taking pictures with my macro lens.

This was going to be all in the details, I could see. But what process I'd learned so far, either in specimen prep or in genetics, hadn't been? This was a detail-oriented place, and great value was placed on the meticulous, the ordered, the reproducible. Particularly when that reproducible order was accomplished out of the "unruly" materials of the natural world and its misbehaving parts and pieces–– imperfect birds made into perfectly similar study skins, insects pinned the exact same height in the drawer, leaves pressed to fit aesthetically on a standard page, just enough tissue to fill a cryovial full but not over-fill it, with the biorepository barcode labels lined up and symmetrical. Beetle pinning, in particular, was all about creating symmetry.

Direct pinning is the insertion of a pin directly through the body of an insect [Figure 6-29], and has been the standard method for preserving insect specimens since at least the eighteenth century, a process little changed in over a hundred years with the exception, perhaps, of an iPhone to look up beetle anatomy (Mawe 1825) [Figure 6-30, Figure 6-31, Figure 6-32, Figure 6-33]. Beetles, flies, bees, wasps and other hard-bodied insects are collected and stored in ethanol (a collecting manual from 1821 suggests preserving in "spirit of wine"), whereas butterflies and moths with wings that would simply dissolve in liquid are netted and euthanized in a dry killing jar, then wrapped in glassine envelopes for re-hydrating and mounting later (Mawe 1825; Gibb and Oseto 2006).

Figure 6-25. Warren Steiner at his workbench
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

Figure 6-26. Warren's workstation (note photo I took of his workstation pinned on back wall)
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

Figure 6-27. Wooden Schmidt boxes for transporting pinned insects
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

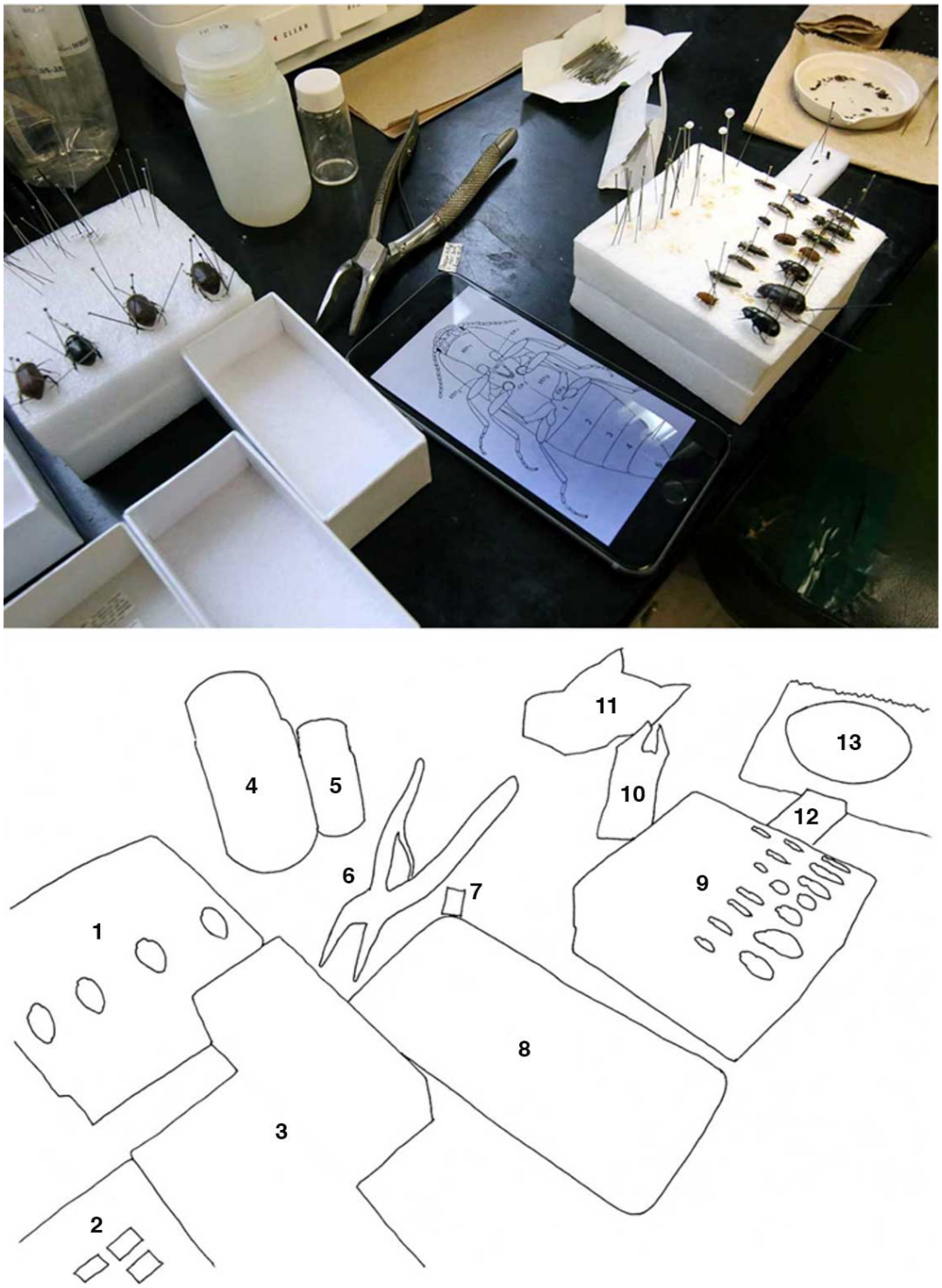


Figure 6-28. Anatomy of an insect pinning station: [1] Pinned beetles drying; [2] Specimen box with labels ready for beetles; [3]Specimen boxes; [4] Bottle of alcohol; [5] Specimen vial for unfinished beetles; [6] Pinning pliers; [7] Label; [8] iPhone with beetle anatomy; [9] Styrofoam block with pinned beetles; [10, 11] Paper packets of entomology pins of different sizes; [12] Auxiliary Styrofoam block; [13] Dish for sorting beetles in alcohol poured out from vial.
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 201

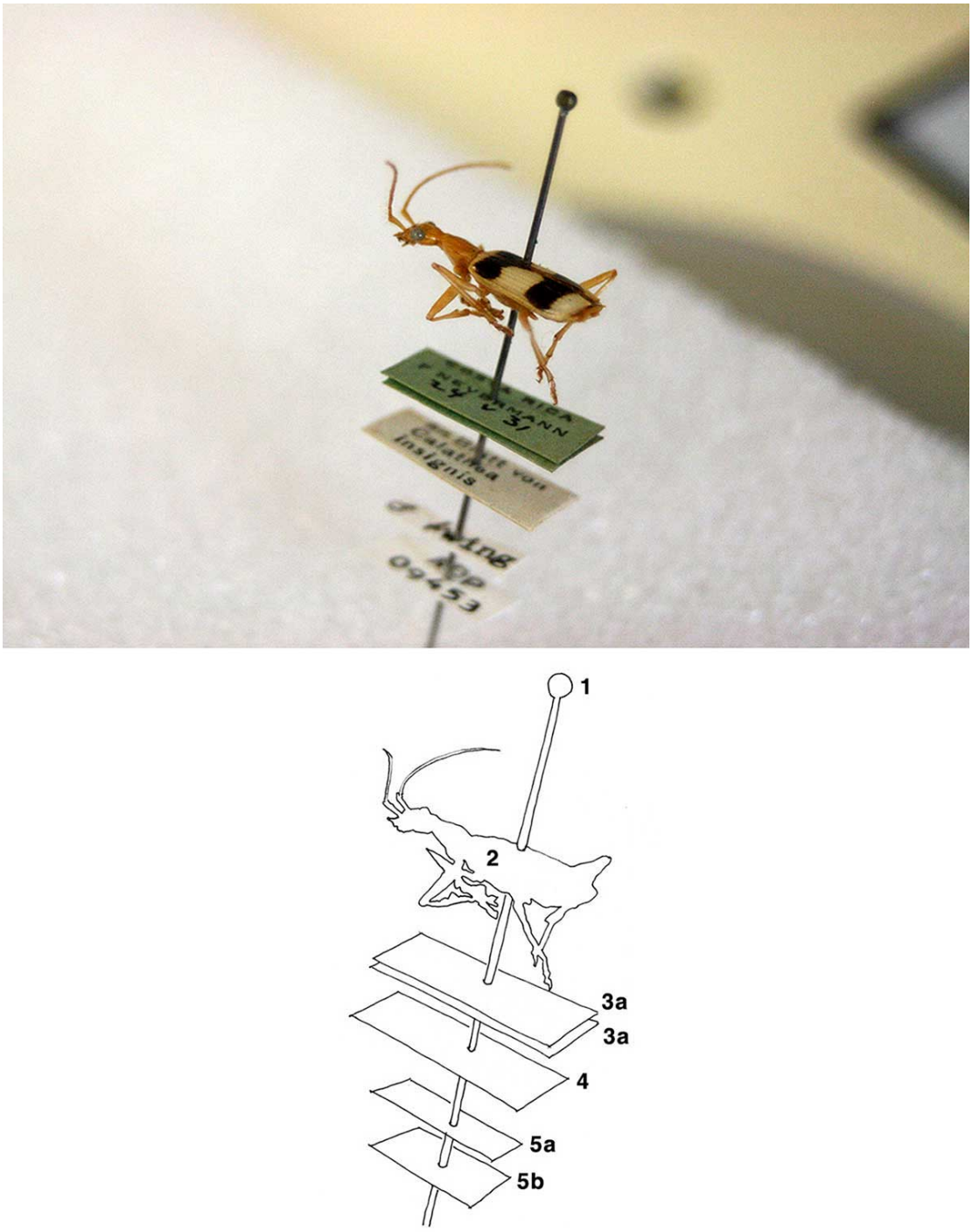


Figure 6-29. Anatomy of a direct pinned insect: [1] Entomology pin; [2] Insect; [3a] Label with collection data (locality, date) collector and species identification; [3b] Second half of information from 3a if it won't fit on one label; [4,5a, 5b] Other "life histories" of the specimen stack up, which may include re-identification of species, genetic sampling or movement between collections at different museums.
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, March 2015)

A lump of camphor may be placed in a piece of cotton cloth and pinned firmly in the corner of the box containing dried insects, for the purpose of preventing the ravages of larvæ. A few drops of kreosote occasionally introduced will also answer the same purpose.

Fig. 1.

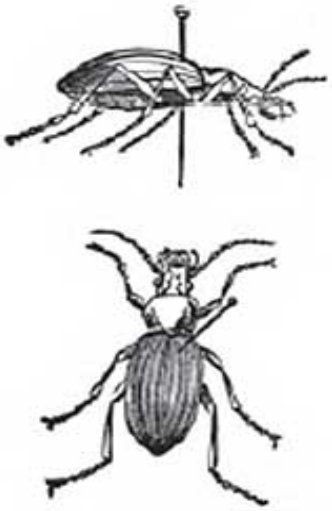
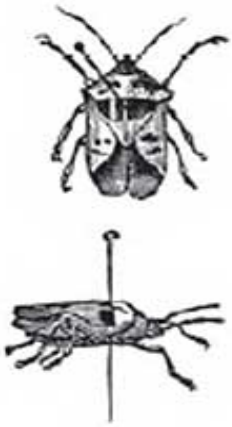


Fig. 2.



Sea-urchins and starfishes may be dried, after having been previously immersed for a minute or two in boiling water, and packed up in cotton, or any soft material which may be at hand.

The hard parts of coral, and shells of mollusca may also be preserved in a dried state. The soft parts are removed by immersing the animals for a minute or two in hot water, and washing clean afterwards. The valves of bivalve shells should be brought together by a string.

Wingless insects, such as spiders, scorpions, centipedes or thousand-legs, earth-worms, hair-worms, and generally all worm-like animals found in the water, should be preserved in alcoholic liquor, and in small bottles or vials.

§ V. EMBRYOS.

Much of the future progress of zoology will depend upon the extent and variety of the collections which may be made of the embryos and fœtuses of animals. No opportunity should be

Figure 6-30. “Insect pinning” in *Directions for collecting, preserving and transporting specimens of natural history.* Fuller Spencerton Baird (1859).

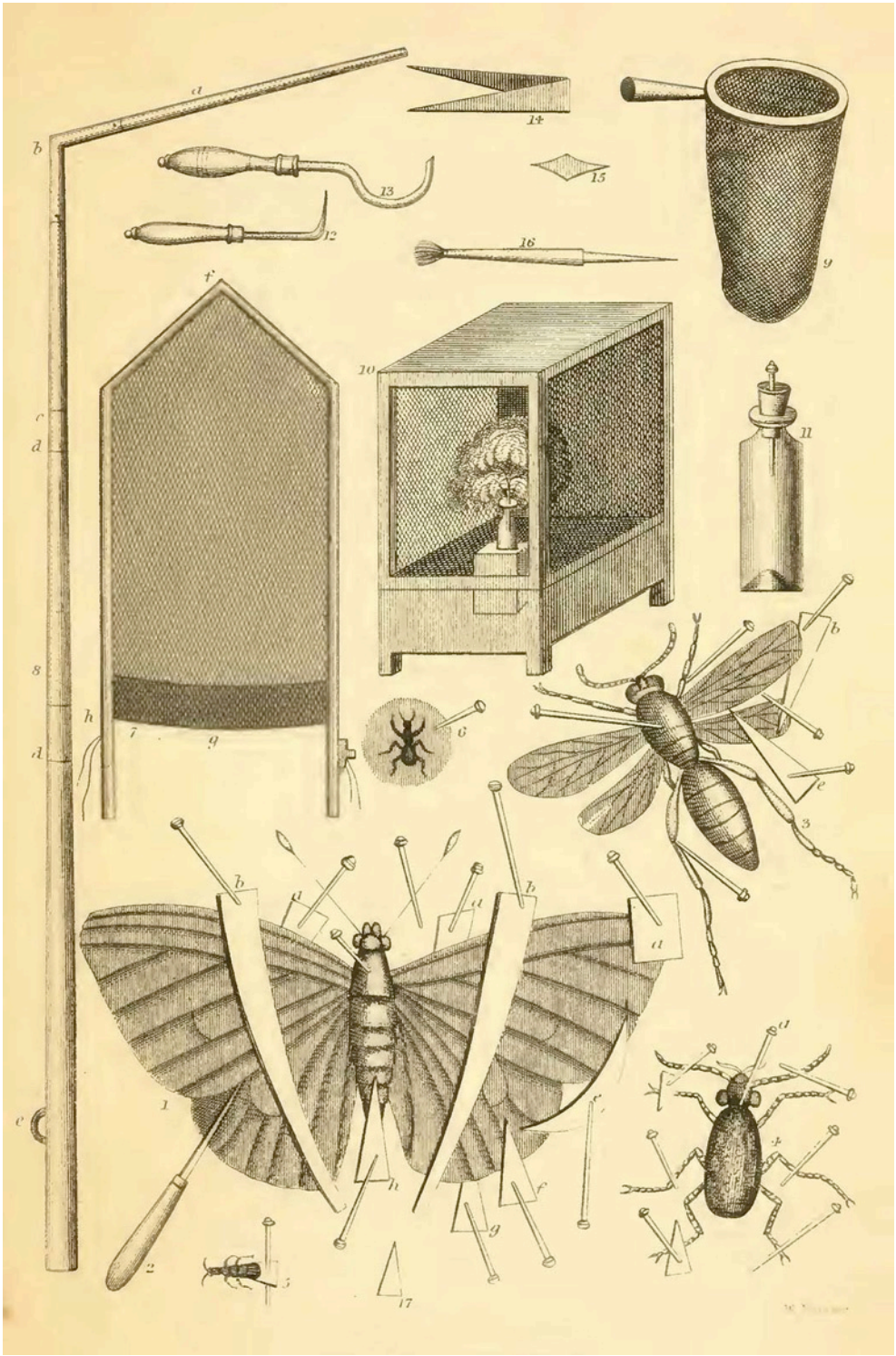
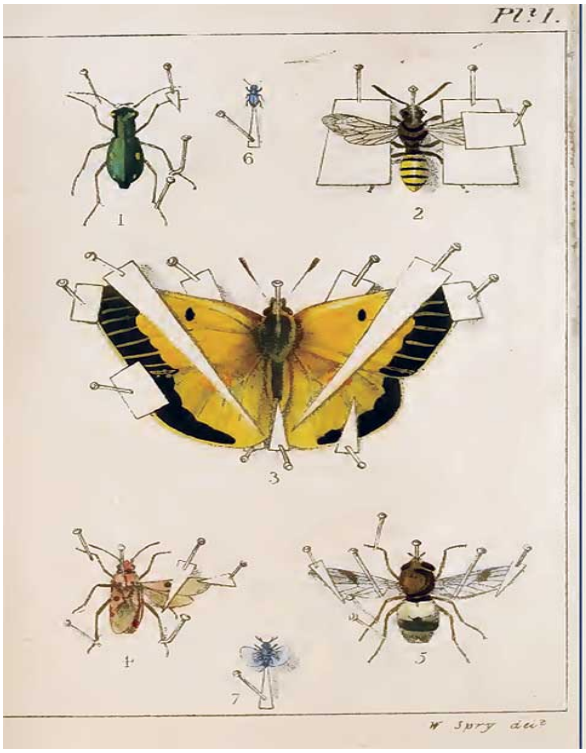


Figure 6-31. “Preservation of Insects,” in The Taxidermist’s Manual, or the Art of Collecting, Preparing and Preserving Objects of Natural History Designed for the Use of Travellers, Conservators of Museums, and Private Collectors. Captain Thomas Brown (1853).



INSTRUCTIONS

FOR COLLECTING, REARING, AND PRESERVING

British & Foreign Insects:

ALSO FOR COLLECTING AND PRESERVING

Crustacea and Shells.

BY ABEL INGPEN, A.L.S. & M.E.S.

" Magna opera JEHOVÆ, explorata omnibus volentibus ea." Ps. cxi. 2.

Second Edition,

WITH CONSIDERABLE CORRECTIONS AND ADDITIONS.

LONDON:

WILLIAM SMITH, 113, FLEET STREET.

1839.

piece of card with gum, place the insects promiscuously upon it and then when dry cut to suit the specimen. Thin pieces of mica are also used in a similar manner.

To place the insects in the cabinet, what are known as pinning forceps are frequently used. These are forceps made after the usual manner, except that the extremities are bent as shown in fig. 7, and the corrugations of the points are so arranged as to hold the pin firmly. The pin is grasped by them about a quarter of an inch from the extremity and forced into the bottom of the case with a gentle pressure. By this method all danger of bending the pins is averted, a result which frequently follows an attempt to set them with the fingers. They may also be set with much greater regularity with the forceps than without.

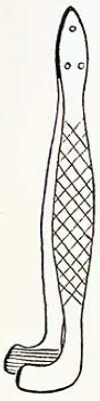


FIG. 7.

SPREADING BUTTERFLIES.

Butterflies and moths should always have the wings extended and it is frequently desirable to mount other insects in the same manner. This is accomplished by means of a "setting board." A strip of pine or other soft wood has a groove ploughed through the middle to the depth of from three-quarters of an inch to an inch. The bottom of the groove is generally lined with cork to hold the point of the pin. It is frequently desirable to have

the surface of the setting board slightly bevelled towards the middle groove, as in this way a drooping appearance of the wings is prevented. See fig. 8.

The pin is passed through the thorax of the insect into the

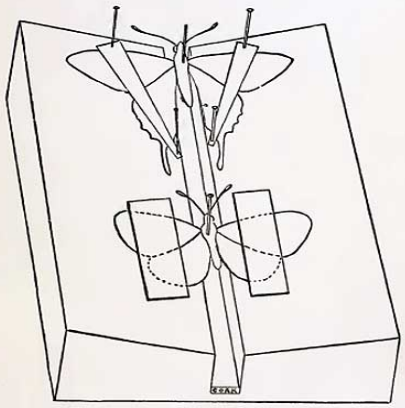


FIG. 8.

cork in the groove and then the body lying in the groove, the wings are taken, first on one side and then on the other, with a fine pair of forceps (never with the fingers), placed

Figure 6-32. "Spreading Butterflies," in Instructions for Collecting, Rearing and Preserving British and Foreign Insects, Also for Collecting Crustacea and Shells. Abel Ingpen (1839).

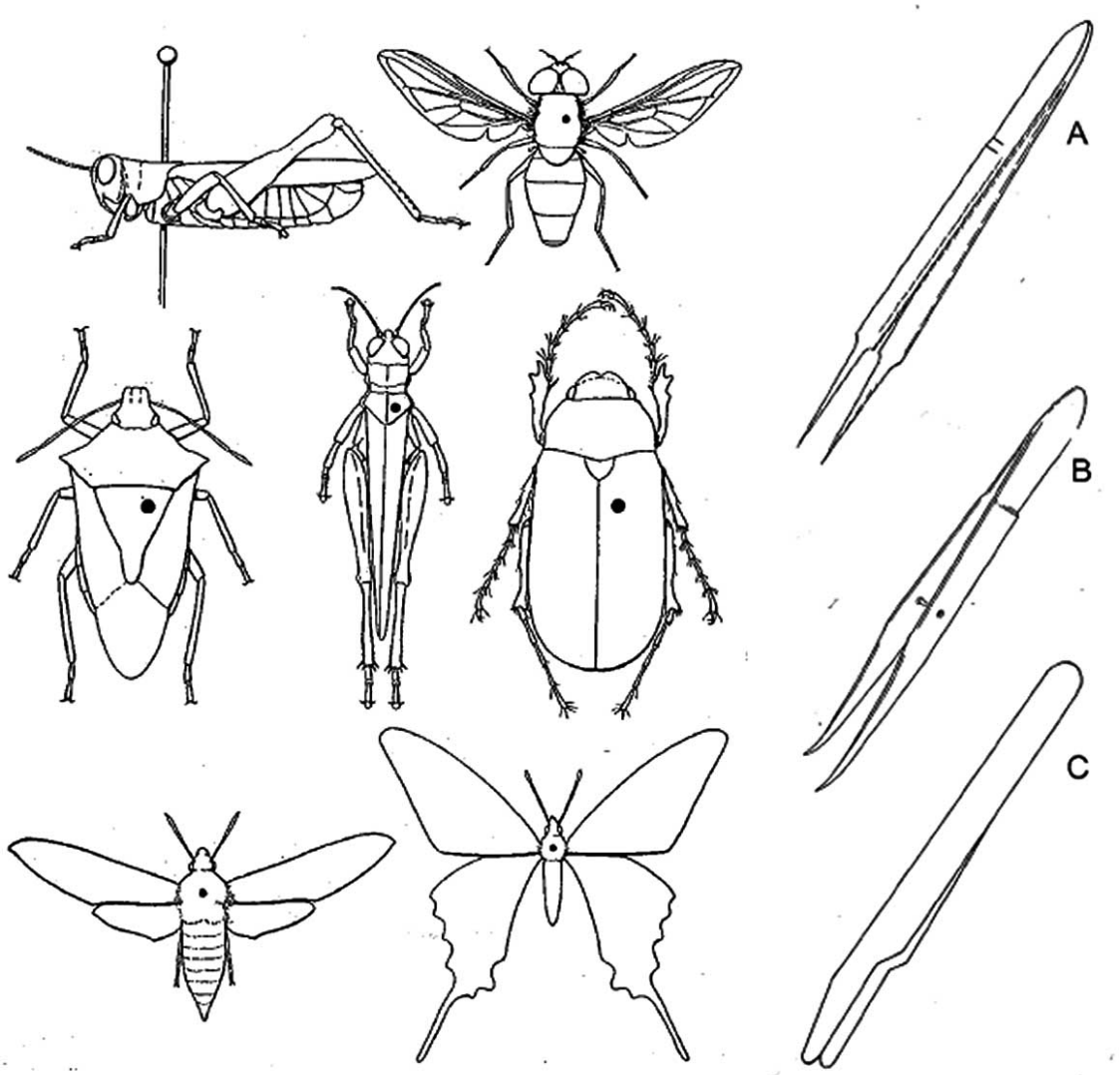


Figure 6-33.“Proper pin placement for pinning insects, with description of forceps,” in *Arthropod Collection and Identification*, Gibbs and Oseto (2006).

Special entomology pins are used, made of spring steel (which is called "black") or alternatively stainless steel with a blued or a lacquered ("Japanned") finish, which range from the thickness of a baby's hair (#000) to a small finishing nail (#7). The stainless steel pins are much preferred by the entomologists I spoke with, as the black pins tend to corrode or rust with exposure to the moisture in the body contents of the insect, and the insect can slide down the pin. Silver and brass pins used to be used, I was told, but the "action" of the insect body contents on the pin caused them to patina verdigris and eventually corrode through. "If you're spending all this time and effort to make this collection, and especially if you're pinning something as a voucher for genetic collections, the last thing you want to do is cheap out on the pin," an entomology curator told me, "We're making these collections to last forever, you want it perfect . . . I only use stainless steel pins, calendared paper, and make sure my labels are just *so*. . . The [DNA] sequences I ran in grade school aren't that relevant anymore, but the [insect] mounts I made are still incredibly valuable."

I use my paintbrush to move beetles around in the small ceramic dish of ethanol, deciding which one to start with. I move a fat black beetle to the side of the dish, then use the featherweight forceps to pick it up, so as not to crush it [Figure 6-34]. Placing it on a paper towel to dry a bit, I assemble my different sized pins (blackened stainless steel), and adjust the magnifying lens over my block of styrofoam—the stage where my beetle pinning will take place [Figure 6-35]. My beetle in place I choose a #2 pin–the pin thickness sized to the insect–and I carefully push the pin through right forewing (wing cover or elytron) near the base.

Many insects are pinned to the right of the midline so that all the characters of at least one side will be visible, similar to other specimens throughout the museum where, for example, genetic sampling is only done on one side of the specimen to leave one side intact for future morphological comparison. When I feel the pin hit the inside of the beetle's shell I lift the foam block and carefully rotate it around, to see if I've gotten the pin lined up straight so the beetle sits level on the pin, not tilting back or listing sideways. I pass the pin all the way through the body and into the foam block, anchoring it, being careful not to damage the legs. Looking through the magnifying lens I use the tip of a pin to carefully pull the legs out from the body, rotating them slightly to loosen them—articulating the joints [Figure 6-36].

Figure 6-34. Selecting a beetle
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

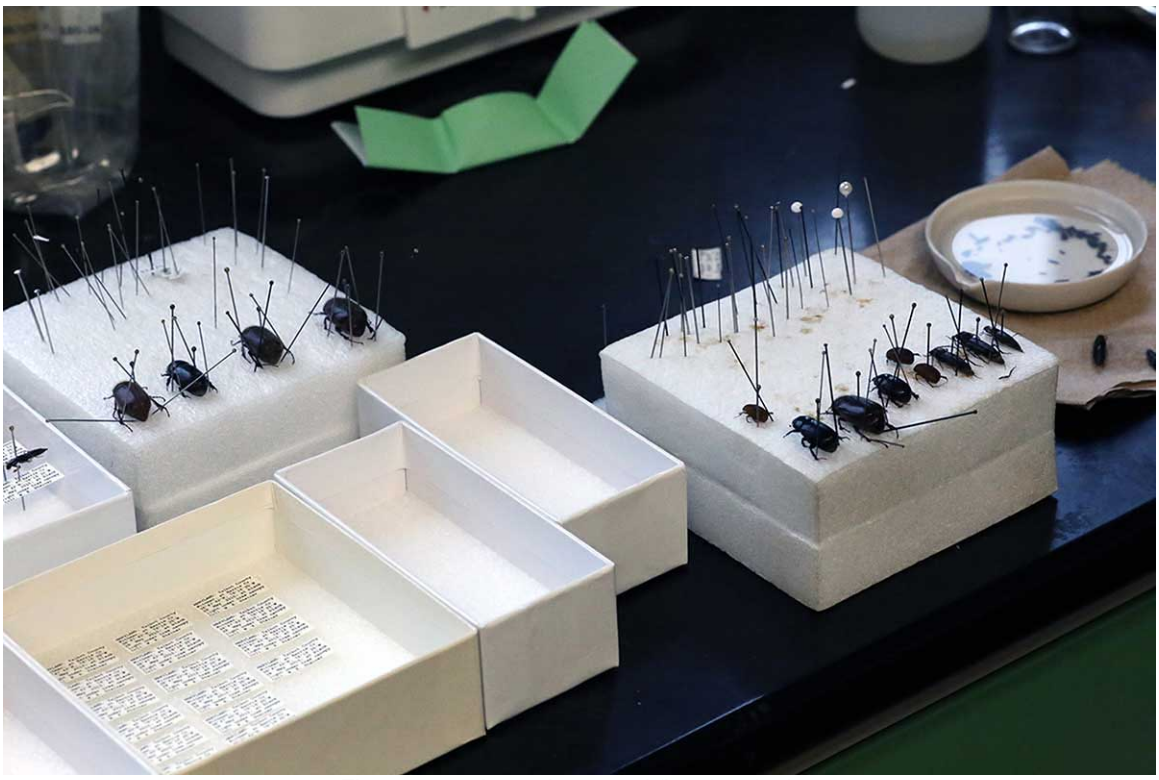


Figure 6-35. Arranging a workflow for pinning
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

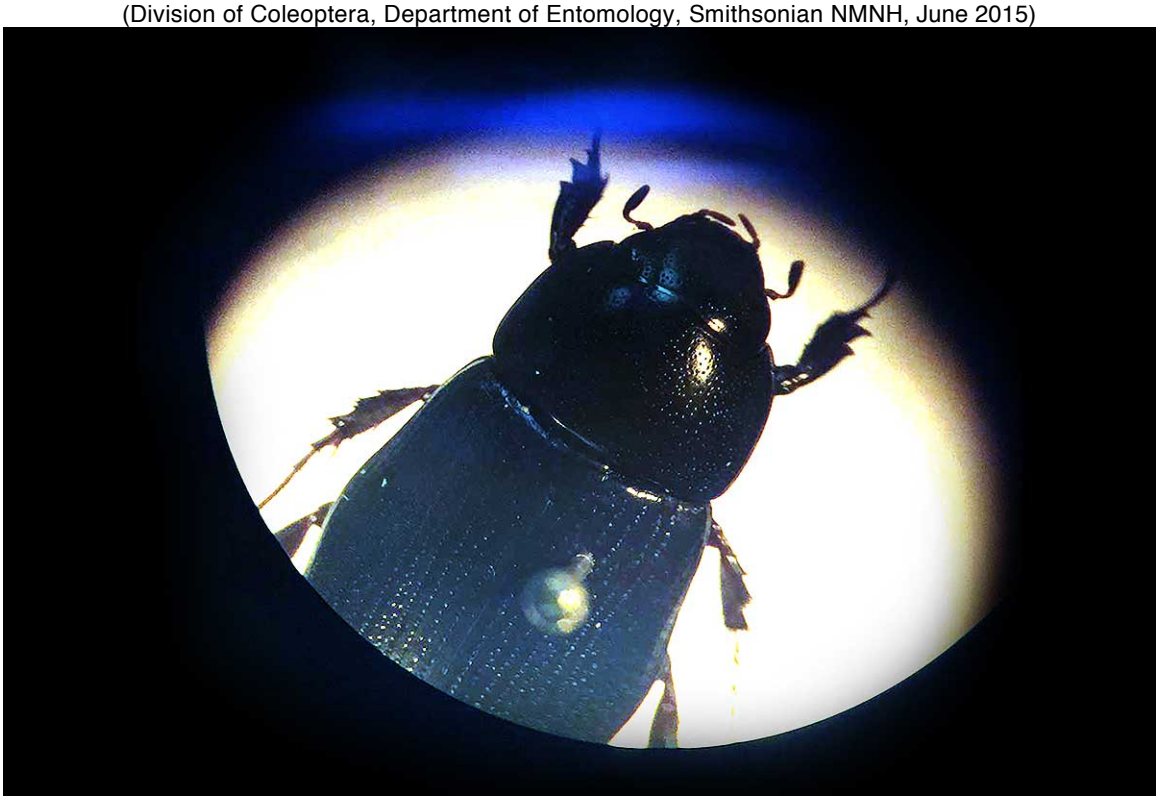


Figure 6-36. Arranging the legs and antennae
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

The tiny clawed feet catch in the surface of the foam, but I gently unstick them and get the legs positioned as if the beetle were walking, in a "natural" pose. Two pins stuck in an X over the foot anchor it in place while they dry. I repeat this for all the legs, making sure to get them symmetrical [Figure 6-37]. With the tip of the pin I gently tease the antennae out from under the chin of the beetle. They curl up when they die, Warren tells me, and its best if you can get your insects to relax before they die or you'll end up with a little shriveled thing with its legs all seized up. Clove oil is used by the herpetologists, for example, to "relax" snakes and lizards before they're euthanized so they can be posed to highlight diagnostic features before they're "fixed," that is, permanently preserved, using formalin (a type of formaldehyde). Long-legged species or specimens with drooping abdomens can present problems, but temporary supports made from bits of foam or cardstock can hold them up while they dry.

The important thing is to arrange the creature so that the key features—diagnostic attributes—are arranged symmetrically so you can look down a drawer and see the similarity or variation. A key diagnostic feature for the beetle, along with the shape of the claws on the feet, are the antennae—so it’s worth spending the time and effort to pull them out while pinning. They are tiny and brittle, and I'm afraid of breaking them. Not to worry, Warren tells me, legs, antennae and even heads fall off all the time—but there's a special insect adhesive. "You can just glue them back together like a model airplane," he says. I manage to extract the antennae without breaking them, though I'm now curious about "insect adhesive."

I pin a row of beetles and let them dry overnight, a handwritten label with their lot number pinned next to them "just in case you get hit by a bus and no one knows what these are." The next day I remove all the pins except for the anchor pin, picking up my beetle grasping the top of the pin between thumb and forefinger [Figure 6-38]. The beetle can now be viewed under a microscope without having to handle the specimen directly–which given how fragile it is, would quickly disintegrate under handling. The pin through the insect becomes an extension of my fingers, and I think about the finger-sized space left on the top of each pinned insect in the collection. The rule of thumb, as it were, is to use your own thumb and forefinger to gauge the amount of space to leave at the top of the pin.

Figure 6-37. Making X's out of pins to anchor the beetles while they dry
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

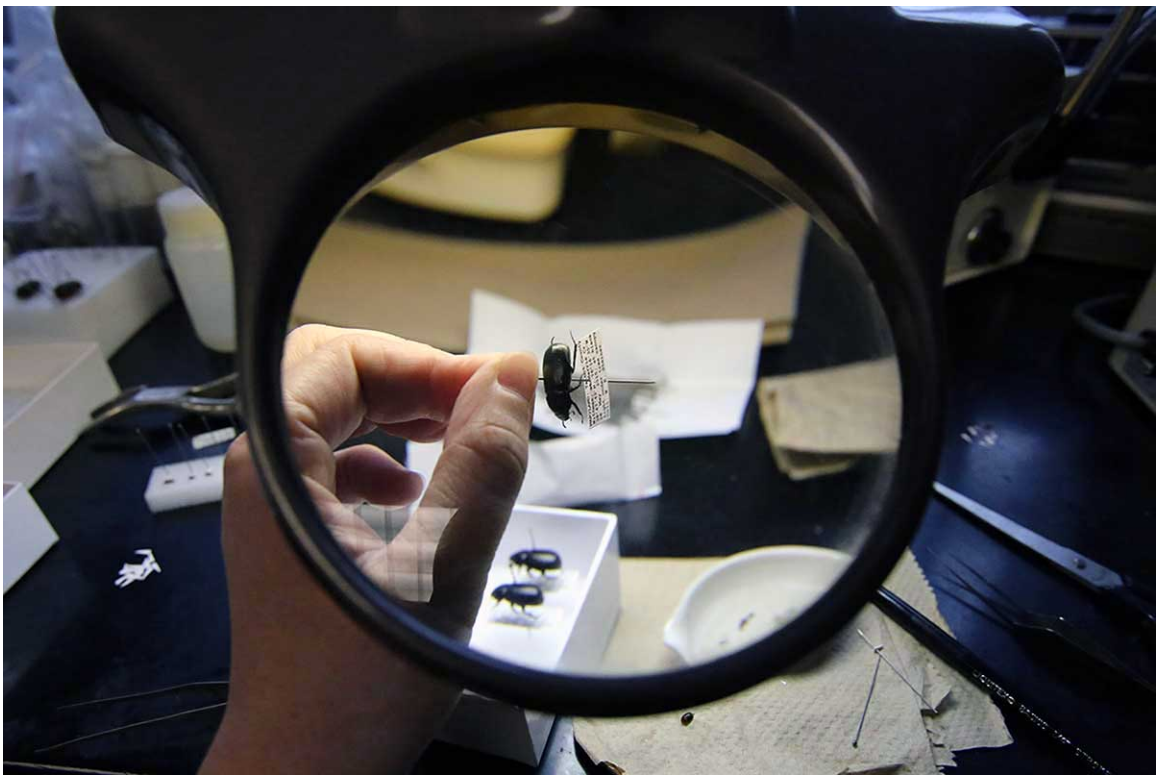


Figure 6-38. A pinned beetle with label
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

Figure 6-39. Beetles, pinned and labeled, ready to go into the collection
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

Different preparators, different fingers, different spaces left at the top of pins. I think about the millions of insects pinned in the collections, and the different fingers that have grasped the top of each pin over a hundred years—an alternative view of this archive, one of the measurements of the people who have made and used the collections, measured out in finger-widths.

We have already printed out the labels. "Laser printers were the turning point for better specimen labels," Warren tells me, "Less cryptic, more complete info. Four-point sans-serif type is the way to go." The tiny labels printed on special archival paper are heated on a hotplate for a moment to melt the toner into the paper, then clipped into individual labels with the tips of sharp scissors. The specimen data has been separated across two labels, which I line up in a two neat rows on one side of a cardboard specimen box. Picking up a beetle by the top of the pin, I center the label under the beetle so the pin doesn't cut through text and it remains legible. I'm careful to center the body mass of the beetle over the label–this will make most efficient use of the space in the specimen drawers [Figure 6-39]. Though one beetle the size of a bean doesn't seem like a problem for storage, when you take into consideration the 5,000 or so specimens brought back by each collector on an expedition, the need for space-saving measures, even measured in millimeters, begins to make sense [Figure 6-40].

Learning to See: Point-Mounting Beetles

Point-mounting is a much more delicate and complicated process than pinning, or, as Warren described it, much more "fiddly." Card stock is cut into small triangles measuring a few millimeters long, either by hand or using a special punch [Figure 6-41]. Insects too small to be pinned are then glued to the end of the triangle point. After the glue dries, the point is moved up the pin and labels stacked under it.

The process seems simple enough until you try for yourself. The tiny beetles, mere black specks in the dish of alcohol, are brushed up the side of the dish and onto a waiting paper towel using the tip of a paintbrush [Figure 6-42]. Trying to grasp them with a pair of forceps while they are still wet results in them flying across the room like a watermelon seed squeezed between thumb and forefinger.

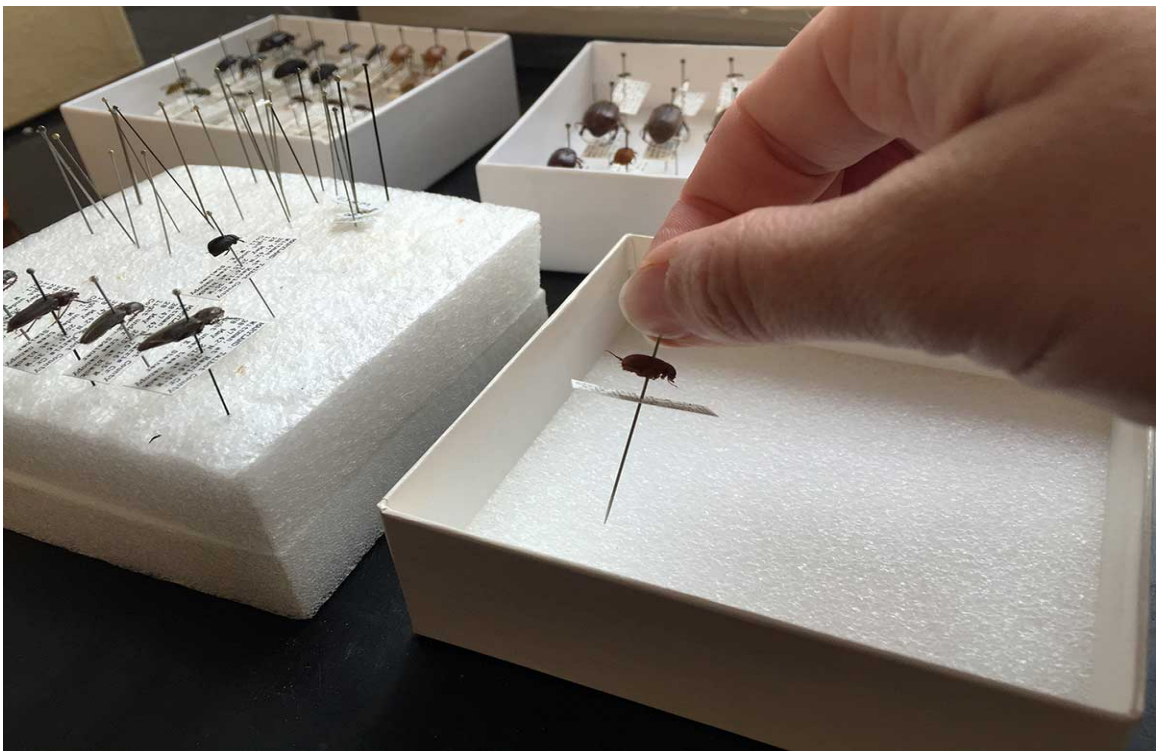


Figure 6-40. Moving the finished beetles from foam block to collection tray
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

Figure 6-41. Point punch and acid-free cardstock
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

Figure 6-42. Selecting micro beetles for point mounting
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

Grasping a beetle fresh from the ethanol with my forceps, I watch in dismay as the tiny black dot arcs across the room, landing somewhere near the sink in the corner. I watch where it lands and spend several minutes on my hands and knees with my featherweight forceps and iPhone (used as flashlight to create a raking light across the floor) locating and retrieving the beetle. Tiny but precious, the LBBs ("Little Brown Beetles") are "where all the biodiversity is" according to Warren. Though several have gone flying, I have not lost one yet. Heeding Warren's suggestion, I let them dry out a bit more before I try to pick them up.

Waiting for the beetle to dry out a bit more, I use the tip of a pin as a drill to start a hole in the paper point. As taught, I use the edge of my sturdier forceps as a wedge to drive the pin through paper without bending it. The tip of the point should be trimmed to match the width of the beetle belly between the legs where it will be glued. "Some folks bend the point tip and glue that–but it obscures everything," I'm told. As I gently rake my trimmed point in the dot of plain white Elmer's glue and arrange the beetle on it I find it would be much easier to do just that, over-glue and obscure the entire bottom of the beetle. Instead I carefully flip the insect and get a tiny dot of glue on the point, making sure it's the right consistency of gumminess (another moment of the "stickiness of practical encounter").

I have to think about my own body to get the position of the point correct–I poke myself in the right lower rib to get correct orientation, lining myself up with the beetle in front of me. *If I were the beetle, this is where the point would get glued*. Opening up the illustration of beetle anatomy on my iPhone as reference, I get a sense of the topography of the underside of the tiny creature and where the paper should go: "You have to know what you're looking at to know what's important," one of the entomology curators tells me later.

I finally get the beetle in place on the point, with the paper not covering the ventral axis, between the correct set of legs [Figure 6-43]. Using the tip of a pin I wiggle the beetle into symmetry, then stick it into a block of foam, so the beetle has something to rest on while it dries. I create a little assembly line, point mounting the swirl of black dots in my dish. Once the glue has dried enough that the beetles won't fall off their paper points, I used a pair of forceps gripped underneath the point to move each one up the pin, leaving just enough room for a pair of fingertips to grip the top of the pin.

Figure 6-43. A tiny point-mounted beetle
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

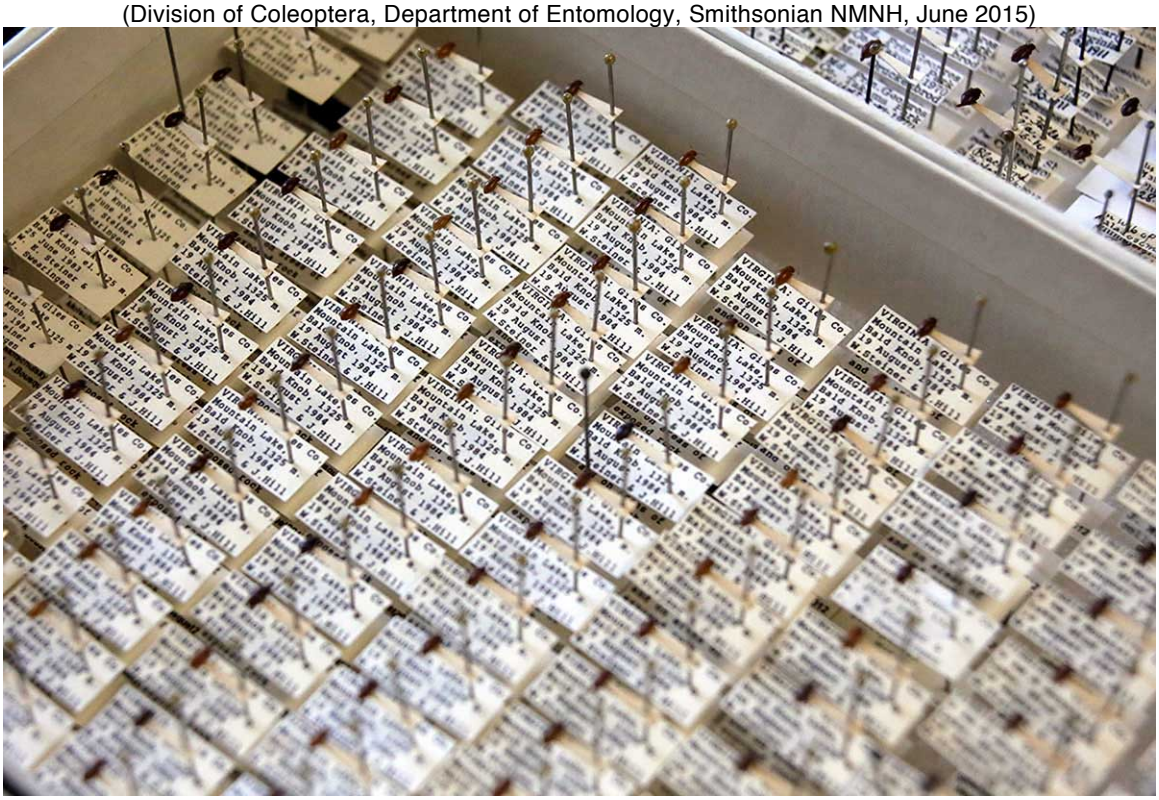


Figure 6-44. Tray of point-mounted beetles in the collections
(Division of Coleoptera, Department of Entomology, Smithsonian NMNH, June 2015)

I add the labels under the specimen, stacked in the correct order and all stuck through in the same place, being careful not to obscure the tiny printed type and using space as efficiently as possible [Figure 6-44]. Going through the entomology collections with Warren looking at different preparation methods, he shows me the "parking garage" and "pinwheel" methods for point-mounting–both are big "space savers," but very time consuming to produce. How things are preserved "depends on what's most important at the time," he tells me.

Collecting Timelines

"We aren't just collecting different things, we're collecting and preserving them differently," Floyd Shockley, the collections managers for the whole of Entomology tells me later. Collectors are still doing what they've been doing for decades: pinning and point mounting all variety of insects, preserving soft-bodied and immature insects in alcohol or inflating and drying them, moths and butterflies folded in triangular glassine envelopes or spread and pinned, dragonflies and damselflies mounted on index cards, dissected genitalia stored in vials, various parts and slices mounted on microscope slides, gold-plated or palladium-plated insect parts mounted on "buttons" for the Scanning Electron Microscope (SEM), along with samples of the different habitats and (bark, leaves) and architectures (spider houses, wasps' nests, cocoons). [Figure 6-45, Figure 6-46, Figure 6-47, Figure 6-48, Figure 6-49, Figure 6-50, Figure 6-51, Figure 6-52, Figure 6-53]. There is less a change in the kinds of things that are collected, I'm told, than a shift in the different methods for genetic collecting (slowly) becoming part of the process in each Division of the Entomology Department, with tissue collections now centrally stored in liquid nitrogen at the Biorepository, other samples in -80 freezers in the curator's own offices and labs, and DNAs and extractions in buffer in freezers in the L.A.B. All becoming part of the "normal" process of the creation and use of collections.

Our noses down our respective microscopes, working away on our collections of beetles fished out of the "soup" jar, Warren and I talk about the details of collecting and preserving, and how he's seen entomology collecting change over time. He tells me about what it's like to collect: "I can see the randomness of nature, see the underlying order and repetition . . . There's a lot of regimented stuff going on at a microscopic and morphological level under all that chaos,

Figure 6-45. Microscope slides of insects, whole and in parts and pieces
(Department of Entomology, Smithsonian NMNH, April 2015)

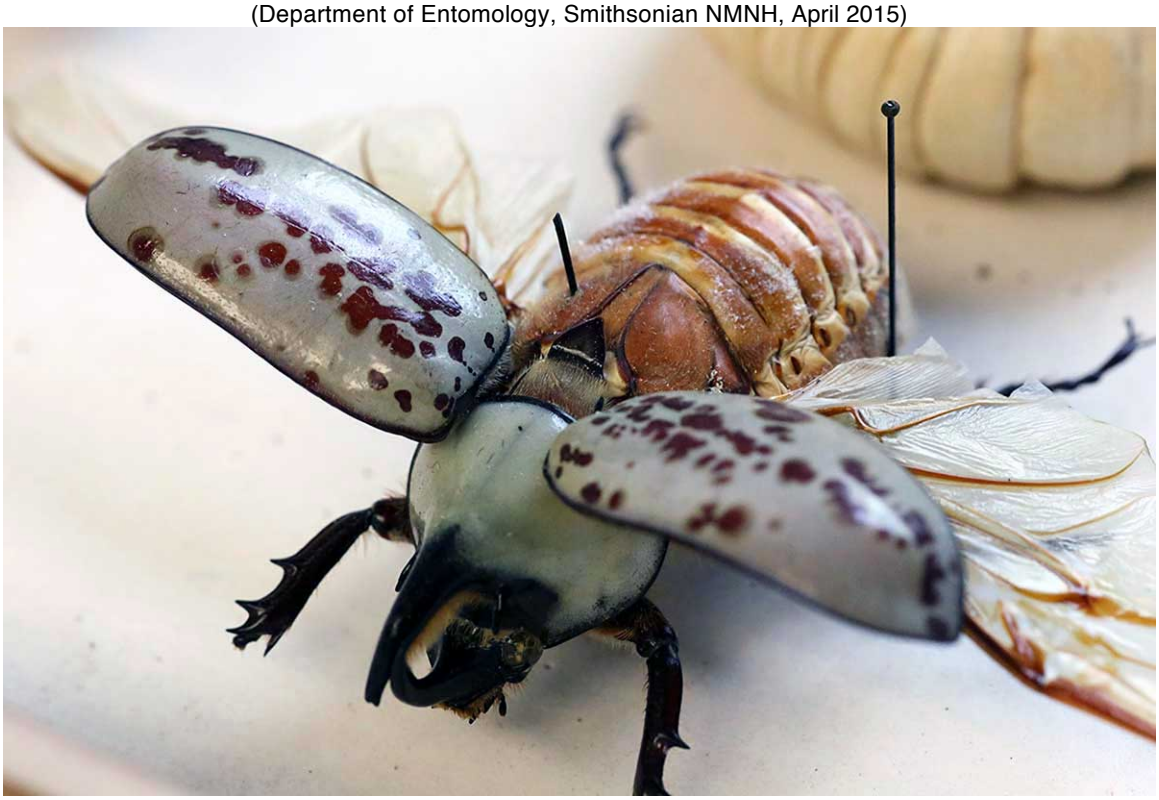


Figure 6-46. Beetle with spread wings
(Department of Entomology, Smithsonian NMNH, April 2015)

Figure 6-47. Dragonflies on index cards
(Department of Entomology, Smithsonian NMNH, June 2015)

Figure 6-48. Spread butterfly from the nineteenth century
(Department of Entomology, Smithsonian NMNH, April 2015)

Figure 6-49. Mounted beetle, with anchor pins along the sides of its head due to its size
(Department of Entomology, Smithsonian NMNH, June 2015)

Figure 6-50. Inflated larva mounted on cork with wire armature, handwritten label below
(Department of Entomology, Smithsonian NMNH, June 2015)

Figure 6-51. Spider and spider nest
(Department of Entomology, Smithsonian NMNH, April 2015)

Figure 6-52. Mounted tarantula, originally found in shipment of bananas in 1930
(Department of Entomology, Smithsonian NMNH, April 2015)

Figure 6-53. Alcohol preserved insect specimens
(Department of Entomology, Smithsonian NMNH, April 2015

you just have to see it . . . To see the random things going on - a bunch of trees falling down a ravine and bugs flying everywhere . . . And then to be able to collect and organize and see the order under it all."

I think about the "folded time" of historical collecting methods, how similar what I'm sitting here doing is to the manuals from the 1850s. The tools are remarkably similar, though my bottle of white Elmer's glue has replaced the hide glue recommended in an 1892 Smithsonian-issued insect collecting manual (Riley 1892). Many of the beetles I look at in the collections were mounted in the nineteenth century and are still useful—perhaps in ways their makers never expected or could have imagined, as detailed in Chapter 2 on the new (genetic) uses for old collections.

Looking through the collections for the drawer of pinned dermestid beetles–the scourge of museum conservationists and collection managers–(I had a perverse desire to see the museum-ified version of the pest stuck on a pin and labeled instead of stuck in a sticky trap at the base of the cabinet) Warren and I came across a drawer of beetles he had pinned in the early 1970s. I asked Warren if he knew how many of his insects were in the collection, he thought for a moment and said he'd lost count long, long ago. "Early on I thought I would remember it all—how many could there be after all? That was tens of thousands of insects ago. But it would be a thing to know," he told me, "You could track your whole life through them [the collections]–where you were, what you were collecting, what you knew. . . Yeah, that would be a thing to know."

Shifting from the context of genomics, the disarticulating of beetle legs from specimens and mounting whole beetles I now turn to think through the process of craft, and how it "articulates" different practices and knowledges within the making of museum specimens.

Conclusion: Crafting Specimens, Articulating Nature

Craft can be used as a way of understanding cultural practices, of learning through making–from the embedded materiality of things, specifically "natural" things classified as *data, tissues, beetles, birds* and *trees*. I have followed a genealogy of hands-on production as a way to understand the reproduction of

knowledge, following a path from Dewey to the Bauhaus to the DIYBio movement and contemporary apprenticeships in museum specimen preparation and genomic labwork, focused on hands-on production as a way to understand the reproduction of knowledge.

I took up craft as a method for understanding and exploring the uniquely handmade nature of scientific objects. Craft can be understood as both an individual process and as a methodology for understanding how (material) culture is made and remade, and through this lens I began to understand how scientific knowledge about the natural world is (re)produced and naturalized–one beetle leg, data set, and tissue tube at a time. Versions of nature and natural order are made in the museum, created in the tiny details of specimen preparation techniques where some parts are discarded, other deemed precious, and the disarticulated assemblage of parts and pieces come to stand for the living thing from which it was all derived. A living thing is transformed into a museum specimen, with a collection of data threads binding the whole back together to create meaning and purpose for the taking of that life.

Each specimen's "life history" can be seen as a collection of moments, important events as it is collected, prepared, accessioned, and sampled–events in the "afterlife" of the specimen that begins after death. Formerly living things are made into different assemblages that combine biological materials (fur, feather, bone, shell), concepts of nature (species, evolution, trees of life), skilled labor (fat wheel, feather pins, forceps) and regimes of value ("banking" precious biodiversity, global collecting networks). These assembled specimens circulate within the museum and beyond to other museums, institutions, and research sites, accumulating and negotiating these concepts of nature and value as they move between domains along their “lines of flight” or “lines of becoming.” To return to Ingold (2010) and Deleuze and Guattari’s entanglement with these threads, Ingold suggests life “issues along such thread-lines . . . Critically, however, these lines do not connect.” For Deleuze and Guatarri, a “line of becoming is not defined by the points it connects, or by the points that compose it; on the contrary, it passes between points, it comes up through the middle … A becoming is neither one nor two, nor the relation of the two; it is the in-between, the … line of flight … running perpendicular to both” (1987:323). To stay at the in-between space, threading a line perpendicular between domains is one way to situate collections within contending disciplinary and global contexts.

Environments in the field, the lab and the museum are also reflected in the specimen, differences that become visible when the specimens shift across boundaries and naturalized practices suddenly become distinctly unfamiliar. Attending to the details of these craft practices is a way to access the competing narratives within and between museums about the proper ethos of preservation and the conservation of (genetic) biodiversity. These narratives are bound up with wide-reaching implications for how we perceive ourselves—from specific culturally-situated vantage points—as a species. The scientists I spoke with articulated, each in their own way, a moral imperative to preserve dwindling biodiversity.

Collections "articulate" nature in specific ways by demonstrating the contingent and linked nature of the biological artifacts in of themselves–such as a carabid beetle on a pin, contextualized by its stacked labels. The stainless steel of the pin, the quality of the paper for the labels (high cotton rag content or cheap cardstock) and the information on the labels themselves (in abbreviated handwritten scrawl or laser printed 4pt sans-serif type)–all of these small details locate the specimen in a particular moment, as a product of the web of social relations (the techniques and preferences of specimen preparators in Entomology), of industrial production (cost and availability of stainless steel and paper) and of global economies (access to fieldsites to collect beetles pre- or post- Convention on Biological Diversity). The craft practices of literally articulating beetle legs (bending them into position) during the process of mounting them can also be extended to the figurative sense of as how they are "articulated" through the intersecting fields, and rhetorics, of the biological, the ecological, the social and the political. “To know the history of science,” writes Evelyn Fox Keller, “is to recognize the mortality of any claim to universal truth” (1995b:178); and any “universal truth” of genomic collecting is called into question when one observes first hand how it is constructed, one beetle leg, and DNA extract and genome at a time.

Each prepared specimen–be it a beetle, bird, tissue sample or extracted DNA—reflects a complex and layered interpretation of an (idealized and evolving) Tree of Life and an (imperfect and dwindling) biosphere. Following the thread of multiple articulations between histories and disciplines on the one hand, and between materials and makers on the other, I now turn to the types of time in the museum in different types of trees—from collecting tree leaves into liquid nitrogen to building a (genomic) Tree of Life.

Chapter 7

TIME/TREES

Types of Time in the Genomic Museum

time—a system or method of measuring or reckoning the passage of events; indefinite and continuous duration regarded as that in which events succeed one another, as in past, present, or future. From the Old English *tīd* "time"; akin to "tide" [52]
trees—a plant having a permanently woody main stem or trunk and usually developing branches at some distance from the ground.[53]

As buds give rise by growth to fresh buds, and these, if vigorous, branch out and overtop on all sides many a feebler branch, so by generation I believe it has been with the great Tree of Life, which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever-branching and beautiful ramifications.
— Charles Darwin (1872:147)

This chapter examines different "trees" in the museum and the types of time they represent, from the deep time of the Tree of Life to the frozen time of the Biorepository. An ethnographic understanding of time is a central organizing principle of thinking through crafting "nature" in the museum, as seen in its collecting cycles, and the future imaginaries for collections both frozen (Radin 2013; Kowal et al. 2013) and traditional (Daston 2004a; Pearce 1992; Rocha et al. 2014). These include the time since death in capturing genomes, and a mapping of relationships between organisms in a singular (genomic) Tree of Life—an orientation to both past and future that has been articulated as "tree-thinking" (Baum 2005).

First, I examine "collecting from the collections" as the GGI Gardens project samples the leaves, branches and seeds of a nineteenth century cocoa tree at the US National Botanical Garden (*How to Build a Tree, Part I*). Next I learn how to mount dried plant specimens onto herbarium pages in the Botany Department, noting the continuities and ruptures caused by the introduction of genetics into this centuries-old practice (*How to Build a Tree, Part II*). Finally, I look at how three organizational forms—the census, the map, and the museum—converge in the building of a phylogenetic Tree of Life (*How to Build a Tree, Part III*).

[52] Online Etymological Dictionary (http://www.etymonline.com/index.php?term=time)
[53] Oxford English Dictionary (http://www.etymonline.com/index.php?term=tree)

The distinct methods—and the implications embedded within these methods—for collecting and using botanical samples, are very different from methods used for the vertebrates which have historically formed the basis for collecting protocols. From the living collections kept in botanical gardens to the genetic sampling methods for flowering plants to the unique loci within the genome required for DNA barcoding (BOLD 2015; Waterton et al. 2013), the methods for collecting plant life disrupt the holistic continuity of an orderly and unified phylogenomic Tree of Life.

These different types of time in the museum all shape and orient the shifting (or evolving) definitions of what constitutes biodiversity, conservation, nature and even life itself (Fabian 1983; Pickering 2010). What is life if it is frozen and still, requiring deep technological intervention to move again? I argue that time, and specifically the changing concepts and scales of *museum* time, are a condition of possibility for collecting and preserving the genomic diversity of "life on ice." Cryopreservation has been called a form of "temporal prosthesis" (Kowal and Radin 2015:68) that functions to suspend time conceptually, with the future potential of the Biorepository's cache of "latent life" (Radin 2013) shaping collection practices. Concepts of museum time at different scales for different purposes require care and maintenance. Evolutionary time is a continual reconstruction of the Tree of Life, time stretching back to the dawn of life itself through molecular markers that must be mapped. Collecting requires following the variously timed cycles of flowering plants, migrating birds and swarming insects. The sense of *time-less-ness* in the genetic collections—collections made to last indefinitely (what Jon Coddington once called "futuromics") rest on much labor to maintain the freezers and nitrogen tanks, and keep the analytical chains of data between sample and voucher tightly knit.

Yet these genetic collections are also consumable, and therefore finite in their life span as tissue samples. Time organizes the assemblages and circulations of people and objects in the museums and the circulation of concepts and specimens across global networks. Stable taxonomic "ontologies" are used across these networks, utilizing craft methods that mesh long histories of specimen preparation with new methods of genetic collecting. These shared terminologies allow a (perceived) continuity of museum practice. The recasting of museum collections as new data sources that reach back into "deep time" (ecologically speaking) are an articulation of the museum tree-thinking exported

into a salvation rhetoric. Use of the collections is framed as a means to preserve and understand biodiversity, parted out into frozen pieces. “[T]o be biological, alive, cellular” in the contemporary moment is to be “suspendable, interruptible, storable, freezable in parts” (Landecker 2005, cited in Kowal and Radin 2015:68).

To build a future, museums need to collect and preserve what is still currently available in an act of “predictive hindsight” (Radin 2013). To understand what kinds of nature are being preserved, I examine what is being preserved, through a detailed attention and engagement with the materials that these ecological futures and environmental policies will derive from—the specimens themselves, their tissue samples and the swirl of data that surrounds them. How are specimens made and unmade, how do they move across boundaries, and how are they valued as they are made and move? These have been the central questions that have driven the previous chapters, and which I now use to look at the entangled *types of trees* and *types of time* in the museum. To begin, I look at how to collect trees (and their parts) into plant presses and liquid nitrogen tanks for the GGI Gardens project—a form of collecting from the collections.

How to Build a Tree, Part I:

Collecting from the Collections: GGI Gardens at the U.S. Botanic Garden

August 2015. It is just after 8am and already the air is heavy with heat, swampy. The humid summers of D.C. are legendary, with Smithsonian staff reminding me that when the United States was a British colony in the eighteenth century, Washington D.C. was considered a tropical posting—with commensurate hazard pay. As I walk towards the sprawling glass-domed Victorian structure of the U.S. National Botanic Garden (USBG), nestled at the foot of the Capitol Building, I begin to comprehend the categorization of DC as “tropical.” The building isn’t yet open, but groups of school children on school trips have already gathered in front of the building, clustered under the available shade offered up by labeled plantings and trees. I make my way through the sea of shining, sweaty faces to the glass doors of the Botanical Garden. Flashing my Smithsonian ID badge I’m granted entry into the blissfully air-conditioned entry hall, a long space lined with

trees reaching up to the glass roof, two shallow fountains down the center. They remind me of the shallow reflecting pool between the Lincoln Memorial and the Washington Monument, but instead of reflecting an obelisk these pools reflect trees gathered from around the world, a living collection.

The Global Genome Initiative (GGI) is officially launching today, though the project has been gathering funds and working on projects for over a year. After much deliberation between the publicity office at NMNH and the GGI project manager and director, it was finally decided to center the GGI launch around one of its projects: GGI Gardens. The project, partially funded by the GGI and lead by Botany curator Vicki Funk, is focused on creating a protocol for gathering genome-quality tissue samples from living collections in botanical gardens and arboretums. The first test case would be the U.S. National Botanic Garden and the U.S. National Arboretum—two living collections of plants that had been gathered and propagated since 1820 and 1927 respectively. In effect, as I came to think of it, collecting from the collections.[54]

The NMNH publicity office had balked at the idea of displaying the more visceral side of natural history collecting—the blood, guts, bits, pieces and tissue sampling in which I'd been arm deep in Birds and Entomology. These processes, in their opinion, would not make the best press release. It would raise questions that would detract from the focus of the GGI's goals, a public affairs staff member told me. There had been a meeting to decide what aspect of the GGI's collecting activities would be the best example for the outside world. Plants, it had been decided, were more accessible and less controversial than other options. Or, as one of the GGI staff quipped, "Who gets upset about picking lettuce?"

In the Botanical Garden hallway of trees I walked over to the group of GGI staff, the Botany curator Vicki Funk and the several interns who were working in Botany Department that summer. Vicki and her crew were busy preparing their collecting kit for the day's activities: a rolling cart carried a dewer of liquid nitrogen, 2ml tubes to put samples into the liquid nitrogen tank, little squares of tin foil to wrap up the tubes, plastic baggies of silica pellets to dry specimens, a plant press to put the voucher specimens in, and a clipboard for recording

[54] Many of the original specimens for the U.S. National Botanical Garden were provided by the United States Exploring Expedition to the South Seas (the Wilkes Expedition), which brought a collection of living plants from around the globe to Washington, D.C. In 1842 (U.S. Botanical Garden, 2010).

collection data [Figure 7-1]. A sharp contrast between new and old: the plant press changed little from illustrations in collecting manuals from 150 hundred years ago [Figure 7-2], with the very visible exception of Vicki's bright orange nylon strap for her press. "I definitely know which straps are mine out in the field," she says with a grin. Black straps are standard, and easily confused even if labeled with the owner's name. The nitrogen tank and tubes are new additions to the collecting regime. Plant DNA behaves very differently from animal DNA, degrading differently and needing an entirely different set of primers and protocols to successfully extract useful sequences (Ellis 2008; Parry 2004; Waterton et al. 2013). "They [plants] just take so much longer to change than animals," Vicki tells me.

The GGI Director, Jon Coddington, the then-Associate Director of Science (ADS) for the Smithsonian, John Kress, and the Director of the Botanical Garden, Ari Novy, were all gathered a one end of a fountain being interviewed by reporters intent on getting sound bites for the story of the Smithsonian putting "Life on Ice," a phrase Jon Coddington had used but gradually rejected. "It doesn't fulfill its function very well—it's catchy, but it's also confusing for those who don't know what we're talking about [liquid nitrogen], and it doesn't sound very serious to those who do know what we're talking about [potential scientific collaborators with interesting collections]. So I chucked it. Except when it's useful," he said breaking into one of his characteristic wide grins.

I heard the phrase "life on ice" drift over from the cluster of reporters and the scientists they were interviewing by the fountain, so I gathered today was one of those "useful" days. Meanwhile another set of photographers and camera crews make their way over to us. They are the B-roll crew, and they want to get process shots of the team collecting, something to show in the background behind a voiceover. We're accompanied by the head collections manager at the Botanical Garden, who will help guide what to collect and from where ("We're a public space, and these [plants] are for display as well as a collection to maintain," he explains to us all). I blend into the group of photographers, my camera ready. I'm also documenting the process of collecting, but taking a wider frame—I'm also documenting the documenters, paying attention to the way things are done differently in front of the camera or not. It is a performance of collecting enacted for the camera and through the images, performed for a wider public audience.

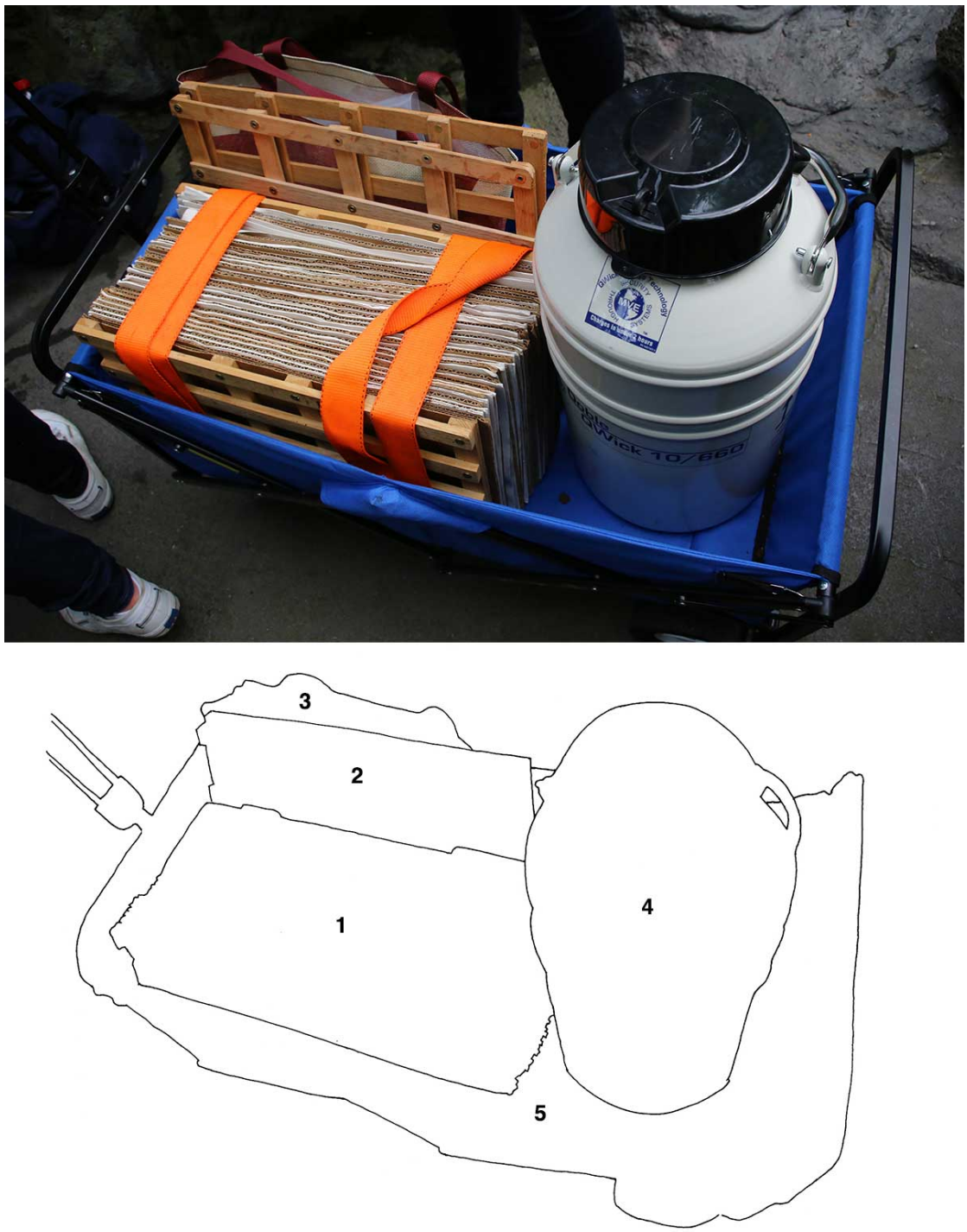
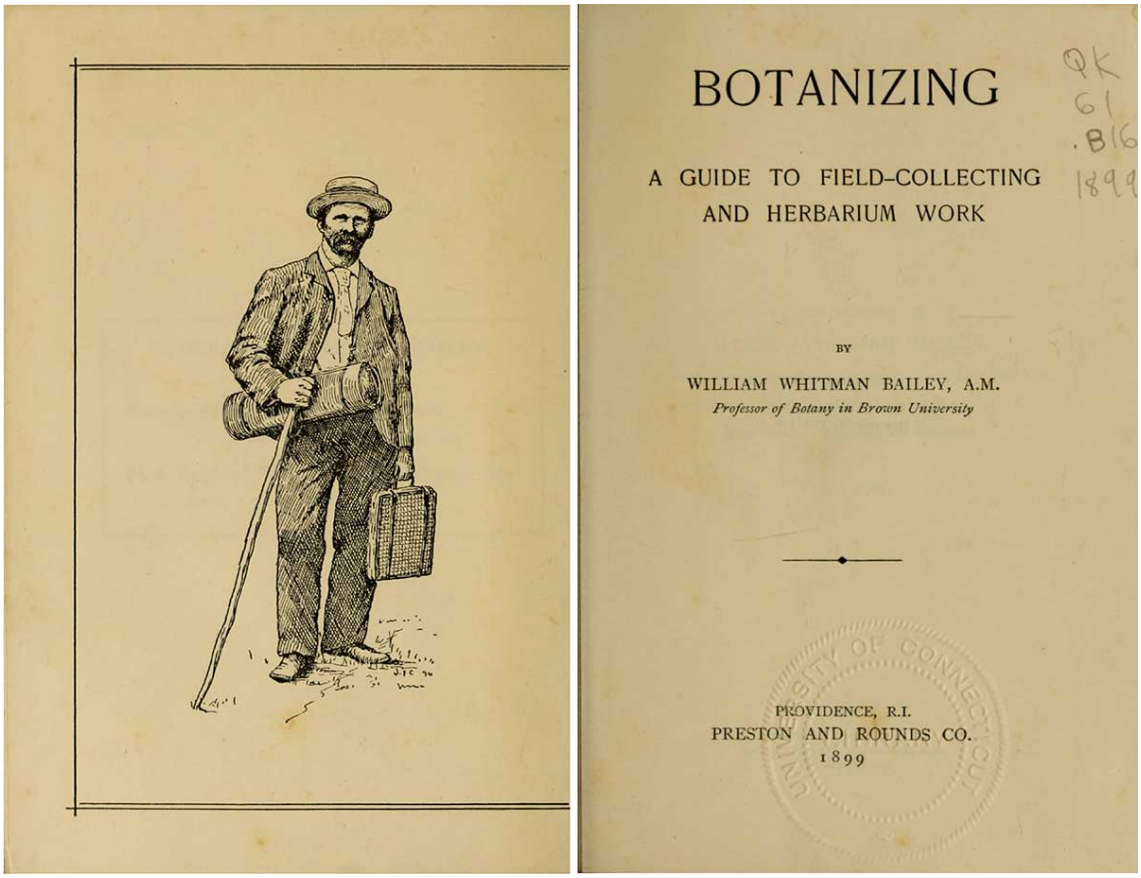


Figure 7-1. Anantomy of a Genomic Collecting Cart, Botanical version: [1] Plant press; [2] extra wood platens; [3] Plastic bags filled with silica pellets, and also 2ml cryotubes - both for collecting plant pieces; [4] Liquid nitrogen dewer. (U.S. Botanic Garden, August 2015)



BOTANIZING

A GUIDE TO FIELD-COLLECTING
AND HERBARIUM WORK

BY

WILLIAM WHITMAN BAILEY, A.M.
Professor of Botany in Brown University

PROVIDENCE, R.I.
PRESTON AND ROUNDS CO.
1899

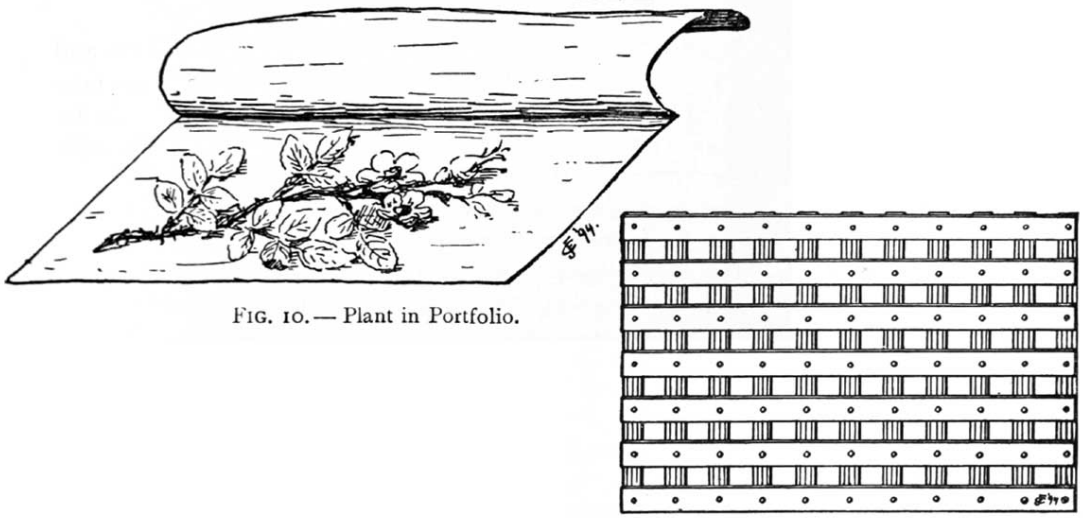


FIG. 10. — Plant in Portfolio.

FIG. 7. — Wooden Portfolio.

Figure 7-2. The tools for collecting botanical specimens, circa 1899,
look remarkably similar to those used by the GGI Gardens in 2015.
[William Baily, *Botanizing: A Guide to Field-Collecting and Herbarium Work* (1899)].

The Botanical Garden collections Manager leads the group over to a cocoa tree (*Theobroma cacao*), in partial flower with several large bright yellow fruits shaped like yams [Figure 7-3]. The fruit are unexpectedly large. The scientific name *Theobroma cacao* was given to the species by the Swedish botanist Carl Linnaeus in 1753, published in his foundational book *Species Plantarum*. Theobroma means "food of the gods" in Latin, and cacao is derived from the Nahuatl (Aztec language) word *xocolatl*, from *xococ* (bitter) and *atl* (water). Sir Hans Sloane, while stationed in Jamaica in the mid-eighteenth century, collected the individual cocoa plant Linnaeus used to describe the species—the type specimen (Young 2007). Sloane's collections later founded the British Museum, and his chocolate specimen can be seen on display in the Darwin Centre in the Natural History Museum in London (Natural History Museum London 2016), while his recipe for a "tonic" made from milk, sugar and the fermented cocoa beans was sold in the nineteenth century to the Cadbury Brothers (Young 2007). The tree on display at the US National Botanical Garden is of a less illustrious provenance than the type specimen or an industrial chocolate empire. However, after today's collecting event its seed pods will be frozen in liquid nitrogen in the NMNH Biorepository —saved in perpetuity for an unknown future [Figure 7-4].

One of the interns wheels the cart as close as possible to the tree and Vicki and her crew step over the border from footpath into "garden," careful not to step on any plantings. They unpack the cart, unbuckling the plant press, getting a page ready for the plant cutting that will be used as the voucher specimen, tubes ready for the seeds, baggies of silica ready for leaves. Vicki takes out her shiny steel pruning shears and the Botanical Garden collections manager winces slightly. This is, in one sense, a destructive sampling event. However the skins, bones and pickled specimens in the rest of the National collections won't grow back after being snipped. Those specimens won't repair themselves after bone fragments are chiseled out of the back of a skull, or a toe pad is clipped from a foot.

The cocoa tree will grow back, but the sight of the pruning shears—looking like they could snip through bone as well as a branch—seems to be slightly unsettling to the steward of this collection. He points out specific places to cut, and soon there is a pulpy yellow fruit being cut open on the ground at the foot of the tree. The seeds are scooped out and put into tubes. These are then wrapped in foil and dropped into the liquid nitrogen tank [Figure 7-5]. Next a branch is cut

Figure 7-3. *Theobroma cocoa*
[F.R. de Tussac, *Flore des Antilles*, t. 13 (1808)]

Figure 7-4.Anatomy of Genomic Collecting tools (Botanical version): [1] Cocoa fruit, seeds taken out; [2] Shears; [3] Bag of foil squares and tissue tubes; [4] Liquid nitrogen dewer. (U.S. Botanic Garden, August 2015)

Figure 7-5. Collecting botanical samples into liquid nitrogen dewer: [1] Putting Biorepository label onto tube; [2] Wrapping tube in tin foil to assure label and tube stay together in “friction” of tank; [3] Dropping the tube-foil bundle into the tank. (U.S. Botanic Garden, August 2015)

and Vicki deftly arranges it on a page in the plant press. Make it fill the page, she tells us (and the reporters listening in), leaving room for the specimen labels and fragment packet later on. And turn one leaf over, she says, so you can see the veining on the underside —it's a diagnostic feature for many species [Figure 7-6].

The branch on its sheet of heavy cotton paper, acid-free to ensure its longevity, is folded between a sheet of newspaper and then a rectangle of cardboard is placed on top of it. *Cut, arrange, fold, stack, repeat.* A plant press is all about moisture, I learn. The pieces of newspaper absorb moisture from the plant as it dries out and the pieces of cardboard between the specimens are cut in such a way that the hollows in the cardboard all face the same direction [Figure 7-7]. This allows air to circulate through the press even when it's strapped closed.

"We'll put this [Vicki taps her plant press] in a drying cabinet for about a week, and then the sheets go to the collections manager in Botany to mount and get sorted into the Botany collections," Vicki tells the reporters and photographers, "The frozen samples go to the biorepository. The baggies [shaking a plastic bag with leaves and silica pellets] also go into the collections, but many are used by curators for their research first . . . You can usually get good DNA out of dried plants, much more so than dried animals . . . Some botanists will also save plants into ethanol for genetic work."

Indeed, one Botany curator recounted his usual collecting methods in the Caribbean, where one of the first stops was at the local distillery to get ethanol for pickling specimens. While there, a good bottle or two of rum were also obtained. At one retirement party at the museum, at the end of the evening as things were winding down, a handful of curators and post-docs went and fetched their various bottles obtained during fieldwork. They had been bought at distilleries in the countries where each one had been doing fieldwork. All had originally gone to get ethanol for their specimens to "pickle" them (preserve them in a glass jar of ethanol), and most ended up instead with both pickled specimens and pickled scientists.

Back in the Botanical garden we packed up the cart with the plant press, nitrogen dewer, silica baggies and clip boards, and then rolled it through a set of glass doors into the next collection site, an entirely different environment. Only forty feet distant, but also a continent away—from the tropical island climate of

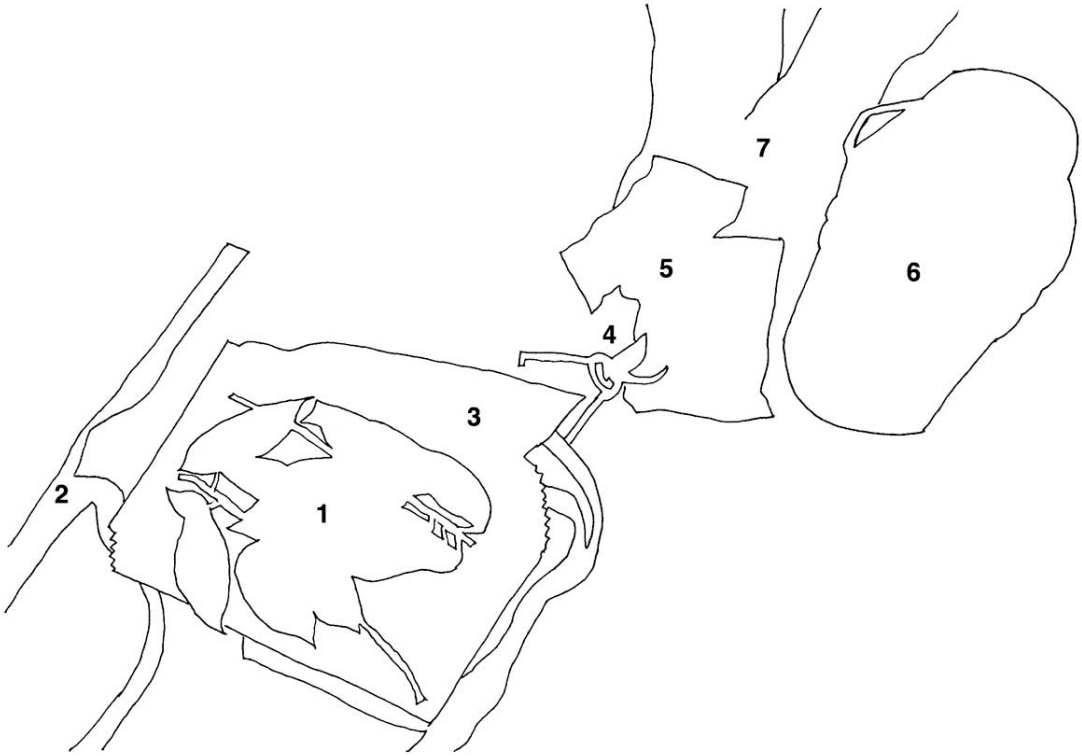


Figure 7-6. Anatomy of a Genomic Collecting setup, Botanical version: [1] Cocoa tree branch; [2] Vicki's bright orange straps; [3] Newsprint; [4] Shears; [5] Bags of silica, tissue tubes, foil squares; [7] Liquid nitrogen dewer; [8] Cocoa tree, site of the "genomic collecting event" (U.S. Botanic Garden, August 2015)

Figure 7-7. [1] Arranging specimens in the plant press;
[2] Stacks of specimens ready to go into press;
[3] Tightening the staps on the press, now ready for drying cabinet.
(U.S. Botanic Garden, August 2015)

Jamaica to the desert highlands of the American southwest and the aloe plant [Figure 7-8]. Vicki and her crew cut, sampled and pressed their way through the habitats of the Botanical Garden, collecting small purple wildflowers from the prairie garden to orchids from the detailed reconstruction of a Hawaiian volcanic cliff [Figure 7-9].

The reporters and photographers followed behind like a swarm of insects, buzzing with directions for what shots to get, requests to the botanists to repeat an action more slowly. The snippet of aloe was replaced and re-collected several times as different photographers cycled in to get the shot, trying to muscle me out of the way. I quickly learned to use my elbows to establish a territory for my shot or lose it. Finally both the plant press and the nitrogen tank began to reach capacity, and the collection data was noted and packed away. The reporters and their camera crews begin to drift away, intent on getting a last interview with one of the scientists they'd missed earlier or a final shot.

I help pack up and then drift away myself, finding Jon Coddington doing one final interview in the front of the building. As I get there the reporter asks him to repeat his last sentence. "Ok," says the reporter, and gives Jon a big double thumbs up. Jon smiles, nods and turns to me with a somewhat bemused look on his face. The performance over, we could get on with the work of collecting and preserving the genomic diversity of life on earth—not just putting it on display.

Consolidating Collections and Interests

This focus on the consolidation of tissue samples from across the museum and the GGI's "collecting from the collections" as I call it, takes us back to Parry's (2004) consideration of the politics of "micro-sourcing" as well as to debates concerning how limited or expansive the scope of genomic collecting for unforeseen future uses should, or could, be. Parry (2004), in her detailed observations of historical and contemporary museum collecting practices, describes collections as performing a "concentration, disciplining, circulation and regulation of assemblages of material" (2004: 15). As such, she explores the ways in which museum and herbaria specimens—both whole organism collections and cryogenically stored tissues samples—are decontextualized and accumulated through practices of ordering.

Figure 7-8. Collecting botanical specimens the traditional way – cut, arrange, press.
(U.S. Botanic Garden, August 2015)

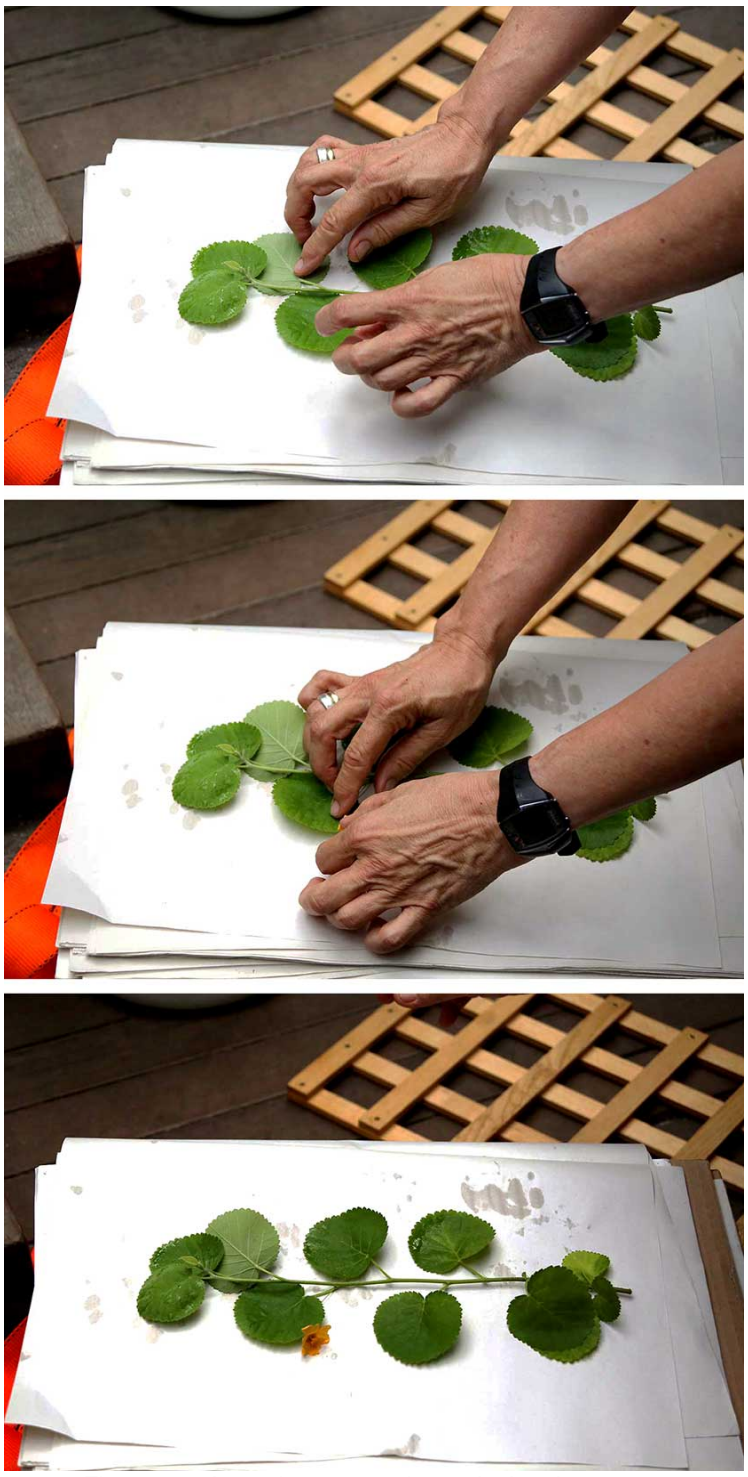


Figure 7-9. Arranging cut specimens in the plant press.
(U.S. Botanic Garden, August 2015)

Removed from the "wild" and subject to the labor of classification and the material transformation of preparation, specimens become, in a sense, "recombinant material" and their value is compounded in new forms (Graeber 2001). By applying the knowledge, technologies and expertise concentrated within the "centers of calculation" to the collected materials (Parry 2004: 32)., it becomes possible to produce entirely new materials or bodies of information, such as beetle bodies pulled apart to value their DNA in Chapter 5, or a (bird) body without organs as a site for inscribing natural order in Chapter 6. The GGI is deeply engaged in assembling and circulating specimens as "recombinant materials," and the body of the specimen becomes multiplied into multiple bodies —from "unbound biologies" (Helmreich 2009: 280), into bodies without organs (Deleuze and Guattari 1987), organs without bodies (Braidotti 1989) and also into a body of information—that is, data (Leonelli 2012b; Strasser 2012b). How each of these is valued in different contexts helps to clarify the connection between past and future in the National Museum of Natural History, as understood through its biomaterials and their transformations.

This episode also highlights one of the circulation paths of specimens, tissues and data that the Global Genome Initiative faced in the process of collecting and processing biomaterials as they circulated into the museum. Where previous scholarship portrays museum collections as distillations of the historical and contemporary politics of collecting (Parry 2004; Waterton et al. 2013), for the GGI, museums are ostensibly more neutralized spaces of conserving and understanding "natural order"—aware of, yet distinct from, the centuries of colonial labor and contemporary politics of access.[55] However, from my interviews and observations with the scientists at the National Museum of Natural History, the "natural order" of taxonomy remains a solid truth, with the Tree of Life as a set of data describing true relationships between species, not as one constructed view of the natural world. The debates center on how best to achieve a fuller, more detailed version of the "true Tree." As I discovered during ym fieldwork, mapping the Tree of Life and understanding the connection of all living things through comparing morphological and molecular understandings of species is the task at hand for most taxonomists. "Do these biologists realize that everything they're doing is a social construction?" one of the NMNH anthropologists asked me, "Linguists came up with the tree metaphor first for

[55] Museum anthropology in particular has been the subject of much scholarship examining its role in colonial projects of creating "natural orders" of social power and knowledge (Richards, 1993; Galison, 2003; Anderson, 2004; Karp, and Lavine, 1991).

mapping genealogies of languages—but we realize it's a metaphor . . . A subject of much debate, of course, but it's always about the human animal at its core, isn't it?" Or as another member of the Anthropology Department put it, "The museum is full of artifacts—*things people have made*—the biologists just don't realize it."

In looking to Parry's (2004) portrayal of museum collections as distillations of the historical and contemporary politics of collecting, I clearly see the layered social lives of the specimens I helped assemble and circulate specimens from lab to freezer to cabinet. In her analyses, Parry examines how museum collections are subject to extensions (and deletions) of these accumulated histories as they become subject to new uses—such as the micro-sourcing of herbaria by pharmaceutical bio-prospectors she examines in her work, in contrast with the "pure science" uses envisioned by the Smithsonian scientists I interviewed. However, once the data sets and sequence data are publicly available on the GGBN website, what are the implications for the Memoranda of Understanding? If data circulates out into the world, how responsible are the museum collectors for the uses it's put to? What is particularly interesting here are the positions of the different curators, collection managers, genetic project managers and museum administrators and their different senses of responsibility for the epistemic uses of the materials they organize and maintain. The curators, collection managers and technicians I have mentioned were sensitive to the fact that genetic sampling introduces a process of "recombining" (Parry 2004) as well as adding new value to specimens through its application to new and potentially unanticipated uses. In line with Parry's argument, the curators' concerns highlight GGI's different sense of responsibility for the collections—the GGI's responsibility of making them accessible for science, versus the Bird, Botany or Entomology curators' responsibility to their own histories of collecting, and the sensitivity of the data collected along with the specimens.

The complex biopolitics of contemporary collecting are a continuing negotiation for the GGI as it attempts to achieve its collecting goals, making many moves to create unproblematic access to biological material. These include much effort and invisible labor on the part of the project manager Katie Barker, as she circulates herself around the museum meeting with collection managers and data managers to keep the tissues, specimens and data flowing towards GGI, as well as negotiations by the project Director Jon Coddington at various meetings, workshops and conferences pitching the GGI's project, negotiating access and

proposing collaborations. As I was repeatedly told, both collections and collectors required a sensitivity not only to histories of collection and the meanings these establish now, but also to the implicit norms and purposes of curation and collection, themselves in flux given the particular new material-semiotic dimensions of natural history objects. In this context, museum collections are in essence being re-collected and re-valued by the Global Genome Initiative itself (Ellis 2008; Graeber 2001; Sunder Rajan and Leonelli 2013).

How to Build a Tree, Part II:

Making Herbarium Sheets—Pressing, Taping, Sewing, Labeling

May 2015. I'm walking through long corridors lined with collection cabinets. Shaped differently from the ones in Entomology or Birds I had come to know so well, some of these cabinets were taller and thinner. Shaped more like gym lockers, these cabinets held pages and pages of pressed plants, stacked on shelves by the bundle. Paper strips protruded from between the pages, organizing them into taxonomic clusters. Some cabinets were stacked counter height, the surface covered piles of specimen pages bound with red string, notes stuck into the bundle designating it as awaiting cataloging, as a loan from another herbarium, or in line for genetic sampling [Figure 7-10]. I turned a corner and found the rooms I was looking for, the offices of the collections manager Melinda Peters. A dozen young faces turned to greet me as I entered the room—summer interns here to learn how to mount an herbarium sheet. And I was here to join in.

An herbarium sheet, at its most basic, is a piece of paper with a flattened and dried plant cutting adhered to it along with identifying information [Figure 7-11]. Plants have been pressed, dried, mounted on pages and labeled with classifications going back to Aldrovandi's museum [Figure 7-12]. The Smithsonian's collections include pages made in the eighteenth century, many cured with mercury vapor to prevent insect damage [Figure 7-13]. If handled frequently, the mercury will damage researchers as much as dermestid beetles. These mercury-cured pages now have a silvery-charcoal patina to them and are handled very carefully. The prize specimens are sealed in archival plastic sleeves.

Figure 7-10. Biodiversity stacked up
(Department of Botany, Smithsonian NMNH, July 2015)

Figure 7-11. Example of sewn cocoa leaves, collected in 1989 in Peru (*Theobroma cacao subsp. sphaerocarpum*, USNM 3135216) (Department of Botany, Smithsonian NMNH, July 2015)

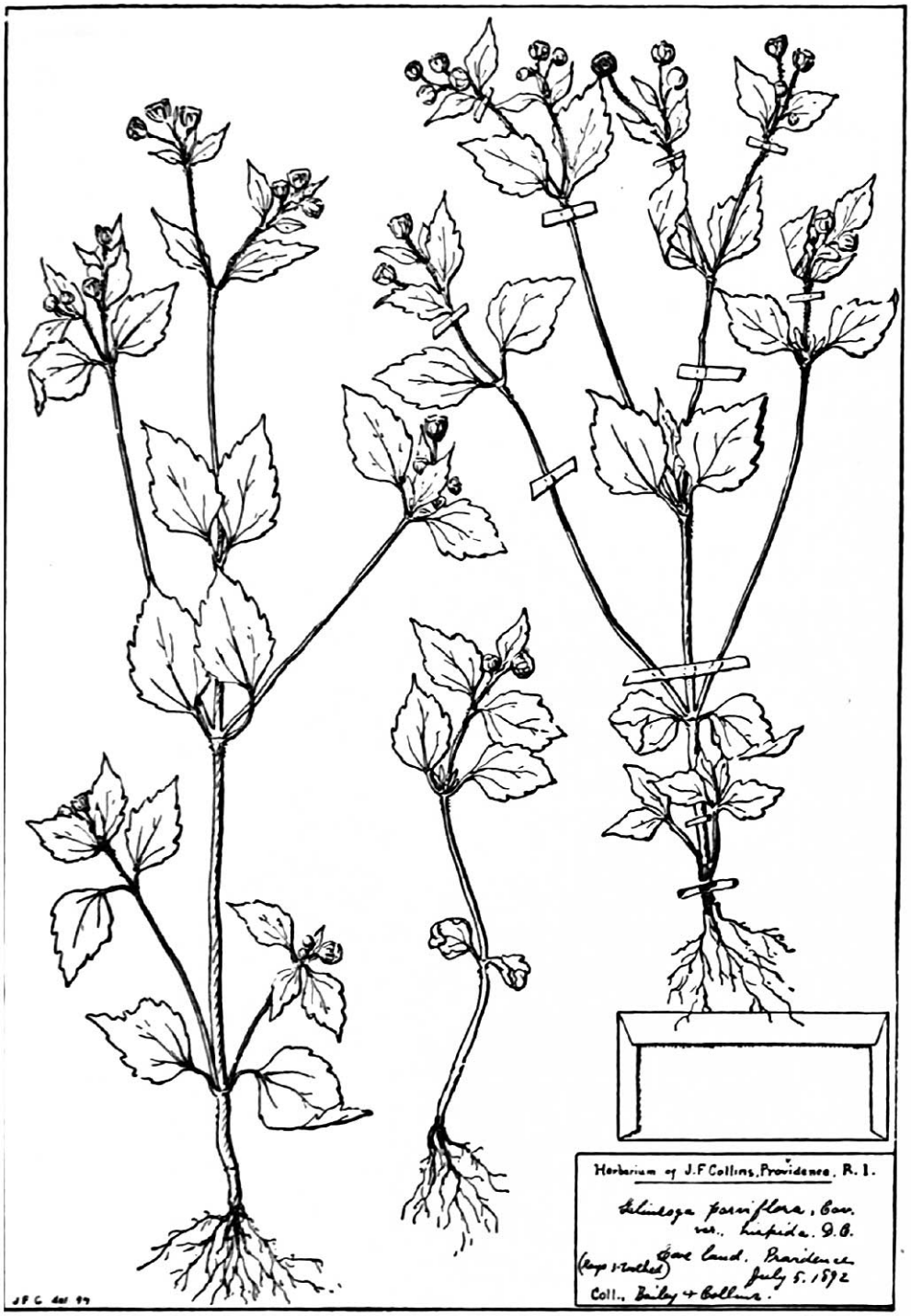


FIG. 15. — Mounted Plants.

Figure 7-12. Illustration of an herbarium page from 1899, a model for my own in 2015 . [William Baily, *Botanizing: A Guide to Field-Collecting and Herbarium Work* (1899)].

Figure 7-13. Historical herbarium pages, with the number “2” [top photo] denoting it as the second specimen ever created in the collection of the United States National Museum – now the National Museum of Natural History. (Department of Botany, Smithsonian NMNH, July 2015)

Various different techniques have been employed over the centuries to affix a plant to a page. Some plants with large seed-pods were “basket-sewn” to the page, employing elaborate crochet stitches to secure the various bulky parts [Figure 7-14]. Others were sewn through the leaves, while the vast majority were simply glued to the page. The glue method is not how the Smithsonian does it, preferring the reversibility of a needle and thread. Seaweed and algae are floated in a tray of formalin, relaxing and then “fixing” them into position much as a lizard or snake would be in Herpetology. The formalin-fixed seaweed is then “floated” onto a mounting sheet, dried and labeled. Today in the Botany collection manager’s rooms were are not doing anything quite so exotic. We will be learning to mount a simpler kind of botanical specimen, a branch or grass clipping mounted in proper Smithsonian style.

The group gathers around Melinda and watches her go through the process, demonstrating the steps: [1] Deciding how to arrange the specimen; [2] Taping and sewing the specimen to the page; [3] Gathering any broken pieces into a fragment envelope and affixing the labels. As she unfolded pages of dried specimens not yet mounted, we looked not only at the plants she held up, but also at the newspapers they were folded into. “When we’re working on the backlog of specimens, some dating way back, we do look at the newspapers,” she told us, “there are some really cool ones . . . we keep a few.” She dug in a cabinet and produced yellowed newspaper pages showing the latest fashions in 1960’s Brazil and from Guatemala in the 1970s.

Arranging. We disperse to the adjacent room, set up with two long worktables. Jars of brushes, bottles of bookbinding glue, sponges in glass dishes, boxes of small square brass weights and bundles of small paper are neatly arranged down the center of each table. At each workspace a blank herbarium sheet awaits us. We each find a spot and Melinda comes by, sliding a pressed specimen in its newspaper sleeve onto the table in front of each of us [Figure 7-15, Figure 16]. I peel back the top layer of newspaper (yellowed, in Spanish, dated June 18, 1992). My specimen, on first take, is your basic branch—twiggy, brown and flat with teardrop shaped leaves. I pick it up very gently, cradling its weight from below with my other hand.

Figure 7-14. An extradordinary example of “basket” stitch for a very dimensional specimen. So-called bulky specimens are now split into flat parts and more three-dimensional parts and stored separately for space reasons. (Department of Botany, Smithsonian NMNH, July 2015)

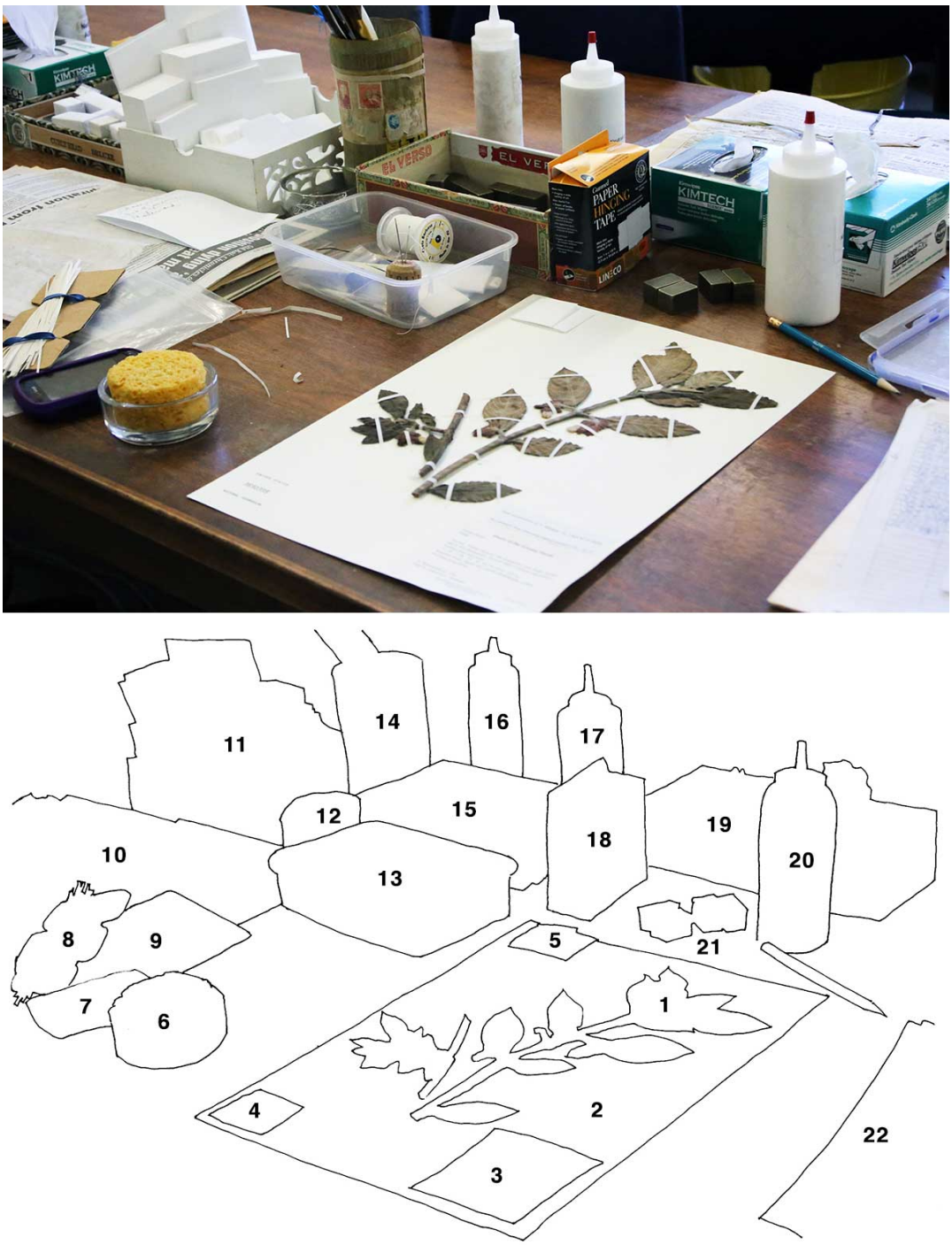


Figure 7-15. Anatomy of an Herbarium Page Mounting Workstation: [1] Plant specimen; [2] Page; [3] Label]; [4] USNM number; [5] Fragment packet]; [6] Sponge for tape; [7] iPhone; [8-9] Bundles of linen tape; [10] Specimens in newspaper ready to mount; [11] Fragment envelopes, unfolded; [12] Clips; [13] Botany prep kit; [14] Brushes; [15, 21] Brass weights to hold down specimen while sewing; [16, 17, 20] Archival glue for labels; [18] Large linen tape; [19] Tissues for wiping up glue. (Department of Botany, Smithsonian NMNH, July 2015)

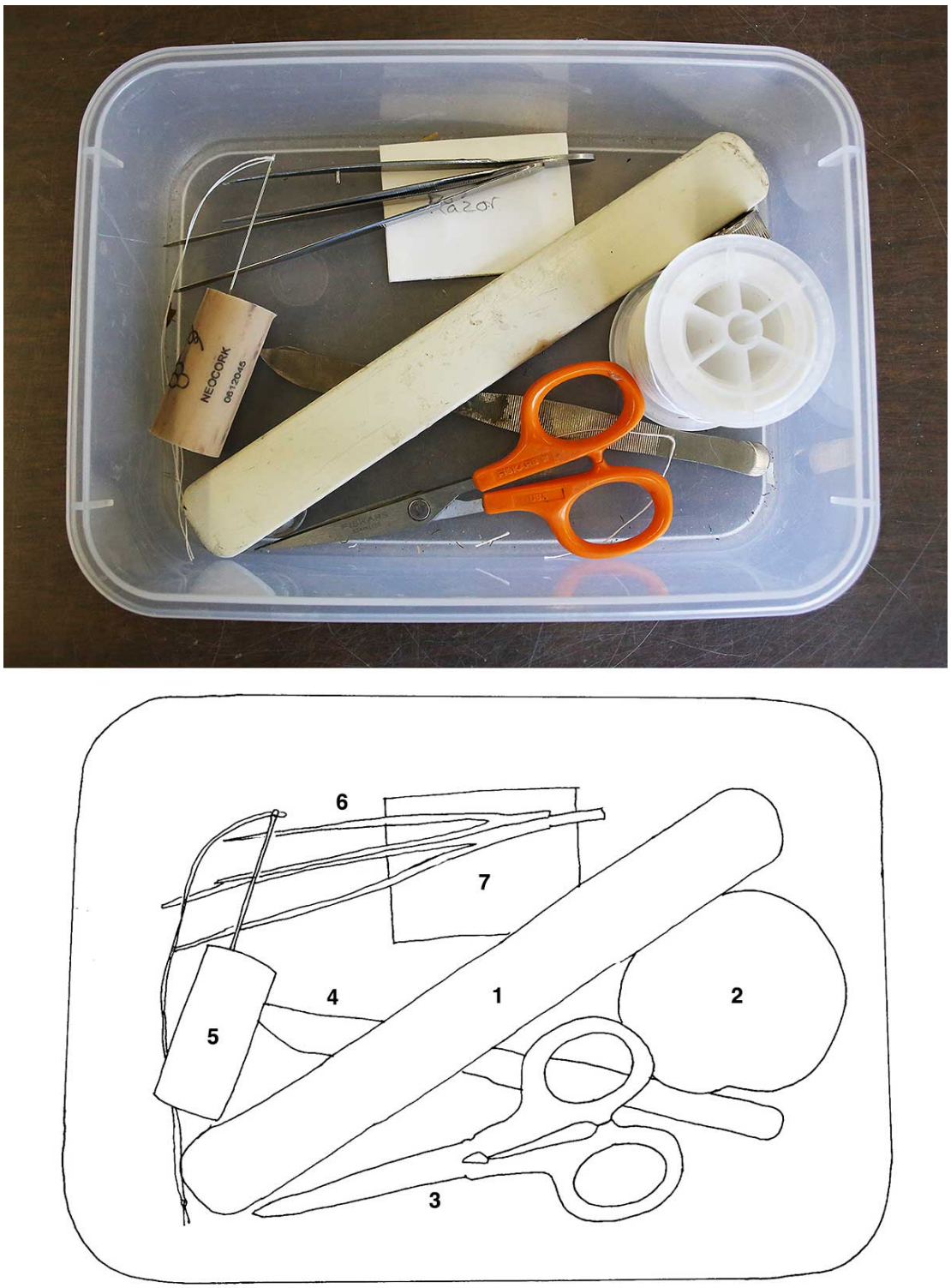


Figure 7-16. Anatomy of an Herbarium Page Prep Kit: [1] Bone folder ; [2] Cotton upholstery thread ; [3] Scissors ;[4] Scalpel ;[5] Needle, secured in a cork ;[6] Tweezers for fragments or arranging ;[7] Razor blade for very delicate cuts.
(Department of Botany, Smithsonian NMNH, July 2015)

The other volunteer plant mounters at my table look around, curious about what everyone has received. Murmurs and comments about who has the nicest specimen—who has flowers or seeds, a particularly pleasing curve in a branch, or preserved colors. My branch does not draw comments. As instructed, I looked for the leaves that had been turned around to display their veining when it had been put in the press. This is a key diagnostic feature for some specimens, I'm told, a characteristic used by botanists to identify different species, like beak shape and plumage for birds or the number of toes and teeth in herbivores.

I find the "front" of my branch and lay it on the blank sheet of paper in front of me. I continue to lay out my page as a "dry run," branch arranged so it fills the page while leaving room for the specimen label and the original collection label (if there was one) in the lower right corner, the fragment packet—a small paper envelope for broken bits—going in the upper right hand corner if it would fit or along the side if not. The page itself is printed with a number, one that is in a continuous sequence running back to the beginning of the Smithsonian, then through its iterations as the United States National Museum (USNM), and now as the National Museum of Natural History (NMNH). The chain of numbers remains unbroken. As specimens return from collecting expeditions they are sorted and put into the workflow, stacks of newspapers from around the world accumulating through time with precious leaves, branches or flowers tucked into their pages awaiting a numbered page.

All herbaria do this, I'm told by Meghann Toner, a museum specialist who had shown me through the Botany collections a few months earlier. "The collection is like a library," Meghann tells me, "a library of plants, all arranged and lined up like books on a shelf. But instead of books we have leaves, branches, stalks, rhizome clumps from bamboo (we had a curator who loved bamboo— we have a cabinet of bamboo tennis rackets and bamboo baskets) . . . giant nuts, tiny seeds, lichens and mosses on index cards and in envelopes, a cross section of a giant sequoia redwood tree, seaweeds mounted on pages but also in ethanol, and lots of other things are preserved in ethanol too — like roots and tubers . . . And we're adding new things all the time, especially with projects like the GGI [Global genome Initiative] funding collecting trips. Now we have specimens frozen in the Biorepository, as well as in freezers in curator's offices along with the silica samples. . . We just keep growing" [Figure 7-17, Figure 7-18].

Figure 7-17. Preserved tree branch pieces on an herbarium sheet.
(Department of Botany, Smithsonian NMNH, July 2015)

Figure 7-18. Sugarcane and rhizomes
(Department of Botany, Smithsonian NMNH, July 2015)

***Taping and Sewing*.** My page arranged but not fixed in place, I begin by taping down the thickest parts of the branch. The linen tape is coated on one side with an acid-free glue, as pH-neutral as possible. The tape arrived in big strips that Melinda painstakingly cut into quarter-inch strips. I put a few of the brass weights on my plant to keep it from moving as I cut off a two-inch length of linen tape. I run it along the damp sponge in the glass dish at my workstation and apply it to the paper, running it up and over the shaft of my branch. I follow the contour as closely as possible. I continue up the length of the central stalk of the branch, spacing out the linen tape straps equally. The goal, Melinda tells us, is to provide a solid even connection between specimen and page. "Nothing should flap around when the page gets picked up. That's how pieces get broken off." Specimens carefully taped to our pages, we gently raise them on edge to see if there's any movement.

Melinda circles past the tables, checking our progress. She is used to organizing and running groups of volunteers, many of whom stay on for years or even decades. They come in one day a week to tape, sew and label countless thousands of specimens. I met one woman who had been volunteering on and off since the 1960's, when she had first accompanied her husband to D.C. for his work. She was interested in volunteering at the museum, and soon found herself mounting herbarium sheets. "It was that or turning birds inside out," she told me. "I liked the plants better." She found it very satisfying, she told me, to do something useful and to spend time with the other volunteers, many of whom were also quilters. "Lots of us quilting ladies," she told me with an amused smile, "We're just sewing up plants instead of fabric."

My branch taped in place, I offer it up to Melinda for assessment. "That could use some stitches," she tells me, pointing to the thickest parts of the branch. "Just for re-enforcement, where it could potentially break off." I nod and thread a needle, running the stitch from the back of the page around the branch and back to the underside, tying it off with a secure knot. Taking another piece of linen tape, I wet it and plaster it over the knot of thread, locking it in place. "Most herbaria use glue [to mount specimens]," Melinda tells me, "but at the Smithsonian we use a process that's more stable and also more reversible. It takes more time but it's more archival. Plus who knows what's in a lot of those glues? How will it effect DNA samples, for instance? No one really knows. So we sew and tape . . . And

luckily we have a lot of very dedicated volunteers to help with that." My branch now firmly taped and sewn in place, I turn to the labels and fragments envelope.

***Labels and Fragments*.** The sheet of newspaper my branch arrived in now moves to the center of my workspace. A few broken bits and pieces are scattered on its surface. I lift my mounted page and gently shake it over the newspaper, dislodging a few straggling bits of leaf. Setting my mounted branch aside, I take a piece of paper from the bundle in the center of the table. It's shaped like a fat plus sign, with creases around the center rectangle. I fold the shape into an envelope, its flaps still standing open. Using a brush I apply a thin layer of glue to the back of the fragment envelope, careful to go all the way to the corners—"so it won't peel off or get caught on something" as Melinda had advised us during her demo—and stick the fragment envelope on the upper right hand corner, burnishing it down. I continue gluing, arranging the labels as I had during the dry run and sticking them in place on the lower right corner: the original label made during the collection event, and the label made in the Botany Dept. When the specimen arrives and is sorted. Some specimens have a mosaic of labels, tracing their "life histories" through collecting events and through different museums. These labels are points of re-evaluation and use on their paths accruing along their edges, marking them as they move between contexts. My own page may be used in the future for genetic samples, visually verifying species, or doing population or environmental studies. The methods I was using to make it would ensure it was used in particular ways, and preserved in others.

My herbarium sheet is almost complete. Making sure the flaps of the fragment envelope are still open, I lift the newspaper and funnel all the fragments into the envelope and fold it shut. "We've had fragment envelopes forever," Melinda tells me, "but only recently have we started using them for genetic sampling requests. We used to use them for the important pieces that broke off specimens—seed pods or flowers, diagnostic parts of the specimen that were important to keep . . .so we had a place to store the broken pieces already, and so we started to keep all the broken pieces [in the fragment envelope]. I mean, why not? We knew we were going to get destructive sampling requests anyway, so why not save everything, and be prepared for when we do?"

Specimens completed, the group of interns grab their cell phones and start taking pictures of each other and themselves with their completed herbarium pages.

Melinda smiles. “Our regular volunteers,” she says with a wry grin, “aren’t really into taking selfies with their herbarium pages.” From the GGI Garden’s process of collecting in the collections, to how the voucher specimens in Botany are made—I now turn to look more closely at the types of time in the museum, tree-thinking, and the Tree of Life.

How to Build a Tree, Part III:

Trees of Life and Types of Time in the Museum

October 2014. I’m walking through Botany, past long cabinets piled high with stacked herbarium pages, sorted into piles. I round a corner and come face to face with a huge slice from a sequoia redwood tree [Figure 7-19]. It is standing on end, strapped to a cart, with a small paper arrow marked “Independence 1776” taped to its front pointing to the thin line of a tree ring.

Trees have been entangled in representing time in various ways and forms, from the social life of trees (Rival 1998), to trees as symbols of genealogy (Deleuze and Guattari 1987; Ingold 2000), to the Tree of Life in both its historical forms (Darwin 1837; Haeckel 1866) [Figure 7-20, Figure 7-21] and more genomic ones (Seberg 2013) [Figure 7-22]. Trees construct different kinds of time in the museum, from providing a window into a-historical “wild nature,” such as trees in dioramas [Figure 7-23], to use as a timeline, marking human events onto the dendrological one in a palimpsest [Figure 7-24].[56]

Types of Time in the Museum

Types of time are integral to making museum assemblages—in crafting a bird study skin or editing a protein sequence, the lab techs and preparators are following their discipline’s histories of what to keep, what to cut out and what the remaining pieces will be used for. That is, what the remaining pieces—be they a bird study skin or a DNA extraction from its toe pad, a mounted herbarium page or a genetic sample taken from it—how they can “speak” for their species (Haraway 1997).

[56] See also Tim Ingold’s discussion of trees and rhizomes in *The Perception of the Environment: Essays on Dwelling, Life and Skill* (Ingold, 2000:134), combining work by Felix Deleuze and Alfred Kroeber.

Figure 7-19. Giant Sequoia specimen
(Department of Botany, Smithsonian NMNH, July 2015)

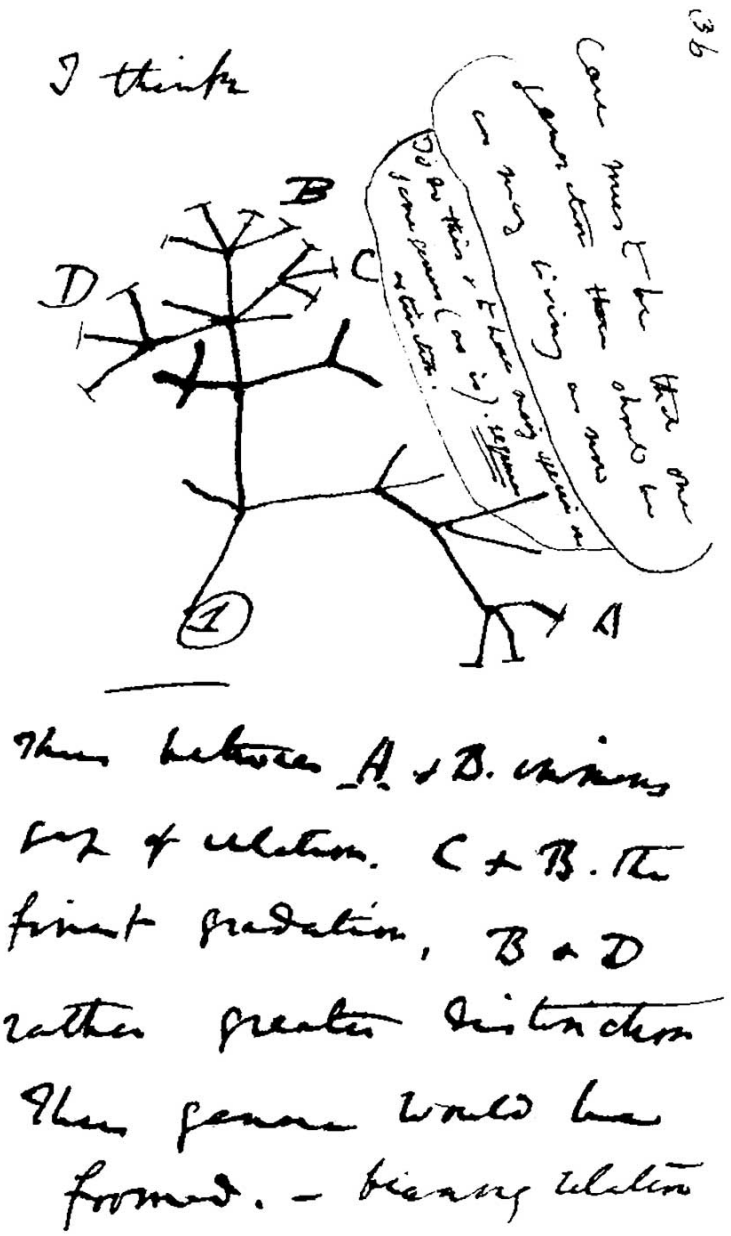


Figure 7-20. Charles Darwin's 1837 sketch, his first diagram of an evolutionary tree from his “First Notebook on Transmutation of Species” (1837)
The inscription reads: *"I think case must be that one generation should have as many living as now. To do this and to have as many species in same genus (as is) requires extinction . Thus between A + B the immense gap of relation. C + B the finest gradation. B+D rather greater distinction. Thus genera would be formed. Bearing relation"* (next page begins) *"to ancient types with several extinct forms"*

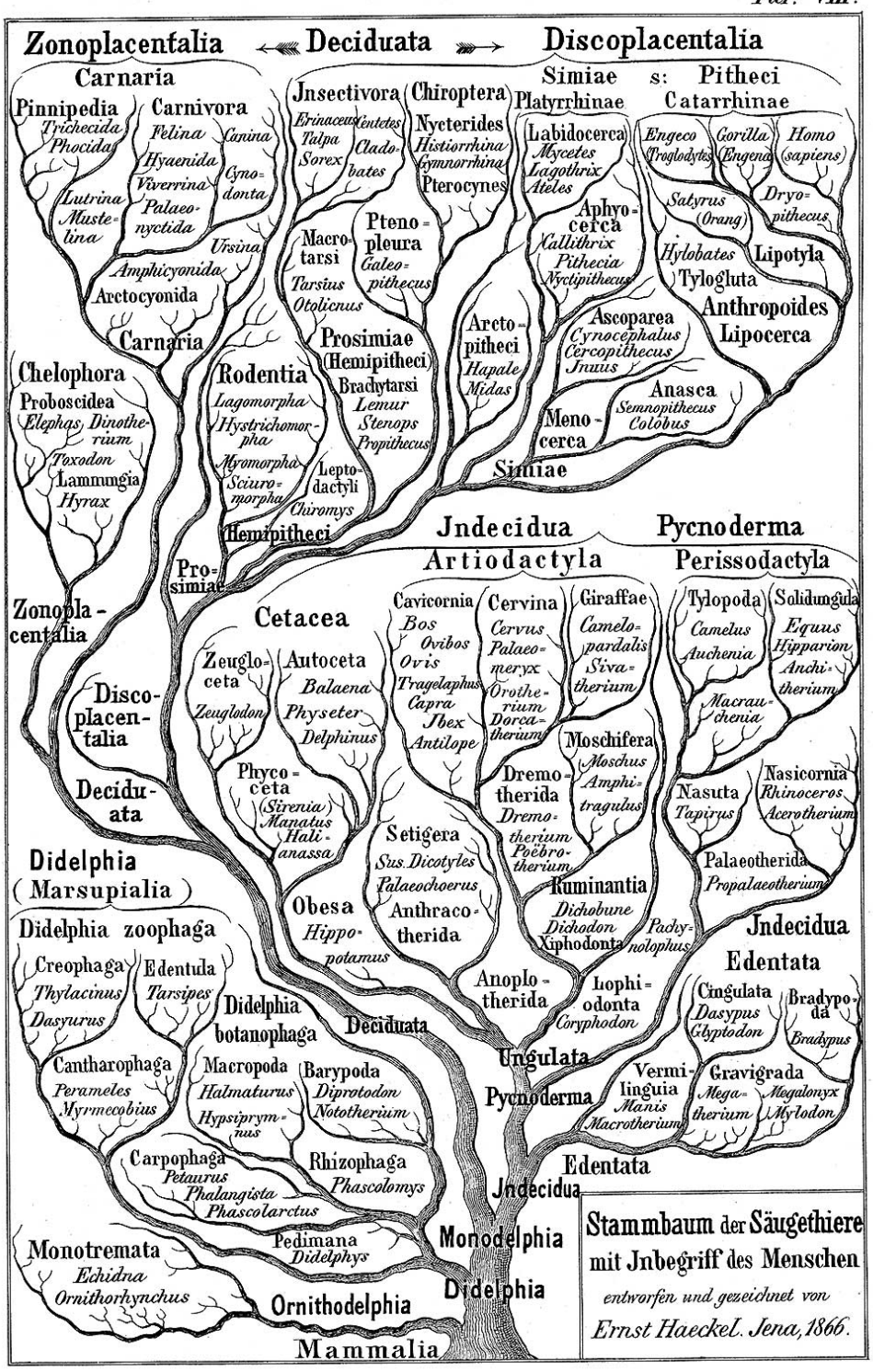


Figure 7-21. Ernst Haeckel's *Family Tree of the Mammals* (1866)

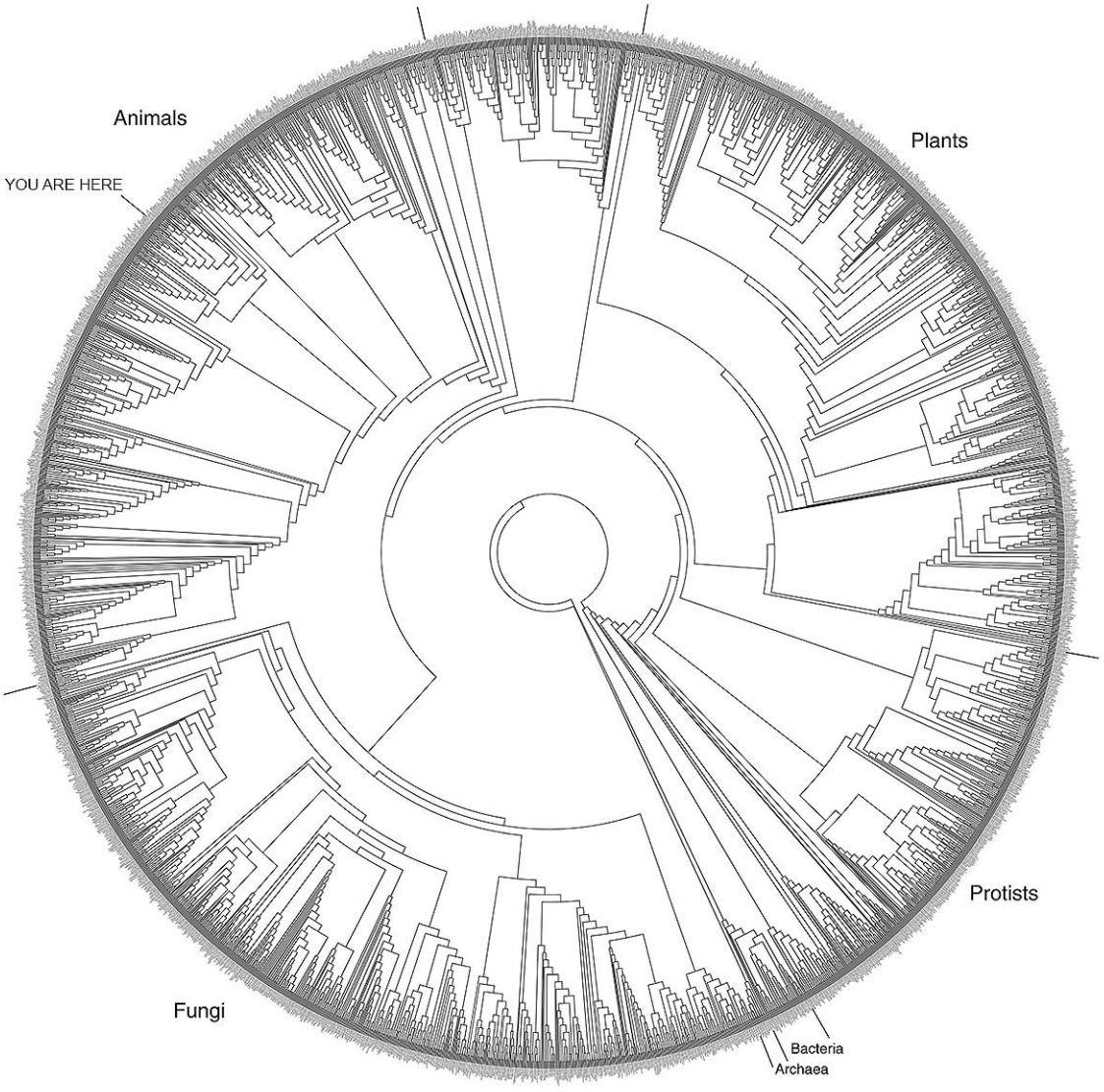


Figure 7-22. Genetic tree of life based on ribosomal RNA sequences,
sampled from about 3,000 species from throughout biodiversity.
Constructed by David Mark Hillis and colleagues, University of Texas at Austin (2014).

Figure 7-23. Preparing Olympic Forest Scene exhibit, Hall of North American Forests, American Museum of Natural History, 1952 (Photo No. 322587, AMNH Archives)

Figure 7-24. Tree as timeline – Giant sequoia in 1958 and 1978 at the American Museum of Natural History (Photos from AMNH Archives, left: No. 2A5964, right: No. 33700)

Biological matter is considered as the source for mutations and recombinations that create "newness" (Helmreich 2007). Drawing on Helmreich's insights to understand the selection of one form of classificatory value over another, I suggest that the pressure and desire to know nature in flattened phylogenetic form feeds into interpretations of genomic collections as condensed value, that is, as leaves on the tree. In Helmreich's terms, the assumption that nature is best knowable and most useful in this form, as variably valuable biologies (that is, as various "species of biocapital") has worked to naturalize the ordering potential of the genomic sample as an index to known life.[57] If. instead, the use-value of a more complex, phylogenetic reading of natural order prevailed, a quite different view of the classification power of genetics could become naturalized. According to the Smithsonian's Center for Conservation and Evolutionary Genetics, to know what there is is necessary in order to know what to save:

"Conservation strategies require knowing what taxonomic units (species, subspecies, or populations, for example) need to be preserved and how unique they are. How much gene flow is there between two geographically isolated populations? How unique are populations or species and which one's extinction would most affect genetic diversity? DNA analyses can be extremely useful for answering these types of questions. . . " (CCEG 2016)

This is the shrinking time of biodiversity loss, time that is collapsing in on itself as extinction rates increase. For projects such as the Global genome Initiative (GGI) GGI, the problem of the lack of time to collect and preserve biodiversity is solved with the frozen time of the Biorepository, where life can be made to stand still. There were many other types of time in the museum that I discerned during my fieldwork—though perhaps my desire to classify and order was influenced by context. Various taxonomies became legible to me, and I saw the ordering of nature and the ordering of time as linked in many ways. As Fabian points out, "there is no knowledge of the Other which is not also a temporal, historical, a political act" (Fabian 1983:1), and so my cataloguing of types of time in the museum requires that I also acknowledge the political nature of my own specific

[57] CCEG scientists have been involved in a large number of genomic studies, many with implications for biodiversity conservation, including systematic and phytogeographic analyses on a menagerie of biodiversity: Hawaiian honeycreepers, Indian wolves, California shrews, yellow-billed cuckoos, fox squirrels, American jays, Brazilian lion-tamarins, clapper rails, Caribbean raccoons, owlet-nightjars, African forest robins, Micronesian white-eyes, frigate birds, gray whales, ivory-billed woodpeckers, Asian elephants, South American deer, olingos, Mariana crows, fur seals, pitohuis, bowerbirds, quaggas, swamp sparrows, giant kangaroo rats, brown boobies, Hawaiian ohia trees, parrots, millerbirds, black-footed ferrets, quolls, Spheniscus penguins, mountain coatis, and common ravens. (CCEG 2016)

framings of time and history.[58] From this perspective, I lay out the multiple types of time I observe in the museum.

There is the deep time of phylogenetics and the Tree of Life, where we (human and non-human biodiversity) are all part of an evolutionary chain. There is the ahistorical time of museums, where things are kept “forever,” preserved and conserved by specialists and special techniques to arrest the decay of time. There is also the cyclical time of collecting cycles, as scientists and researchers ebb and flow in and out of the museums on collecting expeditions, following bird migrations, molting bison, or pollination timetables. From these there erupt the cycles of influx into the freezers and preparation labs of the museum, as the collected specimens migrate back to the museum for sorting, processing and preparation.

There are other phenomenologies of time, where the collectors map their own histories based on the collections they've made over years or decades. While looking through drawers of pinned butterflies with a collection manager in Lepidoptera (butterflies and moths), he plucked one up and peered at the label, telling me he could "recall the stream where I was when I caught this butterfly twenty years ago, the way the light was . . .who I was at the time . . . It's my history in these cabinets.” Timelines of different kinds run through the collections, each with a different conception of—and orientation to—their type of time. As one taxonomist said while giving a lecture on how to build phylogenetic trees, critiquing their rooted or unrooted structures, (quoting Ray Cummings), “Time is what keeps everything from happening at once.”

Trees of Life as Census, Map and Museum

The closer we get to know the creatures around us, the clearer is the understanding we obtain of the chain of nature, and its harmony and system, according to which all things appear to have been created. . . . Nature makes no jumps. [*Natura non facit saltus*] All taxa show relationships on all sides like the countries on a map of the world.
— Carolus Linnaeus, *Philosophia Botanica* (1751:27)

[58] Social development has also been represented as a tree, with societies falling into different genera and species, such that human social evolution can be considered as much a natural “fact” as evolution within the animal kingdom: “J.D.Y. Peel notes that Spencer visualized evolution, not as a *chain* of being, but as a *tree:* “That this image holds true for societies as well as organisms, and for between them as well as for social groupings within them, is clear from the opening to the final volume of the Sociology where [Spencer] says ‘social progress is not linear but divergent and redivergent’ and speaks of species and genera of societies.” (Peel, quoted in Fabian 1983:15)

It has been suggested that three technologies of power characterize the modern age: the census, the map and the museum (Anderson 1991). Although these technologies were in existence before the modern period, it was at that time that they changed and took on the versions that are now familiar. Anderson points out that this triad of signs of modernity—the census, the map and the museum—all of which are ostensibly objective technologies for observation and classification, also act as technologies for creating and maintaining value and power.

The Tree of Life, for example, can also be viewed as a map—one with time and natural order embedded in it. The Tree of Life is an example of human classification practices writ large to cover all known life, past and present, combining in their form a census of life, a map of its divergences, and the museum as an archive of specimens charting those divergences. In thinking about the he Global Genome Initiative's project and the archive of life in the Biorepository, this census of life moves into imagined futures as well.[59] Further, the GGI can also be seen as a combination of all three technologies—as a census of all life on earth, of its genomic mapping, and of its preservation in perpetuity at a global network of museums.

One approach to the role of classification has been to demonstrate that classificatory pursuits are inseparable from dominant political and economic trajectories (Bleichmar and Mancall 2011; Fara 2004; Foucault 1966; Grove 1995; Müller-Wille 2003; Spary 1996; N. Thomas 1991). These authors and others have all, in different ways, demonstrated the tendency for classificatory systems (which include maps, museums and Tress of Life) to embed political and economic visions. The function of classification systems are to select from the totality of the world those aspects that can serve to depict it through ordering, classifying, and constructing pictures of "reality" (Bowker and Star 1999; Lampland and Star 2009).

[59] For example, the Center for Conservation and Evolutionary Genetics at the Smithsonian voices the future promise of genetics for biodiversity conservation work: "DNA-based phylogenies (evolutionary trees for a group of individuals or species), are very powerful devices for learning how species evolve and adapt. A well-resolved phylogenetic tree based on DNA sequences can tell us a lot about evolution. It can tell us what species or groups of species are most closely related, how their adaptive traits evolved, how moved about the Earth, and, with fossil- or geology-based ages to calibrate part of a tree, how rapidly evolution occurred. CCEG scientists are especially interested in adaptive radiation—the process of speciation from a single ancestral species while evolving traits in response to environmental variables. Some key examples of this process include our work on Hawaiian birds and South American mammals" (CCEG 2016).

Maps are legitimating documents, and like museums and phylogenetic trees, they have the authority of the official, of the authenticated. Hierarchies of value are constructed, inclusions and exclusions made, the self and the “other” separated—by borders between countries, or between species. Like phylogenetic trees, maps and museums are not neutral, bearing little relationship to other systems of knowledge. Maps, museums and trees of life all bring the world into an apparent single, rational framework—one with unified, ordered, and assigned relationships between natures and cultures (Bowker and Star 1999).

Maps, like museums and phylogenetic trees, also construct relationships, propose hierarchies, define territories and present a view by choosing what to make visible and what to render invisible. From this perspective we can understand the “mapping” of the workflow diagram of specimens, tissues and data flowing circularly from field to freezer to museum to database, As well as “mapping” the traces of living things assembled from all over the world condensed in a freezer or an electrophoresis gel Or in a seventeenth century cabinet of curiosity, which combines materials from exotic locations to create a model of the universe in miniature, a map of the known world.

Conclusion: Folding Time in the Archive of Life

Museum collections are also, from another perspective, mappings of the world, its histories and its frictions as well as an archive of those encounters. In this chapter I have examined different “trees” in the museum and the types of time they represent. In looking at the folded time of “collecting from the collections” at the U.S. Botanical Garden, to the layered time of the Botany Department and its “library” of tree slices, pressed plants and rhizomes, to the deep time of the (genomic) Tree of Life—I have argued that *time* is a central organizing principle of thinking through crafting “nature” in the museum. This is nowhere more clear than in the hopes and anxieties for the future uses of molecular and morphological collections. In considering the “folding of time" in preparing specimens—from beetles, to birds, to botany—it is perhaps useful to consider not only the juxtaposition of specimen preparation methods from the nineteenth century and the current moment, but also a consideration of the "shallow and deep natural orders" (Ellis 2008:180) these practices represent and reify in crafting an archive of life.

Concepts of time within the archive can be unraveled. In our vernacular understanding of them, archives have usually been understood as storing present and past experiences and knowledge of the world for some use in the future. The archive, writes Derrida, ‘‘has always been a pledge, and like every pledge, a token of the future’’ (1996:18), and embedded within this is ‘‘the question of the future itself, the question of a response and of a responsibility for tomorrow’’ (1996:36). There is also the question of ‘‘memory,’’ what parts of the past should be preserved, how should experience of the world be ordered, classified, formed into a valid representation? These questions pertain to all kinds of archives.

Collections and databases, as specific kinds of archives, for example, have by their very nature been built on shifting concepts of what is valuable in the present moment, entrusting “things and meanings” (1996:36) to imagined futures where they will be interpretable and useful (Bowker 2000, 2005a; Griesemer and Shavit 2011; Leonelli 2012a; Leonelli and Ankeny 2012; Radin 2013). Crafting specimens and crafting natural orders have shifted emphases and approaches over time, with the portrayal of natural order(s) by taxonomists dependent on what properties and material qualities of organisms are considered indicative of order (Daston and Stolleis 2008; Farber 2000; Foucault 1966; Jardine et al. 1996; Kohler 1991, 2013). The central tenets of the Linnaean system remain relevant to contemporary taxonomic practice and practices of creating an archive of life, as taxonomists are still building an ever-better better, more “supported” Tree of Life. These are part of on-going taxonomic practices that seek to understand the relationships between organisms in terms of being able to trace them back to a (hypothetical) common ancestor (O’Leary et al. 2013:662) [Figure 7-25, Figure 7-26].

This orientation to a collective past was evident during my fieldwork and was also reflected in museum exhibits, a flow between the “front and back of house” at the museum. In the Hall of Mammals at the National Museum of Natural History, refurbished in 2003 into a bright modern interpretation of the diorama [Figure 7-27, Figure 7-28], there is what amounts to a temple to DNA ancestry. A small bronze figurine of our (hypothetical) common mammal ancestor sits on a low pedestal surrounded by panels inlaid with curving double-helixes and the silhouetted icons of all the taxidermy creatures in the Hall [Figure 7-29].

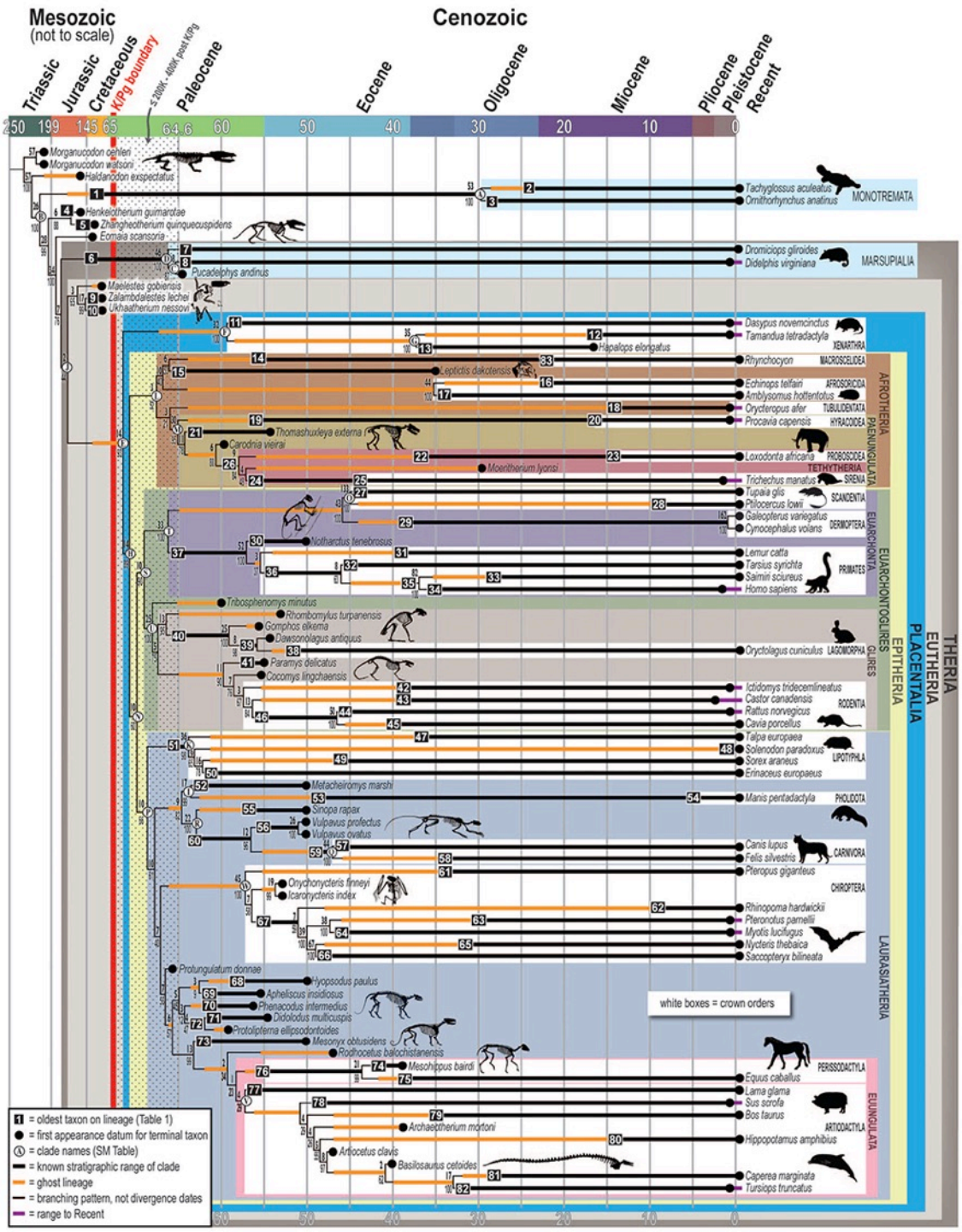


Figure 7-25. Phylogenetic tree mapping the emergence of a (hypothetical) common mammal ancestor (Source: *The Placental Mammal Ancestor and the Post–K-Pg Radiation of Placentals* (O'Leary et al. 2013:665)

Taxon		Oldest crown clade member (this study)		Oldest crown clade member—Age midpoint (range) and difference from our study			
Higher clades	Orders	Taxon	Clade age (range) (Ma)	Bininda-Emonds *et al.* (Ma)	Difference	Meredith *et al.* (Ma)	Difference
Glires Linnaeus 1758		*Mimotona wana*	63.4 (65.0–61.7)	–	–	79.5 (71.5–94.1)	**–14.5**
	Rodentia Bowditch 1821	*Sciuravus* sp.	56.8	85.3 ± 3.0	**–28.5**	69.0 (64.1–74.8)	**–12.2**
	Lagomorpha Brandt 1885	Leporidae [Rose *et al.* (*43*)]	53.0	66.8 ± 5.1	**–13.8**	50.2 (47.4–56.9)	2.8

*Fixed calibration point. †Age between 65.0 and 64.7 Ma, in the Cenozoic portion of Chron C29r, 230 to 420 ky above the K-Pg boundary (*1*, *2*).

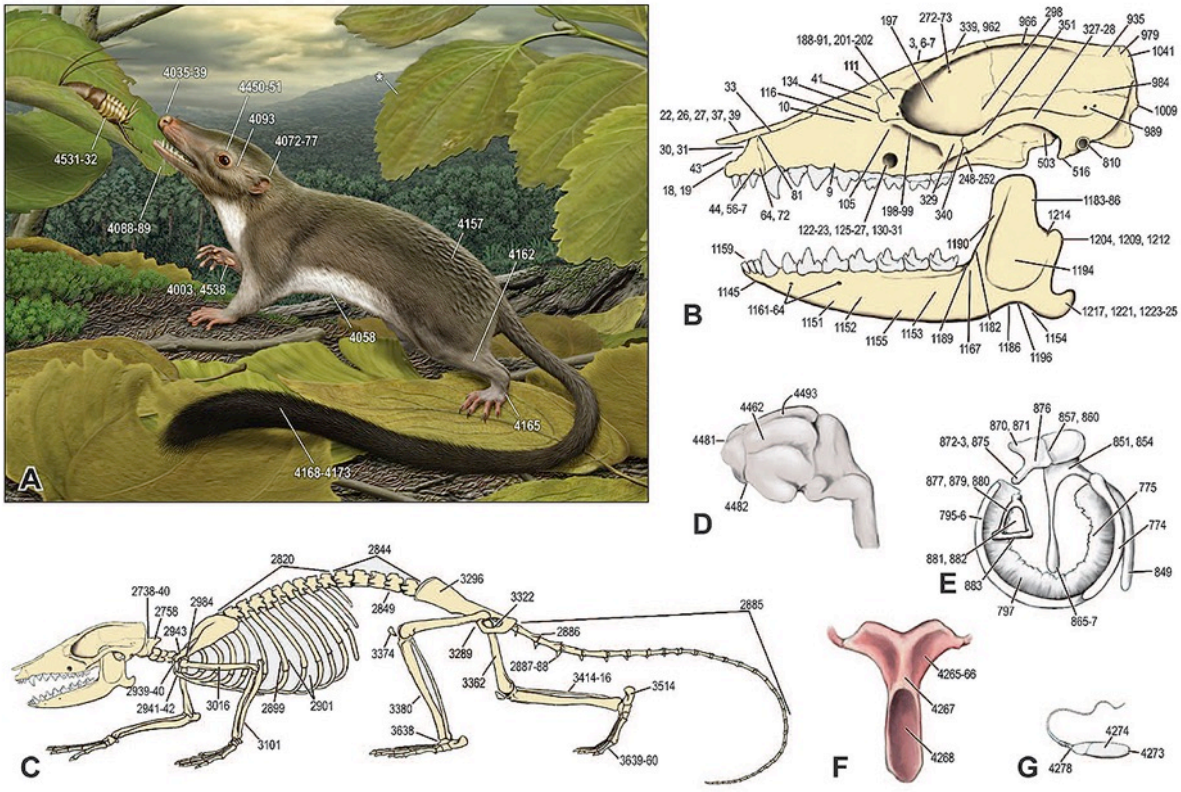


Figure 7-26. Reconstructions of the phenotype (the set of observable characteristics of an individual resulting from the interaction of its genotype with the environment) of the hypothetical mammalian ancestor, derived from the combined data in the tree in Figure 7-25. (Source: The Placental Mammal Ancestor and the Post–K-Pg Radiation of Placentals (O'Leary et al. 2013:663)

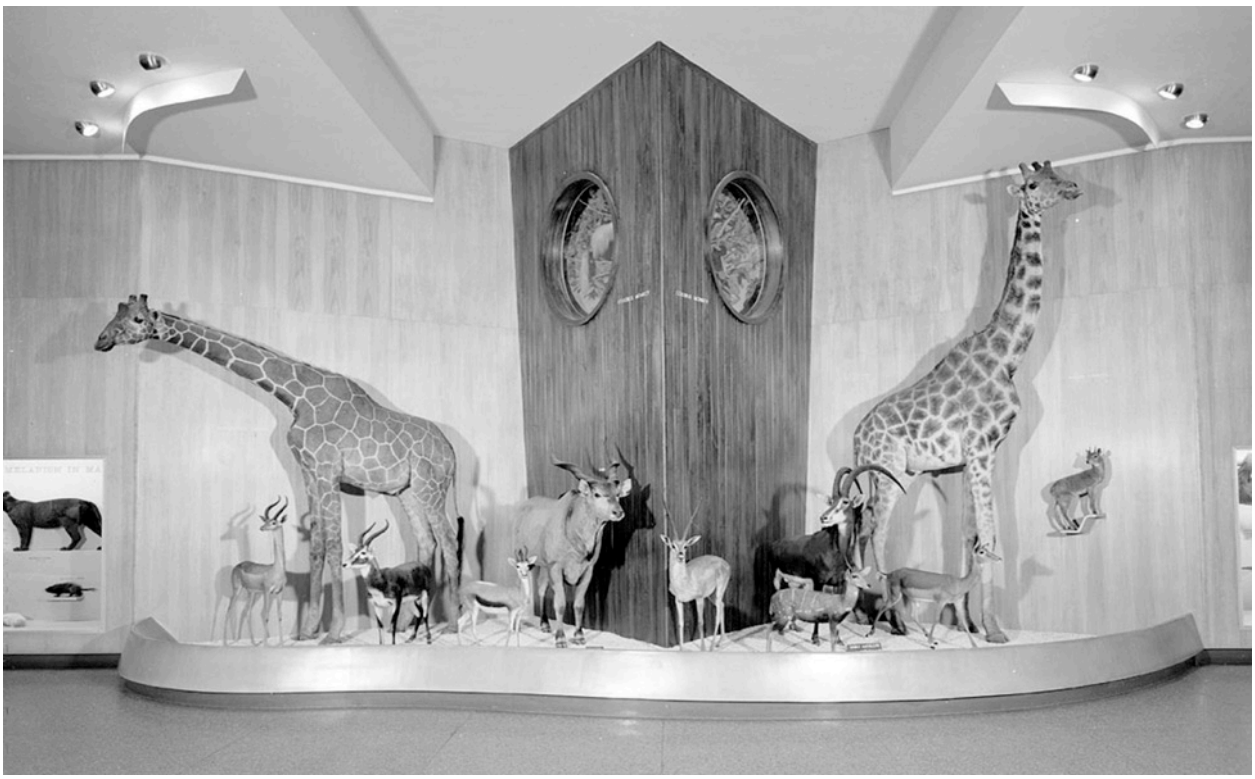


Figure 7-27. Hall of Mammals circa 1953 (photo: Smithsonian Institution Archives No. mnh423)

Figure 7-28. Hall of Mammals, circa 2003 (photo: Smithsonian Institution)

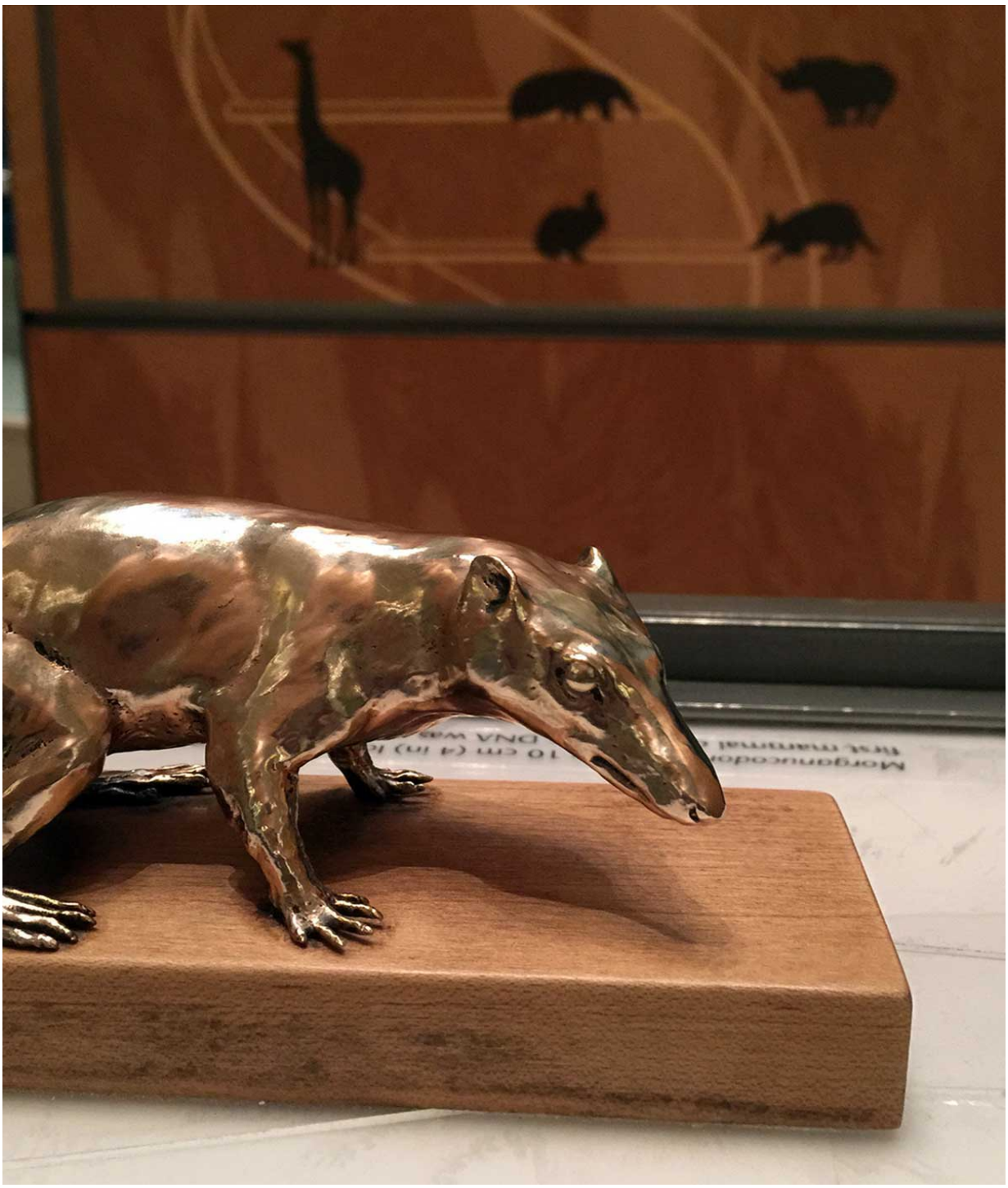


Figure 7-29. Our common mammal ancestor, hypothetical reconstruction
(Hall of Mammals, Smithsonian NMNH, August 2015)

Visitors hands have rubbed the top of figurine shiny, reminding me of the feet of bronze statues in churches where worshippers have touched them for centuries in blessing. What is being consecrated here, however, is the phylogenetic Tree of Life, with the branches wound together with molecular code that functions to offer both authenticity and authority in mapping life. “Emergent forms of life are both biological forms,” as Michael Fischer points out, “and social ones” (2007:566).

As technologies for making representations of the world, I have found it useful to think of collections as a form of archive for the future, as examples of the ‘‘mimetically capacious machines’’ that Taussig describes in *Mimesis and Alterity* (1993:xiv). Conventionally, archives use culture to create copies of nature, or ‘‘second nature’’ as Taussig would put it (1993:xiii). These copies, and the archive or database itself, can be seen as an important border between knowledge of self and knowledge of the “other,” maintained by a sense of alterity and long histories of classification. Yet, Taussig argues, this border is currently unstable; the border zone of representation is currently expanding, proliferating and blurring, becoming permeated by itself, occurring through new technologies that archive and perform the world in increasingly dense and boundary-crossing ways.

The archive, writes Derrida, is built “of memory and the memorial, of conservation and of inscription which put into reserve, ‘store’, accumulate, capitalise, stock a quasi-infinity of layers, of archival layers that are at once superimposed, over imprinted and enveloped in each other’’ (1996:22). “Mimetically capacious” technologies— from the digital camera I used in my fieldwork, to the 3D printer I used to replicate bird skulls, to the Smithsonian’s collections database spread across hundreds of servers— are creating new conditions of entanglement in which ‘‘boundaries of all kinds have become permeated by the supposed other’’ (Hayles 2005:242). This extends to biotechnologies as well, from the gigabytes of photo vouchers to the gigabases of genomic data that circulate in and through the digital spaces and places of global museum networks. As Hayles writes, ‘‘Code permeates language and is permeated by it; electronic text permeates print; computational processes permeate biological organisms; intelligent machines permeate flesh’’ (2005:242). The border itself has become ‘‘unreal . . . and elusive’’ (Taussig 1993:251), which constitutes an ‘‘unlimited upheaval’’ (Derrida 1996:18) in archival (bio)technology—orienting research into the past and thus the anticipation of the future.

The difference between a static—and named—natural order and a more temporally complex natural order is important for understanding the shifting classificatory value of biological specimens since the integration of genomic collecting practices. Museum genomics resonates strongly with the eighteenth-century focus on species collecting, naming and mapping introduced by Linnaeus. This has serious implications both for the kinds of natural orders that become selected as important and revealed through "museomics," and for the corresponding value of museum specimens as they are caught up in the entangled efforts to know, document, protect and use biodiversity through the promise of rendering species information accessible. How the data is crafted—or "articulated"—through the intersecting fields of the people, places, materials and interests involved is just as important as the crafting of the specimens and their tissue samples. In the final chapter, I turn to the afterlives of specimens, tissues and data—examining how these “afterlives” are instrumental in negotiating protection, conservation and care for their living kin.

Chapter 8
CONCLUSION

The Instrumentality of Afterlives

Human nature is a multispecies relationship.
— Anna Tsing (2006:32)

January 2015. I'm in the car with Jon Coddington. We are driving a dewer of liquid nitrogen from the Biorepository, located out at the Museum Support Center in Maryland, back to the Natural History building on the National Mall. Tomorrow the dewer will be used for the Smithsonian Institute on Biodiversity Genomics launch at the Castle, displayed with other biobanking paraphernalia (tissue tubes, temperature sensor) between the displays of bird skins on one side and bioinformatics on the other. It won't have any tissue tubes nestled inside of it, but a temperature sensor will display for curious on-lookers that it does indeed hold liquid nitrogen and have the potential to keep "life on ice." For now, Jon and I talk in the car as we drive along the snowy roads. He asks me about my project, and what I hope to actually *learn* from the research I'm doing in the museum. I tell him about my interest in how science is changing, the shifting ideas about what's worth preserving, and how the collections have been formed by the interests of the collectors themselves—what they chose to collect, what they find valuable changing over time. "But *human beings* don't shape the collections," he interjects, "*evolution* does."

Knowledge is produced and reproduced in these kinds of moments, when the authority to create a version of "natural order" slips seamlessly from the hands of the taxonomists into larger, abstracted evolutionary mechanisms. Where one stands—or is positioned in the museum, or on the Tree of Life—has consequences for how knowledge is gathered and deployed in the world. As several decades of feminist and postcolonial science studies scholarship have demonstrated, knowledge is situated in its production (Fujimura 1996; Harding 1991, 2008; Harding and Hintikka 2012; Haraway 1989, 1991, 2008, 2015; Merchant 1990, 2013; Rader 2004). In my ethnographic examination of crafting

nature I have chosen a view from below (Harding 2008), situating myself at the lab bench pipetting DNA and in the specimen prep labs bent over a microscope pulling beetle legs or stuffing bird skins. Throughout this dissertation, I have shown how these historically and culturally specific techniques of specimen preparation, both molecular and morphological, are bound up with anxieties and imagined futures in an epistemology of preservation. These ways of producing knowledge are rooted in a search for continuity with museological and taxonomic pasts and preservation of biodiversity for the future, to craft a nature that is "whole," or has the potential to be made so once again.

This dissertation has set out to show that the production of museum specimens—both morphological and molecular, study skin, pinned beetle, tissue tube, or pressed branch—can only be adequately understood by studying the different disciplinary "cultures" and their material practices in assembling and circulating specimens. I have followed the "life histories" of specimens as they function to negotiate different conceptions of "nature" and "natural order" in the laboratories, collections and meeting spaces of the Smithsonian National Museum of Natural History (NMNH). The ethnographic episodes, history and theory brought together in the different chapters of this dissertation have emphasized a disciplinary assemblage of objects, practices and discourses. Specimens can be seen as condensed assemblages of people, places, materials and interests—embodied in study skins such as Hsing-Hsing's [Figure 8-1], a companion for Ling-Ling that travelled with her from China in 1972 and then joined her again in a cabinet at the Smithsonian in 1992. The parts and pieces of specimens are re-evaluated as they move across domains, accumulating different values, reflecting different interests and ultimately serving as proxies for a species, a genus or a family. A specimen's distributed parts, such as genetic samples and data sets, create new regimes of value through their circulation. These different regimes of value illustrate the iterations of "nature" being created through specimen preparation craft and discourse, displaying the version of a "natural world" being created and collected, reflecting a specific and culturally-situated relationship of the human to the non-human world. In engaging the production of these regimes of value, I have examined the taking apart and the putting back together of (formerly) living things in an effort to archive life, one specimen tissue tube and genome at a time.

Figure 8-1. Hsing-Hsing (*Ailuropoda melanoleuca*, USNM 582622) together with Ling-Ling in a cabinet (Smithsonian Museum Support Center, Mammal Collections, November 2014)

It is through my hands-on experience with blood, fat and feathers in skinning a bird, in the smell of ethanol and moving delicate beetle limbs with tweezers, in the stickiness of agarose gel when running a DNA gel, or the slipperiness of threading needles to sew a leaf to an herbarium page—where I came to know specimens and their disarticulated biologies in a particular way [Figure 8-2, Figure 8-3, Figure 8-4]. It is through these encounters that I have come to understand some of the ways "nature" is currently being crafted in the Smithsonian NMNH.

I began with natural history collections as "rediscovered" data sources for genetic mining and the standardization of collecting methods for gathering genome-quality tissue samples for all families of life. These provided a frame to begin exploring what specimens were being used for, their "vital inherent value" in the contemporary moment, but also in imagined futures. Moving to the expanding global networks of tissue collections where the Smithsonian's "power to convene" is leveraged, led me to the histories of specimen-as-data in museums. I began to see how specimens exist in a long history of museum collecting, with much labor dedicated to maintaining interconnected threads of the analytical chain between voucher, tissues and data. Shifting scales from global networks, I moved down to the scale of an individual specimen and into the bodies of birds. The boundary crossings of birds and their parasites produce different types of "embodiments"—from bodies with organs (Deleuze and Guattari 1987) to organs without bodies (Braidotti 1989), with the discarded carcass of a bird becoming a field site for parasite harvesting. This is one form of the stickiness of practical encounter (Tsing 2005), which then led to another in the articulations of beetles, the value of their parts and the ways techniques are shared "sideways" down the lab bench. The world of beetles opened up a keyhole view through the microscope, an entire world suddenly visible full of fine hairs on insect legs, curved claws, shiny bead-like eyes, and the iridescent wings tucked beneath hard outer shells waiting to be unfurled with a delicate pull of the forceps. From this microscopic world that collapsed historic and genomic practices I turned to the different temporalities at work in museum time. Looking at how the leaves and twigs on the Tree of Life are being built and rebuilt with genomics, I tracked the types of time in different types of trees in the museum from phylogenomic Trees of Life to the frozen time of the Biorepository.

Figure 8-2. Study skin of an Arctic fulmar in a genomically re-ordered Tree of Life (*Fulmarus glacialis*, USNM 587960) (Castle Commons, Smithsonian Institution, January 2015)

Figure 8-3. Sandpiper and rabbits as bodies without organs, waiting to dry and be catalogued (Vertebrate Zoology Preparation Lab, Smithsonian NMNH, January 2015)

Figure 8-4. Articulated and disarticulated mammal specimens
(Smithsonian Museum Support Center, Mammal Collections, June 2015)

These narratives have accumulated to argue that the very terms of negotiations between different conceptions of "nature'" can be understood as the effect of historical and contemporary practices [Figure 8-5, Figure 8-6]—practices I engaged in the making and remaking of specimens as I pinned beetles, scanned cryovials, skinned birds, took tissue samples, pressed plants, and extracted DNA. [Figure 8-7, Figure 8-8, Figure 8-9]. In analyzing the assemblages within different traditions of knowledge production in the museum, I have attended to how arrangements of materials, words, practices and people have drawn out and made perceptible specific qualities, capacities, and possibilities for crafting specimens for genomic museum collecting.

As I have suggested, collections are *made to matter*—through their preservation, negotiated use and continuing re-evaluation. Made in what particular ways, so that they matter to specific users—my work to answer these questions has been at the center of this dissertation. I have explored the particular ways in which museum specimen collections are being re-valued as they are opened out beyond the walls of the museum, recast as sites for genetic mining and extended with genetic samples. As specimens' biologies are "unbound" (Helmreich 2009) into their differently valued parts and pieces, spread across the spaces of the museum—from cabinet to liquid nitrogen tank, from ethanol-filled tank to pinned in a drawer—it is important to remember that specimens remain sites of contested classificatory meanings. Moving across these contexts they continue to be objects of shifting value and (dis)embodiments of particular "natural orders."

I have suggested that these contested meanings are inseparable from the materials and forces (Deleuze and Guattari 1987) within museums, which shape the potential uses and perceived value of genomic information. Further, their status as objects with an ability to reveal a variety of possible "natural orders" will itself change over time—as underscored by assertions that scientific-epistemic objects are best characterized by their state of continual (re)emergence (Knorr-Cetina 1999; Rheinberger 1997). Information, knowledge, practice, materials, multiple human investments of meaning and the creation of "natural" objects, are relationally produced in a way that engages past, present and future hopes and expectations for salvaging biodiversity. "For an object to be socially powerful in a recognized manner," writes Chris Gosden, "the form of the object lays down certain rules of use which influence the sensory and emotional impacts of the object . . . The forms of objects, the historical trajectories of the class of objects

Figure 8-5. Fetal bison (*Bison bison*, USNM 240968) collected in 1886, and genetically sampled in 2013 to help assemble a bison genome that pre-dates the introgression of cattle genes (Mammal fluid collections, Smithsonian Museum Support Center, June 2015)

Figure 8-6. One pickled fetus (*Bison bison,* USNM 240968) among many in the collections (Mammal fluid collections, Smithsonian Museum Support Center, June 2015)

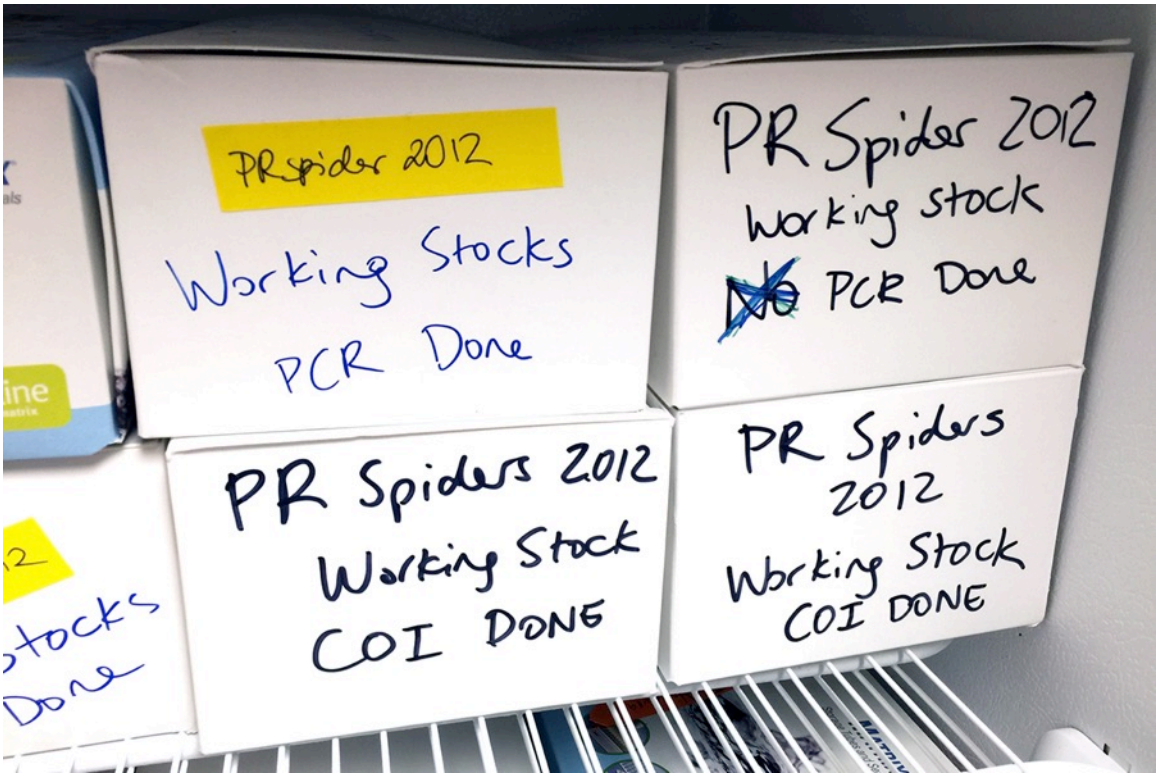


Figure 8-7. Biodiversity in a box (Biolab, Smithsonian Museum Support Center, June 2015)


Figure 8-8.Reptiles await new labels
(Reptile and Amphibian collection, Smithsonian Museum Support Center, June 2015)

Figure 8-9. Cryopreserved biodiversity (Biorepository, Smithsonian Museum Support Center, February 2015)

and their perceived sources combine to have social effects on people, *shaping people as socially effective entities*" (2005:193 emphasis added). From this perspective objects—through their specific material qualities, histories and perceived value—can shape people. Perhaps then, specimens can collect people, drawing them into specific social relations and shaping the possibilities of encounter. "Objects are not innocent," as Lucy Suchman reminds us, "but fraught with significance for the relations they materialize" (2005:279).

Objects (innocent or not) as well as persons can be seen as composed in relation to one another (Appadurai 1986). In living and moving through "social lives," objects can be traced along their particular paths, providing a chart to the layers that accrue within them of past, present and future encounters that each in turn shape their value. Much of the analysis in this dissertation hinges on charting the "life histories" of museum specimens, looking at them as "natural objects" with biographies, following scholarship that has charted the cultural biography of things (Kopytoff 1986), museums as relational entities (Bell 2012; Gosden and Marshall 1999; Moutu 2006), and the afterlives of animals moving through exhibits, collections and labs (Alberti 2011; Haraway 1985; Thorsen et al. 2013). One aspect of this approach is that it emphasizes recursive relationships between people and objects (Gell 1998; Gosden 2005; Gosden and Marshall 1999; Ingold 2010; Keane 2003; D. Miller 1997; Tilley et al. 2006).

Objects move between different cultural spaces and multiple regimes of value, creating a biography in their wake (Appadurai 1986). Through exploring museum objects in biographical terms, as mobile and transformative of a variety of relationships, I reiterate that there is multiplicity not only *between* but also *within* objects as they circulate in "tournaments of value" (Appadurai 1986:21). This multiplicity within objects is brought about through shifting (human, material, epistemic) relationships—such as a discarded bird carcass becoming a valuable site for collecting parasites, or a tissue tube becoming a proper (genetic) voucher specimen. Genomic collections in museums embody multiple kinds of significance, telling complex biographies which are both generative of—and witness to—vitally different possibilities for the orderings of "nature." It is these possibilities, located in the *material transformations* of the specimens, which are a vital component of the object's biographical structure. Within this dissertation I have created and followed scientific objects as they travel and are transformed by different processes, makers and users in their movement between different sites, communities of practice and epistemic expectations. In contrast to the

object biography, Joyce and Gillespie use the concept of "object itinerary" as an alternative mode for describing "things in motion," advocating for a "broader engagement with the mobility of things of all kinds." (Joyce and Gillespie 2015:3). They offer up *itinerary* as a more complex construct than *biography*, as it:

"traces the strings of places where objects come to rest or are active, the routes through which things circulate, and the means by which they are moved . . . Itineraries are spatial and temporal, and they converge with sites and routes singular, multiple, virtual, and real. They have no real beginning other than where we enter them and no end since things and their extensions continue to move. Itineraries may include stoppages, knots, or nodes . . . Our understanding of an itinerary may be fragmented, filled with gaps" (Joyce and Gillespie 2015:3)

Ascribing an object a biography is further critiqued as a form of anthropocentrism, as it "commits . . . to equating the lives of things to the lives of humans in ways that do not always realize the full potential to trace the conjunctions of things over time and space." (Joyce and Gillespie 2015:3–4). However, is a biography solely the domain of humans? Though I see great potential in the use of "object itineraries" to extend the conceptual use of object biographies, within the context of this dissertation I look very intentionally to the *afterlives* of the formerly living "objects." In attending to their biographies, both before and after death, I examine the ways their deaths are instrumentalized for environmental conservation and preservation–a narrative of sacrificing the few to save the many. This relationship between few-to-many situates the precious dead in the museum collections as subjects that speak *sotto voce* through their genomes, with those using the collections "looking through" the genomes to the future possibilities lying dormant within them:

"We look through objects because there are codes by which our interpretive attention makes them meaningful, because there is a discourse of objectivity that allows us to use them as facts . . . We begin to confront the thingness of objects when they stop working for us . . . when their flow within the circuits of production and distribution, consumption and exhibition, has been arrested, however momentarily. The story of objects asserting themselves as things, then, is the story of a changed relation to the human subject and thus the story of how the thing really names less an object than a particular subject-object relation." (B. Brown 2001:4, cited in Joyce and Gillespie 2015:3)

In thinking through what can be extracted from a specimen in the future, my research has led me to understand that limitations are crafted into the specimen during the preparation process along with specific capacities. These limitations and capacities are, as Brown suggests (2001:1), a particular set of subject-object relations that hinge on the methods and materials of preparation practices, in turn creating a collection's "vital inherent value" (Kress 2014:1310). What is valued is

preserved; how it is preserved determines its future use. The various decisions of keeping or discarding specific aspects of a living thing as it is transformed into a museum specimen are not stable, as clearly seen in what is considered most valuable in a specimen at different historic moments and by different collectors. A bird carcass is sometimes thrown away, or sometimes pickled in ethanol, or sometimes the entire bird is pickled – going the "way of the fishes." This creates what Haraway (1989) calls "'typified' nature," that is, making nature true to type even though the practices through which the types are made change over time. For Haraway the move in creating museum "nature" (specifically in taxidermy dioramas) is the creation of "the single story about nature's unity" (1989). The various practices bound up in naturalizing objects, such as crafting a specimen or a tissue tube, makes them "typical" as well as type specimens. Moreover, these practices articulate the ways and means of nature-making. These typifying practices become visible or legible in the smallest details of production and conservation—*how matter comes to matter* (Barad 2003) in the back rooms of the museum's prep labs, biolabs and the Biorepository. This proved to be true not only for the biological collections of the Smithsonian NMNH, I came to learn, but for their ethnographic collections as well—particularly in the way collections were entangled across disciplinary boundaries in unexpected ways.

In the Introduction to Friedrich Ratzel's *History of Mankind* (Tylor 1896), Edward Tylor describes the "object lessons" made possible through the study of artifacts brought back from ethnographic expeditions, as material for "looking before and after" (1896:iv). We are now at another point of "looking before and after"—towards our reconstructed pasts and towards our projected futures as conceived through genomics. The "object lessons" of genetic collecting within the museum—specifically the ways in which different conceptions of nature and its value orient conservation strategies—are central to shaping ecological futures we will all share. My research has focused on these emerging collecting practices in the lab and the museum, locating genomic collecting in a genealogical context historically within the museum—as well as anthropologically.

As my research progressed, another set of questions emerged around the role of anthropology within a natural history museum and the historical entanglements between collecting natures and collecting cultures (Alberti 2008; Bell et al. 2013; Goodman et al. 2003; Karp and Lavine 1991; Pearce 1994c, 1994b). As I explored the collections of the different non-human biological collections in the departments of Vertebrates (Birds, Mammals, Reptiles and Fishes), Botany,

Invertebrate Zoology and Entomology, I noticed a number of what I would consider ethnographic items tucked away in the zoological and botanical collections—a cowrie shell carved with the Lord's prayer in Invertebrate Zoology [Figure 8-10], cabinets full of bamboo tennis rackets in Botany, beetles decorated with rhinestones and gold chains as jewelry in Entomology [Figure 8-11]. Biological scientists collected these objects/artifacts/specimens on expeditions ranging from those at the beginning of the Smithsonian in the 1850's to some from recent years. Collectively these formed a question for me about the inherently tangled categories within the museum (Bowker and Star 1999; Daston 2004b).

In thinking through the mining of natural history collections and the different kinds of value being produced by such projects, I had conversations with social and biological scientists across the NMNH about the potential of the ethnographic collections as a source for new kinds of "data"—some of which might prove valuable to the biological scientists and to anthropologists looking "sideways" at their own collections. In such cross-disciplinary engagements cutting across the traditional boundries of nature/culture there is a possibility to "mine" and "extend" collections of both organisms and artifacts. Research collaborations between cultural anthropologists and biologists could examine human-ecosystem interactions through time from multiple, layered and intersecting perspectives—examining pairings of what have been categorized as discretely "natural" and "cultural" artifacts instead as complex "meshworks" (Ingold 2007:80–84) of people, places, (bio)materials and varied interests. Such ethnographic and biological collections pairings could include birds and featherwork, bison and hide artifacts, marine mammals and scrimshaw, grasses and textiles or beetles and insect jewelry.

The (bio)artifacts being produced and displayed in the research areas of the museum existed in different registers along a natural/cultural spectrum, valued for different purposes by different audiences. This circled me back to one of the main recurring themes of my research—the production of different meaning from the same materials, which provides insight into the naturalized assemblage of people, place, materials and interests collapsed in the objects of "specimens." These "unruly" specimens highlight the tenuous and constructed nature of those boundaries, as traced through their "biographies" and the relations they materialize in their various border-crossings.

Figure 8-10. Inscribed shell (Department of Invertebrate Zoology, Smithsonian NMNH, March 2015)

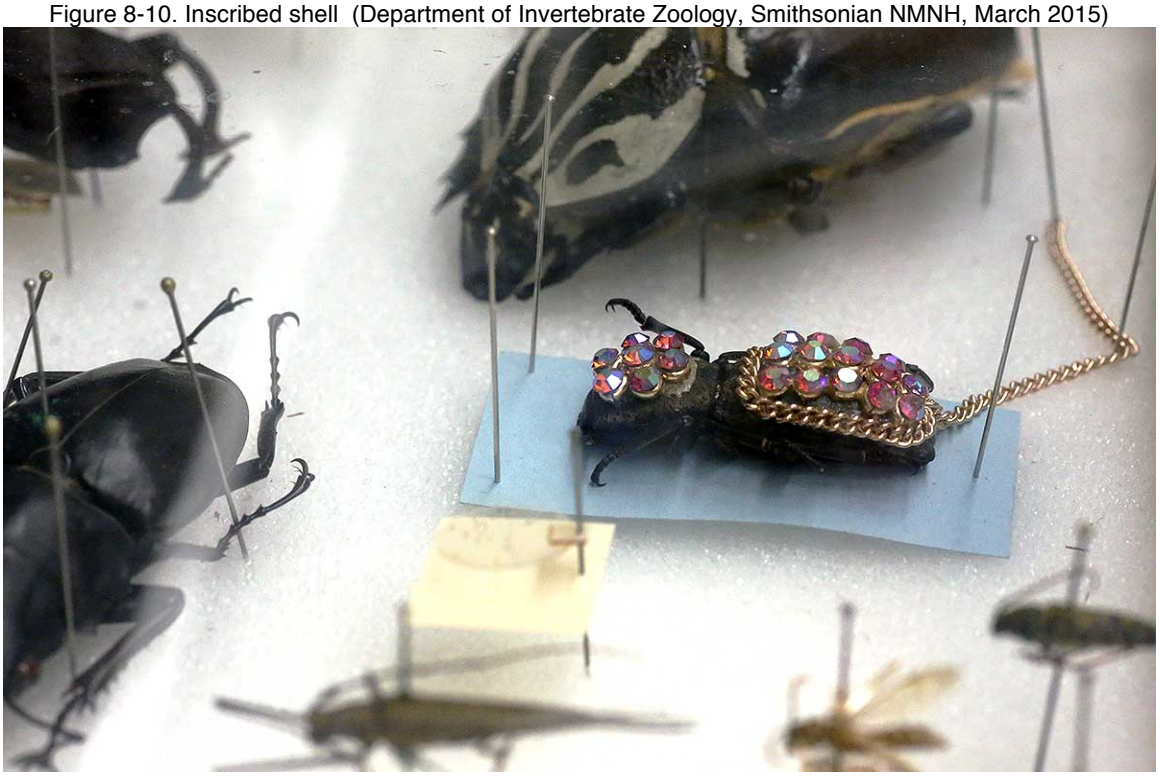


Figure 8-11. Mekech beetle pin (Department of Entomology, Smithsonian NMNH, July 2015)

In engaging the different practices of "crafting nature" in different contexts across the museum—tracing the social lives of voucher specimens, the life histories of tissue tubes, the standardization of protocols for capturing genomes—I have explored how the Global Genome Initiative's project collects and condenses biodiversity from every corner of the world into a network of liquid nitrogen tanks, databases and voucher specimens. This network of institutions, the Global Genome Biodiversity Network (GGBN), is also cross-linking networks of interests that have the Smithsonian NMNH at its center. However, I suggest these contemporary modes of assembling life are framed by an inheritance of centuries of collection practices—specifically the history of the museum as an apparatus for articulating knowledges, power and natures into an ordered whole. There are, however, various kinds of labor that go into naturalizing and maintaining these relationships.

I have suggested that things, in the context of museum genomics, are leaking in multiple ways and in multiple directions: "[T]hings leak, forever discharging through the surfaces that form temporarily around them . . . the thing has the character . . . of a knot whose constituent threads, far from being contained within it, trail beyond, only to become caught with other threads in other knots" (Ingold 2010:4). My selected ethnographic episodes and my analysis of them gather together these multiple threads—situated and embodied in the entanglement between things and people—that illustrate the ways (bio)materials are put together and taken apart, used to "fill the gaps" in the catalog of captured genomes. The collective effort in each Division and Department, on every collecting expedition, the care and maintenance of the curated specimens—all these gesture towards the types of time in the museum, from preservation for posterity to future research uses. "Museums," as Jon Coddington, Director of the Global Genome Initiative said repeatedly, "are in the forever business." As much as I saw the deep histories of collecting and preparing specimens reflected in the contemporary practices I observed and learned first-hand, there was also a sense of a horizonless *future* time. This produced a sense of continuity with the past, but also created certain tensions in how things were prepared, for unknown future uses in the face of unknown future crises.

With the increasing rate of extinctions (IUCN Red List 2015), the urgency and scope of biodiversity biobanking projects such as the Global Genome Initiative will correspondingly expand, facilitated by the increase in speed and accessibility of genomics technologies and the decrease in their cost. Biobanking is getting

cheaper, easier and faster, and will continue to be articulated as a solution for biodiversity loss among other global concerns. The initial emergence of museums as instruments for organizing the natural world and the relations in it between humans, animals, technologies, markets and knowledges has extended through to the contemporary museum and its genetic collecting practices. The museum as a sociocultural apparatus creates a natural order of things, naturalizing power relations, and then replicates these relations in its architecture, exhibitions, research platforms, collection strategies and conservation narratives. As I have argued, thinking through natural history collections—morphological and molecular—as transformed and reformatted *life* raises many questions as well as offering up opportunities for thinking through how, why and by whom life is archived.

In this research I have taken as my beginning point, as previous laboratory ethnographies and museum studies have demonstrated (Clarke and Fujimura 1992; Fujimura 1996; Haraway 1985, 1989, 1991, 1997, 2015; Hayden 2003b; Franklin 2007; Franklin and Lock 2003b; Rader 2004; Star 2014), that the production of knowledge is an inherently political act. From this standpoint I recognize that the museum collections are by definition imbued with interests, opportunities and continually emerging challenges. In analyzing these different modes of producing value through producing specimens, I seek to render visible the ways collections are made, valued and articulate the conditions of possibility for multispecies futures.

The term of "cryopolitics" has been offered as a concept to "express the various political, ethical and temporal conundrums presented by the practice of freezing" (Kowal and Radin 2015:63). In Emma Kowal and Joanna Radin's examination of frozen biological collections of indigenous populations, they frame cryopolitics as a mode of Michel Foucault's biopolitics: "If biopolitical assemblages make live and let die, cryopolitical ones reveal the dramatic consequences of mundane efforts to make live and *not let die*" (Kowal and Radin 2015:63, italics in original). Within Kowal and Radin's examination of the biopolitics of frozen samples, life seen as "latent life" cannot be destroyed; the liveliness inside the frozen tube has the ability to persist into the future as inherently viable. This resonates with my encounters with various specimens at NMNH that were either frozen, preserved whole or in part, abstracted and extracted as DNAs, or transformed into genomic data. The property of frozen biological samples to carry the cargo of "latent life" prompts Kowal and Radin to ask "what is the status of

tissues that were once living inside bodies, and can be made to live again" (2015:67). In this frame, the cryopreserved biodiversity of the Global Genome collections speaks to the potential for taxonomic research, ecological conservation and species preservation. Yet it also speaks to the future as a site that could, in some sense, be curated by the careful collection and preservation of dwindling biodiversity in the current moment. These potential futures for the "latent life" within the thousands of 2ml tubes stored in the vats of liquid nitrogen at the NMNH Biorepository (and in tanks of the Global Genome Biodiversity Network partner institutions the world over) are all oriented towards these imagined futures—and I suggest these "future imaginaries" in turn structure the underlying questions and material practices that shape contemporary genomic collecting.

Biodiversity biobanking at the Smithsonian National Museum of Natural History at present epitomizes and further promotes an encyclopedic representation of the natural world in pursuit of "preserving and understanding the genomic biodiversity of life on earth" (GGI 2016). It does so at the risk of relegating more historically and socially complex "natures" to the shadows of the scientific imaginary. Throughout this dissertation I have shown how *materials matter*, focused on the Global Genome Initiative and the Smithsonian NMNH's distinctive disciplinary "cultures," examining the on-going negotiations on what to collect, how it should be preserved and standardized, what threads of data should bind it together, and for what potential future uses. These practices draw upon but also reinterpret histories of collecting, archiving life and crafting "nature" as they each seek integration between multiple sites, multiple materials and multiple human and non-human participants. "Human nature," as Ann Tsing reminds us, "is a multispecies relationship" (2006: 32).

Bibliography

Abt, J. 2011. “The Origins of the Public Museum.” In *A Companion to Museum Studies*, edited by Sharon Macdonald. John Wiley and Sons.

Adamson, G. 2007. *Thinking Through Craft*. Oxford: Berg.

Agamben, G. 1998. *Homo Sacer: Sovereign Power and Bare Life*. Translated by Daniel Heller-Roazen. Stanford: Stanford University Press.

“Agilent Technologies.” 2016. http://www.genomics.agilent.com/.

Alberti, S. J. M. M. 2005. “Objects and the Museum.” *Isis* 96 (4): 559–71.

———. 2008. “Constructing Nature Behind Glass.” *Museum and Society* 6 (2): 73–97.

———. 2011. *The Afterlives of Animals: A Museum Menagerie*. Richmond: University of Virginia Press.

Alberti, S. J. M. M., J. Atkinson, S. Chaplin, V. Elizabeth, M. Cain, V. E. Moffit, E. E. Ferry, et al. 2014. “Building the Museum: Knowledge, Conflict, and the Power of Place.” *Museum and Society* 6 (2): 586–601.

Anderson, B. 1991. *Imagined Communities: Reflections on the Origins and Spread of Nationalism*. London: Verso.

Appadurai, A. 1986. “Commodities and the Politics of Value.” In *The Social Life of Things*, 3–63. Cambridge: Cambridge University Press.

Arnoldi, M. 1999. “From the Diorama to the Dialogic: A Century of Exhibiting Africa at the Smithsonian’s Museum of Natural History (Du Diorama Au Dialogue: Un Siècle D’exposition Sur l’Afrique Au Smithsonian Museum of National History).” *Cahiers d’Études Africaines* 39 (155/156): 701–26.

Astrin, J. J., Xin Zhou, and B. Misof. 2013. “The Importance of Biobanking in Molecular Taxonomy, with Proposed Definitions for Vouchers in a Molecular Context.” *ZooKeys*, no. 365: 67–70.

“Avian Phylogenomics Project.” 2016. http://avian.genomics.cn/en/.

Avise, J. C. 1994. *Molecular Markers, Natural History and Evolution*. New York: Chapman and Hall.

Bachelard, G. 1964. *The Poetics of Space*. New York: The Orion Press Inc.

Baird, S. F. 1856. “Directions for Collecting, Preserving, and Transporting Specimens of Natural History.” Annual Report of the Smithsonian Institution. Washington D.C.: Smithsonian Institution.

Baird, S. F., and W. H. Emory. 1857. *Report on the United States and Mexican Boundary Survey*. Smithsonian Institution.

Baker, A. 2005. *Barcoding Life Takes Flight: All Birds Barcoding Initiative (ABBI) Report of Inaugural Workshop*. Cambridge: Museum of Comparative Zoology, Harvard University.

Baker, R.J. 1998. “Bioinformatics, Museums and Society: Integrating Biological Data for Knowledge-Based Decisions.” *Occasional Papers, Museum of Texas Tech University* 187: 1–4.

Bamford, S. 2007. *Biology Unmoored: Melanesian Reflections on Life and Biotechnology*. Berkeley: University of California Press.

Barad, K. 1996. “Meeting the Universe Halfway: Realism and Social Constructivism without Contradiction.” In *Feminism, Science, and the Philosophy of Science*, edited by Lynn Hankinson Nelson and Jack Nelson, 161–94. Synthese Library 256. Springer Netherlands.

———. 2003. “Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter.” *Signs: Journal of Women in Culture and Society* 28 (3): 801–31.

Barcode of Life. 2016. “What Is DNA Barcoding? Barcode of Life (BOL).” http://www.barcodeoflife.org/content/about/what-dna-barcoding.

Barley, S. R., and B. A. Bechky. 1994. “In the Backrooms of Science The Work of Technicians in Science Labs.” *Work and Occupations* 21 (1): 85–126.

Barrow, M. V., Jr. 2009. *Nature's Ghosts: Confronting Extinction from the Age of Jefferson to the Age of Ecology*. Chicago: University of Chicago Press.
Baudrillard, J. 1994. *Simulacra and Simulation*. Ann Arbor, MI: University of Michigan Press.
Baum, D. A. 2005. "Evolution: The Tree-Thinking Challenge." *Science* 310 (5750): 979–80.
Bell, J.A. 2009. "For Scientific Purposes a Stand Camera Is Essential: Salvaging Photographic Histories in Papua." In *Photography, Anthropology and History: Expanding the Frame*, edited by Chris Morton and Elizabeth Edwards, 143–70. Surrey: Ashgate.
———. 2010. "Out of the Mouth of Crocodiles: Eliciting Histories in Photographs and String-Figures." *History and Anthropology* 21 (4): 351–73.
———. 2012. "Museums as Relational Entities: The Politics and Poetics of Heritage." *Reviews in Anthropology*, no. 41: 70–92.
———. 2013. "The Sorcery of Sugar: Intersecting Agencies within Collections Made by the 1928 USDA Sugarcane Expedition to New Guinea,." In *Reassembling the Collection: Indigenous Agency and Ethnographic Collections*, edited by R. Harrison, A. Clark, and S. Byrne, 117–42. Santa Fe: School of Advanced Research.
Bell, J.A., A.K. Brown, and R.J. Gordon, eds. 2013. *Recreating First Contact: Expeditions, Anthropology, and Popular Culture*. Washington, D.C.: Smithsonian Institution Scholarly Press.
Benjamin, W. 1968. *Illuminations: Essays and Reflections*. Translated by Hannah Arendt. Translated. New York: Schocken.
———. 1979. "A Short History of Photography." In *One Way Street and Other Writings*. London: Verso.
Bennett, T. 1995. *The Birth of the Museum: History, Theory, Politics*. London: Routledge.
———. 2005. "Civic Laboratories: Museums, Cultural Objecthood and the Governance of the Social." *Cultural Studies* 19 (5): 521–47.
Bennett, T., and P. Joyce. 2010. *Material Powers : Cultural Studies, History and the Material Turn*. London : New York: Routledge.
Biagioli, M., P. Jaszi, and M. Woodmansee. 2011. *Making and Unmaking Intellectual Property: Creative Production in Legal and Cultural Perspective*. Chicago: University of Chicago Press.
Bi, K., T. Linderoth, D. Vanderpool, J.M. Good, R. Nielsen, and C. Moritz. 2013. "Unlocking the Vault: Next-Generation Museum Population Genomics." *Molecular Ecology* 22 (24).
Biodiversity Information Standards. 2015. "Biodiversity Information Standards (BIS)." http://rs.tdwg.org/dwc/.
Bios Technika. 2014. "Bios Technika." http://www.bios-technika.net/.
Birke, Lynda. 1994. *Feminism, Animals and Science: The Naming of the Shrew*. Buckingbam and Philadelphia: Open University Press.
———. 1999. *Feminism and the Biological Body*. Edinburgh: Edinburgh University Press.
Bishop, R., and S. Cubitt. 2013. "Camera as Object and Process: An Interview with Victor Burgin." *Theory, Culture and Society* 30 (7-8): 199–219.
Bleichmar, D., and P.C. Mancall. 2011. *Collecting Across Cultures: Material Exchanges in the Early Modern Atlantic World*. Philadelphia: University of Pennsylvania Press.
BOLD. 2015. "Biodiversity of Life Database, Systems v3." http://www.boldsystems.org/.
Bourdieu, P. 1977. *Outline of a Theory of Practice*. Edited by Jack Goody. Cambridge Studies in Social Anthropology. Cambridge: Cambridge University Press.
Bowker, G. 2000. "Biodiversity Datadiversity." *Social Studies of Science* 30 (5): 643–83.
———. 2005a. *Memory Practices in the Sciences*. Cambridge: MIT University Press.
———. 2005b. "Time, Money and Biodiversity." In *Global Assemblages: Technology, Politics, and Ethics as Anthropological Problems*, edited by Aihwa Ong and Stephen Collier, 107–23. Oxford: Blackwell.
Bowker, G., and S.L. Star. 1999. *Sorting Things Out: Classification and Its Consequences*. Cambridge: MIT University Press.

Braidotti, R. 1989. “Organs Without Bodies.” *Differences* 1: 147–61.
Brand, S. 2009. *Whole Earth Discipline: An Ecopragmatist Manifesto*. New York: Viking Press.
Brown, B. 2001. “Thing Theory.” *Critical Inquiry* 28 (1): 1–22.
Brown, T. 1853. *The Taxidermist’s Manual, Or, The Art of Collecting, Preparing, and Preserving Objects of Natural History : Designed for the Use of Travellers, Conservators of Museums, and Private Collections / by Captain Thomas Brown*. 11th ed. Dublin: A. Fullarton and Co. http://www.biodiversitylibrary.org/bibliography/42325.
Burgin, V., ed. 1982. *Thinking Photography*. London: Macmillan.
———. 1986. *Between*. Oxford and London: Basil Blackwell and ICA.
Canguilhem, G. 2008. *Knowledge of Life*. Edited by Paola Marrati and Todd Meyers. New York: Fordham University Press.
Cardinale, B. J., J.E. Duffy, A. Gonzalez, D.U. Hooper, C. Perrings, P. Venail, A. Narwani, et al. 2012. “Biodiversity Loss and Its Impact on Humanity.” *Nature* 486 (7401): 59–67.
Casas-Marce, M., E. Revilla, and J.A. Godoy. 2010. “Searching for DNA in Museum Specimens: A Comparison of Sources in a Mammal Species.” *Molecular Ecology Resources* 10 (3): 502–998.
Castellani, C. 1970. *“Ulisse Aldrovandi”. Dictionary of Scientific Biography*. New York: Charles Scribner’s Sons.
CCEG. 2016. “Center for Conservation and Evolutionary Genetics, National Zoological Park, Smithsonian Institution.” http://nationalzoo.si.edu/SCBI/CCEG/systematics.cfm.
Church, G.M., and E. Regis. 2012. *Regenesis: How Synthetic Biology Will Reinvent Nature and Ourselves*. New York: Basic Books.
Clark, A. 2011. *Design Anthropology: Object Culture in the 21st Century*. Vienna: New York: Springer.
Clarke, A., and J. Fujimura. 1992. *The Right Tools for the Job: At Work in Twentieth-Century Life Sciences*. Princeton: Princeton University Press.
Clifford, J. 1986. “Partial Truths.” In *Writing Culture: The Poetics and Politics of Ethnography*, edited by J. Clifford and G. Marcus, 1–26. Berkeley: University of California Press.
———. 1997. *Routes: Travel and Translation In the Late Twentieth Century*. Cambridge: Harvard University Press.
———. 2004. “Looking Several Ways: Anthropology and Native Heritage in Alaska.” *Current Anthropology* 45 (1): 5–30.
Coddington, J. A., M. W. Gates, A. L. Norrbom, R. A. Ochoa, N. J. Vandenberg, and M. H. Greenstone. 2007. “Vouchering DNA-Barcoded Specimens: Test of a Nondestructive Extraction Protocol for Terrestrial Arthropods.” *Molecular Ecology Notes* 7: 915–24.
Cole, K. C. 1997. *The Universe and the Teacup: The Mathematics of Truth and Beauty*. New York: Houghton Mifflin Harcourt.
Collier, J. 2001. “Approaches to Analysis in Visual Anthropology.” In *Handbook of Visual Analysis*, edited by T. van Leeuwen and C. Jewitt, 35–60. London: Sage.
Comaroff, J., and J. Comaroff. 1992. *Ethnography and the Historical Imagination*. Boulder: Westview Press.
Cong, L. 2013. “Multiplex genome engineering using CRISPR/Cas systems.” *Science* 339 (6121): 819–23.
Cooper, M. 2008. *Life as Surplus: Biotechnology and Capitalism in the Neoliberal Era*. Seattle: University of Washington Press.
Coupaye, L. 2009. “Ways of Enchanting Chaînes Opératoires and Yam Cultivation in Nyamikum Village, Maprik, Papua New Guinea.” *Journal of Material Culture* 14 (4): 433–58.
Coy, M.W. 1989. *Apprenticeship: From Theory to Method and Back Again*. Albany: SUNY Press.
Crick, F. H. C., and J.D. Watson. 1953. “A Structure for Deoxyribose Nucleic Acid.” *Nature* 171: 737–38.
CRISPR/Cas9 Guide. 2016. “CRISPR/Cas9 Guide.” https://www.addgene.org/CRISPR/guide/.

Darnton, R. 2000. “An Early Information Society: News and the Media in Eighteenth-Century Paris.” *The American Historical Review* 105 (1): 1–1.
Darwin, C. 1837. “Origin of Species.” http://darwin-online.org.uk/Variorum/1861/1861-147-c-1872.html.
———. 1872. *The Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. London: John Murray.
Dasmann, R.F. 1968. *A Different Kind of Country*. New York: MacMillan Company.
Daston, L. 2000a. *Biographies of Scientific Objects*. Chicago: University of Chicago Press.
———. 2000b. “The Coming into Being of Scientific Objects.” In *Biographies of Scientific Objects*. Chicago: University of Chicago Press.
———. 2004a. *Things That Talk: Object Lessons from Art and Science*. New York Cambridge, Mass.: Zone Books : MIT Press distributor.
———. 2004b. “Type Specimens and Scientific Memory.” *Critical Inquiry* 31 (1): 153–82.
Daston, L., and P. Galison. 2007. *Objectivity*. New York: Cambridge: Zone Books ; Distributed by the MIT Press.
Daston, L., and K. Park. 1998. *Wonders and the Order of Nature, 1150-1750*. New York: Zone Books.
Daston, L., and M. Stolleis. 2008. *Natural Law and Laws of Nature in Early Modern Europe: Jurisprudence, Theology, Moral and Natural Philosophy*. Farnham, England ; Burlington, VT: Ashgate Publishing Company.
Daston, L., and F. Vidal. 2004. *The Moral Authority of Nature*. Chicago: University of Chicago Press.
Dean, J. 1979. “Controversy over Classification: A Case Study from the History of Botany.” In *Natural Order*, edited by B. Barnes and S. Shapin. Beverley Hills: Sage.
Deleuze, G. 1968. *Difference and Repetition*. New York: Columbia University Press.
Deleuze, G., and F. Guattari. 2004. *Anti-Oedipus: Capitalism and Schizophrenia Vol.1*. London: A&C Black.
———. 1987. *A Thousand Plateaus: Capitalism and Schizophrenia*. Minneapolis: University of Minnesota Press.
Derrida, J. 1974. *Of Grammatology*. Baltimore: Johns Hopkins University Press.
———. 1996. *Archive Fever: A Freudian Impression*. Chicago: University of Chicago Press.
Dewey, J. 1916. *Democracy and Education (The Middle Works of John Dewey, Volume 9, 1899-1924)*. Carbondale: Southern Illinois University Press.
———. 1938. *Experience and Education*. New York: Macmillan.
DiEuliis, D. 2016. “Opinion: Specimen Collections Should Have a Much Bigger Role in Infectious Disease Research and Response.” 113. Proceedings of the National Academy of Sciences. Washington D.C.: National Academy of Sciences.
Dobres, M.A. 1999. “Technology’s Links and Chaines: The Processual Unfolding of Technique and Technician.” In *The Social Dynamics of Technology*, edited by C.R. Hoffman and M.A. Dobres, 124–46. Washington D.C.: Smithsonian Institution Press.
———. 2000. *Technology and Social Agency*. Oxford: Blackwell.
Dougal, W.H., F.D. Stuart, and C. Wilkes. 1844. *United States Exploring Expedition. During the Year 1838, 1839, 1840, 1841, 1842.* Philadelphia: Printed by C. Sherman.
Droege, G., J.A. Coddington, K. Barker, J.J. Astrin, P. Bartels, C. Butler, D. Cantrill, and F. Forest. 2013. “The Global Genome Biodiversity Network (GGBN) Data Portal.” *Nucleic Acids Research* 1: 6.
Dudley, J.P., and M.H. Woodford. 2002. “Bioweapons, Biodiversity, and Ecocide: Potential Effects of Biological Weapons on Biological Diversity Bioweapon Disease Outbreaks Could Cause the Extinction of Endangered Wildlife Species, the Erosion of Genetic Diversity in Domesticated Plants and Animals, the Destruction of Traditional Human Livelihoods, and the Extirpation of Indigenous Cultures.” *BioScience* 52 (7): 583–92.

Dudley, K.M. 2014. *Guitar Makers : The Endurance of Artisanal Values in North America*. Chicago: University of Chicago Press.
Durkheim, E., and M. Mauss. 1963. *Primitive Classification*. Translated by R Needham. Chicago: University of Chicago Press.
Dyson, F. 1999. *Sun, the Genome, and the Internet*. Oxford: Oxford University Press.
Eco, U. 1997. *Kant and the Platypus: Essays on Language and Cognition*. London: Verso.
Edwards, E., ed. 1992. *Anthropology and Photography, 1860–1920*. New Haven: Yale University Press.
Ellen, R. 1993. *The Cultural Relations of Classification: An Analysis of Nuaulu Animal Categories from Central Seram*. Cambridge: Cambridge University Press.
Ellis, R. 2008. "Rethinking the Value of Biological Specimens: Laboratories, Museums and the Barcoding of Life Initiative." *Museum and Society* 6 (2): 172–91.
Ellis, R., C. Waterton, and B. Wynne. 2009. "Taxonomy, Biodiversity and Their Publics in 21st Century Barcoding." *Public Understanding of Science* 19 (4): 497–512.
Encyclopedia of Life. 2014. "Encyclopedia of Life (EOL)." http://eol.org/.
Ewing, H. 2008. *The Lost World of James Smithson: Science, Revolution, and the Birth of the Smithsonian*. New York: Bloomsbury Publishing.
FAA. 2015. "Smithsonian Institution, Feather Identification Lab." http://www.faa.gov/airports/airport_safety/wildlife/smithsonian/.
Fabian, J. 1983. *Time and the Other: How Anthropology Makes Its Object*. New York: Columbia University Press.
Fara, P. 2004. *Sex, Botany and Empire: The Story of Carl Linnaeus and Joseph Banks*. Cambridge: Icon Books.
Farber, P.L. 2000. *Finding Order in Nature: The Naturalist Tradition from Linnaeus to EO Wilson*. Baltimore: John Hopkins University Press.
Ferme, M. 2001. *The Underneath of Things: Violence, History, and the Everyday in Sierra Leone*. Berkeley: University of California Press.
Ferry, E.E., and M.E. Limbert, eds. 2008. *Timely Assets: The Politics of Resources and Their Temporalities*. Santa Fe, NM: School for Advanced Research Press.
Findlen, P. 1989. "The Museum: Its Classical Etymology and Renaissance Geneaology." *Journal of the History of Collections* 1 (1): 59–78.
———. 1991. "From Aldrovandi to Algarotti: The Contours of Science in Early Modern Italy." *The British Journal for the History of Science* 24 (03): 353–60.
———. 1994. *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy*. Berkeley: University of California Press.
———. 2002. "Inventing Nature: Commerce, Art, and Science in the Early Modern Cabinet of Curiosities." In *Merchants & Marvels: Commerce, Science, and Art in Early Modern Europe*. New York: Routledge.
Fischer, M.M. J. 2007. "Four Genealogies for a Recombinant Anthropology of Science and Technology." *Cultural Anthropology* 22 (4): 539–615.
Fontaine, B., K. van Achterberg, M.A. Alonso-Zarazaga, R. Araujo, M. Asche, H. Aspöck, U. Aspöck, et al. 2012. "New Species in the Old World: Europe as a Frontier in Biodiversity Exploration, a Test Bed for 21st Century Taxonomy." *PloS One* 7 (5): e36881–e36881.
Fortun, M. 2008. *Promising Genomics: Iceland and deCODE Genetics in a World of Speculation*. Berkeley: University of California Press.
Foucault, M. 1966. *The Order of Things: An Archaeology of the Human Sciences*. New York: Vintage.
Franklin, S. 2007. *Dolly Mixtures: The Remaking of Genealogy*. Durham and London: Duke University Press.
Franklin, S., and M. Lock. 2003a. "Animation and Cessation: The Remaking of Life and Death." In *Remaking Life and Death: Toward an Anthropology of the Biosciences*, edited by Sarah Franklin and Margaret Lock, 3–22. Santa Fe, NM: School of American Research Press.

———. , eds. 2003b. *Remaking Life and Death: Toward an Anthropology of the Biosciences*. Santa Fe: School of American Research Press.
Fujimura, J. 1987. “Constructing `Do-Able’ Problems in Cancer Research: Articulating Alignment.” *Social Studies of Science* 17 (2): 257–93.
———. 1996. *Crafting Science: A Sociohistory of the Quest for the Genetics of Cancer*. Cambridge; London: Harvard University Press.
———. 2003. “Future Imaginaries: Genome Scientists as Socio-Cultural Entrepreneurs.” In *Genetic Nature/Culture: Anthropology and Science Beyond the Two Culture Divide*, 176–99. Berkeley: University of California Press.
Galison, P. 1997. *Image and Logic : A Material Culture of Microphysics*. Chicago: University of Chicago Press.
Galison, P., M.D. Gordin, and D. Kaiser. 2001. *Science and Society : The History of Modern Physical Science in the Twentieth Century*. New York: Routledge.
Galison, P., and D.J. Stump. 1996. *The Disunity of Science: Boundaries, Contexts, and Power*. Stanford, CA: Stanford University Press.
Gaston, K.J. 2000. “Global Patterns in Biodiversity.” *Nature* 405 (6783): 220–27.
Geertz, C. 1973. *The Interpretation of Cultures: Selected Essays*. New York: Basic Books.
Geismar, H. 2009. “The Relational Museum.” *Material World*. http://www.materialworldblog.com/2009/01/the-relational-museum/.
———. 2013. “Defining the Digital.” *Museum Anthropology Review* 7 (1-2): 254–63.
Gell, A. 1998. *Art and Agency*. Oxford: Clarendon Press.
Genome 10K Project. 2016. “Genome 10K Project.” https://genome10k.soe.ucsc.edu/.
GGBN. 2015. “Global Genome Biodiversity Network.” http://www.ggbn.org/ggbn_portal/.
GGI. 2013. “Smithsonian Global Genome Initiative.” http://www.mnh.si.edu/ggi/.
Gibbon, S., and C. Novas. 2008. *Biosocialities, Genetics and the Social Sciences: Making Biologies and Identities*. London: Routledge.
Gitelman, L. 2006. *Always Already New: Media, History and the Data of Culture*.
Godoy, J.A., J.J. Negro, F. Hiraldo, and J.A. Donázar. 2004. “Phylogeography, Genetic Structure and Diversity in the Endangered Bearded Vulture (Gypaetus Barbatus, L.) as Revealed by Mitochondrial DNA.” *Molecular Ecology* 13: 371–90.
Goode, G.B. 1897. *The Smithsonian Institution, 1846-1896: The History of Its First Half Century*. Washington D.C.: Smithsonian Institution Press.
Goodman, A., D. Heath, and S. Lindee. 2003. *Genetic Nature/Culture: Anthropology and Science beyond the Two-Culture Divide*. Berkeley: University of California Press.
Gordon, Robert J, Alison K Brown, Joshua A. Bell, and Smithsonian Libraries. African Art Index Project. 2013. *Expeditions, Their Films and Histories: An Introduction*. Washington D.C.: Smithsonian Institution Scholarly Press.
Gosden, C. 2005. “What Do Objects Want?” *Journal of Archaeological Method and Theory* 12 (3): 193–211.
Gosden, C., F. Larson, and A. Petch. 2007. *Knowing Things: Exploring the Collections at the Pitt Rivers Museum, 1884-1945*. Oxford: University of Oxford Press.
Gosden, C., and Y. Marshall. 1999. “The Cultural Biography of Objects.” *World Archaeology* 31 (2): 169–78.
Graeber, D. 2001. *Toward an Anthropological Theory of Value: The False Coin of Our Own Dreams*. New York: Palgrave Macmillan.
Greenblatt, S. 1992. *Marvelous Possessions: The Wonder of the New World*. Oxford: Clarendon Press.
Greenhill, E.H. 1992. *Museums and the Shaping of Knowledge*. London: Routledge.
Green, R.E., J. Krause, S.E. Ptak, A.W. Briggs, M.T. Ronan, J.F. Simons, L.Du, et al. 2006. “Analysis of One Million Base Pairs of Neanderthal DNA.” *Nature* 444 (7117): 330–36.

Griesemer, J. 1992. “The Role of Instruments in the Generative Analysis of Science.” In *The Right Tools for the Job: At Work in Twentieth-Century Life Sciences*. Princeton: Princeton University Press.
Griesemer, J., and A. Shavit. 2011. “Transforming Objects into Data: How Minute Technicalities of Recording ‘Species Location’ Entrench a Basic Challenge for Biodiversity.” In *Science in the Context of Application*, 169–93. Dordrecht; Heidelberg; London; New York: Springer Netherlands.
Grove, R. 1995. *Green Imperialism*. Cambridge: Cambridge University Press.
Haeckel, E. 1866. *Generelle Morphologie Der Organismen : Allgemeine Grundzüge Der Organischen Formen-Wissenschaft, Mechanisch Begründet Durch Die von Charles Darwin Reformirte Descendenz-Theorie.* Berlin.
Haila, Y., and C. Dyke. 2006. *How Nature Speaks: The Dynamics of the Human Ecological Condition*. Durham and London: Duke University Press.
Hallam, E., and T. Ingold. 2007. *Creativity and Cultural Improvisation*. London: Berg.
Hanner, R., A. Corthals, and R. DeSalle. 2009. “Biodiversity, Conservation, and Genetic Resources in Modern Museum and Herbarium Collections.” In *Conservation Genetics in the Age of Genomics*, 115–23. New York: Columbia University Press.
Haraway, D. 1976. *Crystals, Fabrics, Fields: Metaphors That Shape Embryos*. Berkeley: North Atlantic Books.
———. 1985. “Teddy Bear Patriarchy: Taxidermy in the Garden of Eden, New York City, 1908-1936.” *Social Text* 11 (Winter): 20–64.
———. 1989. *Primate Visions: Gender, Race, and Nature in the World of Modern Science*. London: Verso.
———. 1991. *Simians, Cyborgs, and Women: The Reinvention of Nature*. New York: Routledge.
———. 1997. *Modest_Witness@Second_Millennium.FemaleMan Meets_OncoMouse: Feminism and Technoscience*. New York: Routledge.
———. 2003. *A Companion Species Manifesto: Dogs, People, and Significant Otherness*. Chicago: Prickly Paradigm.
———. 2008. *When Species Meet*. Minneapolis: University of Minnesota Press.
———. 2015. “Anthropocene, Capitalocene, Plantationocene, Chthulucene: Making Kin.” *Environmental Humanities* 6: 159–65.
Harding, S. 1991. *Whose Science? Whose Knowledge?: Thinking from Women’s Lives*. Ithaca: Cornell University Press.
———. 2008. *Sciences from Below: Feminisms, Postcolonialities, and Modernities*. Durham and London: Duke University Press.
Harding, S, and M. Hintikka. 2012. *Discovering Reality: Feminist Perspectives on Epistemology, Metaphysics, Methodology, and Philosophy of Science*. Springer Science & Business Media.
Harris, M. 2007. *Ways of Knowing : Anthropological Approaches to Crafting Experience and Knowledge*. New York: Berghahn Books.
Harrison, R., S. Byrne, and A. Clarke, eds. 2013. *Reassembling the Collection: Ethnographic Museums and Indigenous Agency*. Santa Fe: School for Advanced Research Press.
Hastrup, K. 1990. “The Ethnographic Present: A Reinvention.” In *Cultural Anthropology*, 5:45–61. 1.
Haussler, D., S.J. O’Brien, O.A. Ryder, F.K. Barker, M. Clamp, A.J. Crawford, R. Hanner, O. Hanotte, W.E. Johnson, and J.A. McGuire. 2009. “Genome 10K: A Proposal to Obtain Whole-Genome Sequence for 10 000 Vertebrate Species.” *Journal of Heredity* 100 (6): 659–74.
Hayden, C. 2003a. “From Market to Market: Bioprospecting’s Idioms of Inclusion.” *American Ethnologist* 30 (3): 359–71.
———. 2003b. *When Nature Goes Public: The Making and Unmaking of Bioprospecting in Mexico*. Princeton: Princeton University Press.

———. 2007a. “A Generic Solution? Pharmaceuticals and the Politics of the Similar in Mexico.” *Current Anthropology* 48 (4): 475–95.
———. 2007b. “Taking as Giving: Bioscience, Exchange, and the Politics of Benefit-Sharing.” *Social Studies of Science* 37 (5): 729–58.
———. 2010. “The Proper Copy: The Insides and Outsides of Domains Made Public.” *The Journal of Cultural Economy*, 85–102.
Hayles, N.K. 2005. *My Mother Was a Computer: Digital Subjects and Literary Texts*. Chicago: University of Chicago Press.
Helmreich, S. 2007. “Blue-Green Capital, Biotechnological Circulation and an Oceanic Imaginary: A Critique of Biopolitical Economy.” *BioSocieties* 2 (03): 287–302.
———. 2008. “Species of Biocapital.” *Science as Culture* 17 (4): 463–78.
———. 2009. *Alien Ocean: Anthropological Journeys in Microbial Seas*. Berkeley: University of California Press.
Henare, A., M. Holbraad, and S. Wastell. 2007. *Thinking through Things: Theorising Artefacts Ethnographically*. London: Routledge.
Heraty, J.M., J.B. Woolley, K.R. Hopper, D.L. Hawks, J.W. Kim, and M. Buffington. 2007. “Molecular Phylogenetics and Reproductive Incompatibility in a Complex of Cryptic Species of Aphid Parasitoids.” *Molecular Phylogenetics and Evolution* 45 (2): 480–93.
Hesse, M. 1974. *The Structure of Scientific Inference*. Berkeley: University of California Press.
Hornaday, W.T., and Frederic Collin Walcott. 1914. *Wild Life Conservation in Theory and Practice, Lectures Delivered before the Forest School of Yale University, 1914*. New Haven: Yale University Press.
Horváth, M.B., B. Martínez-Cruz, J.J. Negro, L. Kalmár, and J.A. Godoy. 2005. “An Overlooked DNA Source for Non-Invasive Genetic Analysis in Birds.” *Journal of Avian Biology* 36: 84–88.
Hull, D. 1988. *Science as Process: An Evolutionary Account of the Social and Conceptual Development of Science*. Chicago: University of Chicago Press.
“Human Genome Diversity Project, Workshop 1.” 1992. Stanford, CA: Stanford University Press.
“Human Genome Diversity Project, Workshop 2.” 1992. College, PA: State.
Hykin, Sarah M., Ke Bi, and Jimmy A. McGuire. 2015. “Fixing Formalin: A Method to Recover Genomic-Scale DNA Sequence Data from Formalin-Fixed Museum Specimens Using High-Throughput Sequencing.” *PLOS ONE* 10 (10): e0141579.
Impey, O., and A. MacGregor, eds. 1985. *The Origins of Museums: The Cabinet of Curiosities in Sixteenth-and Seventeenth-Century Europe*. Oxford: Clarendon Press.
Ingham, R. 2013. “Breakthrough in Storing 700 Terabytes of Data in 1 Gram of DNA.” *The Sydney Morning Herald*. http://www.smh.com.au/technology/sci-tech/breakthrough-in-storing-700-terabytes-of-data-in-1-gram-of-dna-20130123-2d89q.html.
Ingold, T. 1988. *What Is an Animal?* Psychology Press.
———. 1993. “Globes and Spheres: The Topology of Environmentalism.” In *Environmentalism: The View from Anthropology*, edited by K Milton, 31–42. London: Routledge.
———. 2000. *Perception of the Environment: Essays on Livelihood, Dwelling and Skill*. London: Routledge.
———. 2006. “Rethinking the Animate, Re-Animating Thought.” *Ethnos* 71 (1): 9–20.
———. 2010. “Bringing Things to Life: Creative Entanglements in a World of Materials.” *World* 44 (July): 1–25.
———. 2011a. *Being Alive: Essays on Movement, Knowledge and Description*. London: Routledge.
———. 2011b. *Redrawing Anthropology: Materials, Movements, Lines*. Ashgate Publishing, Ltd.
———. 2012. “Toward an Ecology of Materials.” *Annual Review of Anthropology* 41: 427–42.
———. 2013. *Making: Anthropology, Archeology, Art and Architecture*. New York: Routledge.
Ingold, T., and G. Palsson. 2013. *Biosocial Becomings: Integrating Social and Biological Anthropology*. Cambridge: Cambridge University Press.

Isaac, G. 2007. *Mediating Knowledges: Origins of a Zuni Tribal Museum*. Phoenix: University of Arizona Press.
———. 2011. “Whose Idea Was This? Replicas, Museums and the Reproduction of Knowledge.” *Current Anthropology* 52 (4): 585–95.
IUCN Red List. 2015. “IUCN Red List of Threatened Species.” IUCN, The World Conservation Union.
Jacknis, I. 1988. “Margaret Mead and Gregory Bateson in Bali: Their Use of Photography and Film.” *Cultural Anthropology* 3 (2): 160–77.
Janecka, A., A. Adamczyk, and A. Gasińska. 2015. “Comparison of Eight Commercially Available Kits for DNA Extraction from Formalin-Fixed Paraffin-Embedded Tissues.” *Analytical Biochemistry* 476 (May): 8–10.
Jardine, N., J.A. Secord, and E.C. Spary. 1996. *Cultures of Natural History*. Cambridge: Cambridge University Press.
Jasanoff, S., ed. 2004. *States of Knowledge: The Co-Production of Science and Social Order*. London: Routledge.
———. 2005. *Designs on Nature: Science and Democracy in Europe and the United States*. Princeton: Princeton University Press.
Joyce, R.A., and S.D. Gillespie. 2015. “Making Things out of Objects That Move.” In *Things in Motion: Object Itineraries in Anthropological Practice*, edited by S.D. Gillespie and R.A. Joyce. Santa Fe: School of Advanced Research Press.
Jubien, M. 2001. “Thinking About Things.” Edited by Susan Pearce. *Nous* 35 (s15): 1–15.
Karp, I., and S. Lavine, eds. 1991. *Exhibiting Cultures: The Poetics and Politics of Museum Display*. Washington D.C.: Smithsonian Institution Press.
Kaufman, S.R., and L.M. Morgan. 2005. “The Anthropology of the Beginnings and Ends of Life.” *Annual Review of Anthropology* 34 (1): 317–41.
Kay, L.E. 2000. *Who Wrote the Book of Life? A History of the Genetic Code*. Stanford: Stanford University Press.
Keane, W. 2003. “Semiotics and the Social Analysis of Material Things.” *Language and Communication* 23: 409–25.
Keller, E.F. 1995a. *Refiguring Life: Metaphors of Twentieth-Century Biology. The Wellek Library Lecture Series at the University of California, Irvine*. New York: Columbia University Press.
———. 1995b. *Reflections on Gender and Science*. New Haven: Yale University Press.
———. 2009. *The Century of the Gene*. Cambridge: Harvard University Press.
Kirksey, S.E., and Stefan Helmreich. 2010. “The Emergence of Multispecies Ethnography.” *Cultural Anthropology* 25 (4): 545–76.
Knecht, H. 1991. “The Role of Innovation in Changing Early Upper Paleolithic Organic Projectile Technologies.” In *Techniques et Culture*, 17-18:115–44.
Knorr-Cetina, K. 1997. “Sociality with Objects: Social Relations in Postsocial Knowledge Societies.” *Theory, Culture & Society* 14 (4): 1–30.
———. 1999. *Epistemic Cultures: How the Sciences Make Knowledge*. New Haven and London: Harvard University Press.
———. 2013. *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science*. New York: Pergamon Press.
Kohler, R.E. 1991. *Partners in Science: Foundations and Natural Scientists, 1900-1945*. Chicago: University of Chicago Press.
———. 1994. *Lords of the Fly: Drosophila Genetics and the Experimental Life*. Chicago: University of Chicago Press.
———. 2002. *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology*. Chicago: University of Chicago Press.
———. 2007. “Finders, Keepers: Collecting Sciences and Collecting Practice.” *History of Science* 45 (4): 428–54.

———. 2013. *All Creatures: Naturalists, Collectors, and Biodiversity, 1850-1950*. Princeton: Princeton University Press.
Kohlstedt, S.G. 2005. “Thoughts in Things.” *Isis* 96 (4): 586–601.
Kohn, E. 2013. *How Forests Think: Toward an Anthropology Beyond the Human*. Berkeley: University of California Press.
———. 2014. “What an Ontological Anthropology Might Mean — Cultural Anthropology.” *Fieldsights—Theorizing the Contemporary, Cultural Anthropology Online* January 13. http://www.culanth.org/fieldsights/463-what-an-ontological-anthropology-might-mean.
Kopytoff, I. 1986. “The Cultural Biography of Things: Commoditization as Process.” In *The Social Life of Things: Commodities in Cultural Perspective*, edited by Arjun Appadurai, 64–91. Cambridge: Cambridge University Press.
Kowal, E., J. Radin, and J. Reardon. 2013. “Indigenous Body Parts, Mutating Temporalities, and the Half-Lives of Postcolonial Technoscience.” *Social Studies of Science* 43 (4): 465–83.
Kress, J. 2014. “Valuing Collections.” *Science* 346 (6215): 1310–1310.
Kuhn, T. 1962. *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.
Lampland, M., and S.L. Star. 2009. *Standards and Their Stories : How Quantifying, Classifying, and Formalizing Practices Shape Everyday Life*. Ithaca: Cornell University Press.
Landecker, H. 2007. *Culturing Life: How Cells Became Technologies*. Cambridge, MA: Harvard University Press.
———. 2005. “Living Differently in Time: Plasticity, Temporality and Cellular Biotechnologies,” *Culture Machine 7.*
Lander, E.S. 2016. “The Heroes of CRISPR.” *Cell* 164: 18–28.
Lander, E.S., and R.A. Weinberg. 2000. “Journey to the Center of Biology.” *Science* 287 (5459): 1777–82.
Latimer, J., and M. Miele. 2013. “Naturecultures? Science, Affect and the Non-Human.” *Theory, Culture & Society* 30 (7-8): 5–31.
Latour, B. 1988. *The Pasteurization of France*. Translated by A. Sheridan and J. Law. Cambridge, MA: Harvard University Press.
———. 1999a. “Circulating Reference: Sampling the Soil in the Amazon Forest.” In *Pandora’s Hope: Essays on the Reality of Science Studies*, edited by Bruno Latour, 24–79. Cambridge, Mass: Harvard University Press.
———. 1999b. *Pandora’s Hope: Essays on the Reality of Science Studies*. Cambridge: Harvard University Press.
Latour, B., and S. Woolgar. 1979. *Laboratory Life: The Social Construction of Scientific Facts*. Beverly Hills: Sage.
Lave, J.. 2011. *Apprenticeship in Critical Ethnographic Practice*. Chicago: University of Chicago Press.
Lave, J., and E. Wenger. 1991. *Situated Learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press.
———. 2002. “Legitimate Peripheral Participation in Communities of Practice.” *Supporting Lifelong Learning* 1: 111–26.
Lavoie, C. 2013. “Biological Collections in an Ever Changing World: Herbaria as Tools for Biogeographical and Environmental Studies.” *Perspectives in Plant Ecology, Evolution and Systematics* 15 (1): 68–76.
Lechtman, H. 1977. “Style and Technology: Some Early Thoughts.” In *Material Culture: Styles, Organization and Dynamics of Technology*, edited by R. S. Merrill and H. Lechtman, 3–20. St. Paul, MN: West.
Lemonnier, P. 1993. *Technological Choices: Transformation in Material Cultures since the Neolithic*. London: Routledge.
Leonelli, S. 2012a. “Introduction: Making Sense of Data-Driven Research in the Biological and Biomedical Sciences.” *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 43 (1): 1–3.

———. 2012b. “When Humans Are the Exception: Cross-Species Databases at the Interface of Biological and Clinical Research.” *Social Studies of Science* 42 (2): 214–36.
———. 2013a. “Why the Current Insistence on Open Access to Scientific Data? Big Data, Knowledge Production, and the Political Economy of Contemporary Biology.” *Bulletin of Science, Technology & Society* 33 (1-2): 6–11.
———. 2013b. “Integrating Data to Acquire New Knowledge: Three Modes of Integration in Plant Science.” *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 44 (4): 503–14.
———. 2014. “What Difference Does Quantity Make? On the Epistemology of Big Data in Biology.” *Big Data & Society* 1 (1).
Leonelli, S., and R.A. Ankeny. 2012. “Re-Thinking Organisms: The Impact of Databases on Model Organism Biology.” *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 43 (1): 29–36.
Leonelli, S., A.D. Diehl, K.R. Christie, M.A. Harris, and J. Lomax. 2011. “How the Gene Ontology Evolves.” *BMC Bioinformatics* 12 (1): 325–325.
Leroi-Gourhan, A. 1964. *La Geste et La Parole I: Techniques et Language*. Paris: Albin Michel.
———. 1993. *Gesture and Speech*. Cambridge, MA: MIT Press.
Levi-Strauss, C. 1966. *The Savage Mind*. Chicago: University of Chicago Press.
Linnaeus, C. 1751. *Philosophia Botanica*. Stockholm and Amsterdam.
Lonetree, A., and A.J. Cobb, eds. 2008. *The National Museum of the American Indian: Critical Conversations*. Lincoln: University of Nebraska Press.
Lowe, C. 2006. *Wild Profusion: Biodiversity Conservation in an Indonesian Archipelago*. Princeton: Princeton University Press.
Lyman, R.L. 2010. “Paleozoology’s Dependence on Natural History Collections.” *Journal of Ethnobiology*, no. 30: 126–36.
Macdonald, S. 2002. *Behind the Scenes at the Science Museum*. New York: Berg.
Malkogeorgou, T. 2011. “Folding, Stitching, Turning: Putting Conservation into Perspective.” *Journal of Material Culture* 16 (4): 441–55.
Marchand, T.H.J. 2010. “Making Knowledge: Explorations of the Indissoluble Relation between Minds, Bodies, and Environment.” *Journal of the Royal Anthropological Institute* 16: S1–21.
Marcus, G. 1995. “Ethnography In/of the World System: The Emergence of Multi-Sited Ethnography.” *Annual Review of Anthropology* 24: 95–117.
———. 2000. *Para-Sites: A Casebook against Cynical Reason*. Chicago: University of Chicago Press.
———. 2008. “The End(s) of Ethnography: Social/Cultural Anthropology’s Signature Form of Producing Knowledge in Transition.” *Cultural Anthropology* 23 (1): 1–14.
Marcus, G., and D. Cushman. 1982. “Ethnographies as Texts.” *Annual Review of Anthropology* 11: 25–69.
Margulis, L., and D. Sagan. 2002. *Acquiring Genomes: A Theory of the Origins of Species*. New York: Basic.
Marsh, D. 2014. “From Extinct Monsters to Deep Time: An Ethnography of Fossil Exhibits Production at the Smithsonian’s National Museum of Natural History.” Ph.D. Dissertation. University of British Columbia, Vancouver, BC.
Martin, P.Y., and B.A. Turner. 1986. “Grounded Theory and Organizational Research.” *The Journal of Applied Behavioral Science* 22 (2): 141–57.
Marx, K. 1867. *Das Kapital: A Critique of Political Economy, Volume 1*. Washington D.C.: Regenry Publications.
Mauss, M. 1954. *The Gift: Forms and Functions of Exchange in Archaic Societies*. New York: Cohen and West.
———. 2007. *Manual of Ethnography [Manuel D’ethnographie]*. New York ; Oxford: Durkheim Press/Berghahn Books.

Mead, M. 1995. “Visual Anthropology in a Discipline of Words.” edited by Paul Hockings, 3–10. New York: Mouton de Gruyter.
Mead, M., and G. Bateson. 1977. “On the Use of the Camera in Anthropology.” In *Studies in the Anthropology of Visual Communication, Dec*, 4:78–80. 2.
Mearns, B., and R. Mearns. 1998. *The Bird Collectors*. Michigan: Academic Press.
Merchant, C. 1990. *The Death of Nature: Women, Ecology, and the Scientific Revolution*. New York: Harper Collins.
———. 2013. *Reinventing Eden: The Fate of Nature in Western Culture*. New York: Routledge.
Miller, D. 1997. *Material Culture and Mass Consumption*. Oxford and New York: Wiley-Blackwell.
Miller, W., D. Drautz, J.E. Janecka, A.M. Lesk, A. Ratan, L.P. Tomsho, M. Packard, et al. 2008. “The Mitochondrial Genome Sequence of the Tasmanian Tiger (Thylacinus Cynocephalus).” *Genome Research* 19 (2): 213–20.
Mitchell, R., and C. Waldby. 2006. *Tissue Economies: Blood, Organs, and Cell Lines in Late Capitalism*. Durham: Duke University Press.
Moeran, B. 2010. “Book Fairs as a Tournament of Values.” Journal of the Royal Anthropological Institute 16 (1): 138–54.
———. 2013. The Business of Creativity: Toward an Anthropology of Worth. Walnut Creek, CA: Left Coast Press.
Mohns, W., and H. Geismar. 2010. “Database Relations: Rethinking the Database in the Vanuatu Cultural Centre and National Museum.” Edited by N. Mookherjee and C. Pinney. *Special Issue of the Journal of the Royal Anthropological Institute*.
Mol, A., and J. Law, eds. 2002. *Complexities: Social Studies of Knowledge Practices*. Durham and London: Duke University Press.
Moutu, A. 2006. “Collection as a Way of Being.” In *Thinking through Things: Theorising Artefacts Ethnographically*, edited by Amiria Henare, Martin Holbraad, and Sari Wastell. London: Routledge.
Müller-Wille, S. 2003. “Nature as a Marketplace: The Political Economy of Linnaean Botany.” In *Economies in the Age of Newton, Supplement to History of Political Economy*, edited by M. Schabas and N. de Marchi, 35:154–72. Durham and London: Duke University Press.
Munn, N. 1986. *The Fame of Gawa: A Symbolic Study of Value Transformation in a Massim (Papua New Guinea) Society*. Cambridge: Cambridge University Press.
Murray, K., L. Skerratt, G. Marantelli, L. Berger, D. Hunter, M. Mahoney, and H. Hines. 2011. “Cryopreservation and Reconstitution Technologies : A Proposal to Establish A Genome Resource Bank For Threatened Australian Amphibians.” olr.npi.gov.au.
Nachman, M. 2013. “Genomics and Museum Specimens.” *Molecular Ecology* 22 (24).
Nadasdy, P. 2007. “The Gift in the Animal: The Ontology of Hunting and Human–Animal Sociality.” *American Ethnologist* 34 (1): 25–43.
Nagel, T. 1989. *The View From Nowhere*. Oxford: Oxford University Press.
National Geographic. 2013. “DeExtinction: Bringing Extinct Species Back to Life.” http://www.nationalgeographic.com/deextinction/.
Natural History Museum London. 2016. “Darwin Centre.” http://www.nhm.ac.uk/research-curation/scientific-resources/collections/botanical-collections/sloane-herbarium/about-sloane/index.html.
Needham, R. 1979. *Symbolic Classification*. Santa Monica: Goodyear.
Noske, B. 1989. *Beyond Boundaries: Humans and Other Animals*. Montreal: Black Rose Books.
Ogilvie, B.W. 2003. “The Many Books of Nature: Renaissance Naturalists and Information Overload.” *Journal of the History of Ideas* 64 (1): 29–40.
———. 2008. *The Science of Describing: Natural History in Renaissance Europe*. Chicago: University of Chicago Press.
Okely, J., and H. Callaway. 1992. *Anthropology and Autobiography*. London: Routledge.

O'Leary, M.A., J.I. Bloch, J.J. Flynn, T.J. Gaudin, A. Giallombardo, NP. Giannini, S.L. Goldberg, et al. 2013. "The Placental Mammal Ancestor and the Post–K-Pg Radiation of Placentals." *Science* 339 (6120): 662–67.

Olmi, G., L. Laurencich-Minelli, A. Aimi, V. de Michele, A. Morandotti, E. Scheicher, R. Distelberger, E. Fucikova, Ol. Neverov, and H.C. Ackermann. 2001. *The Origins of Museums: The Cabinet of Curiosities in Sixteenth-and Seventeenth-Century Europe*. London: House of Stratus.

Ong, A., and S. Collier, eds. 2005. *Global Assemblages: Technology, Politics, and Ethics as Anthropological Problems*. Malden. MA: Blackwell Press.

Ortner, S.B. 1984. "Theory in Anthropology since the Sixties." *Comparative Studies in Society and History*, 26:126–66. 1.

———. 2006. *Anthropology and Social Theory : Culture, Power, and the Acting Subject*. Durham: Duke University Press.

Ostrom, P.H., A.E. Wiley, S. Rossman, C.A. Stricker, and H.F. James. 2014. "Unexpected Hydrogen Isotope Variation in Oceanic Pelagic Seabirds." *Oecologia* 175 (4): 1227–35.

Paabo, S. 1989. "Ancient DNA: Extraction, Characterization, Molecular Cloning, and Enzymatic Amplification." *Proceedings of the National Academy of Sciences* 86 (6): 1939–43.

Page, L.M., B.J. MacFadden, J.A. Fortes, P.S. Soltis, and G.Riccardi. 2015. "Digitization of Biodiversity Collections Reveals Biggest Data on Biodiversity." *BioScience* 65 (9): 841–42.

Parry, B. 2004. *Trading the Genome: Investigating the Commodification of Bio-Information*. New York: Columbia University Press.

Paxson, H. 2010. *Toward an Animal Anthropology of Farmstead Cheesemaking. Paper Presented at the Meetings of the Society for Cultural Anthropology*. Santa Fe, New Mexico, May 7–8.

Pearce, S. 1992. *Museum Objects and Collections: A Cultural Study*. London: Leicester University Press.

———. 1994a. "Collecting Reconsidered." *Interpreting Objects and Collections*, 193–204.

———. 1994b. *Museums and the Appropriation of Culture*. New Resear. London: Athlone Press.

———. 1994c. "Objects as Meaning, or Narrating the Past." *Interpreting Objects and Collections*, 19–29.

———. 1995. *On Collecting: An Investigation into Collecting in the European Tradition*. New York: Routledge.

———. 2010. *Objects of Knowledge*. Bloomsbury: A&C Black.

Peterson, A.T., D.A. Vieglais, and A.G. Navarro-Siguenza. 1998. *Assembly of a Distributed Biodiversity Information Network for North America: Lessons Learned. Draft Report to the Commission on Environmental Cooperation*. Montreal, Canada: North American Free Trade Agreement.

Philbrick, N. 2004. *Sea of Glory: America's Voyage of Discovery, The U.S. Exploring Expedition, 1838-1842*. New York: Penguin.

Pickering, A. 2010. *The Mangle of Practice: Time, Agency, and Science*. Chicago: University of Chicago Press.

Pickstone, J. 2001. *Ways of Knowing: A New History of Science, Technology, and Medicine*. Chicago: University of Chicago Press.

Pinney, C. 1997. *Camera Indica: The Social Life of Indian Photographs*. London: Reaktion.

Pinney, C., and N. Peterson, eds. 2003. *Photography's Other Histories*. Durham, NC: Duke University Press.

Poinar, H.N., C. Schwarz, J. Qi, B. Shapiro, R.D.E. MacPhee, B. Buigues, A. Tikhonov, et al. 2006. "Metagenomics to Paleogenomics: Large-Scale Sequencing of Mammoth DNA." *Science* 311 (5759): 392–94.

Poliquin, R. 2012. *The Breathless Zoo: Taxidermy and the Culture of Longing*. University Park: Pennsylvania University Press.

Pomian, K. 1990. *Collectors and Curiosities: Paris and Venice, 1500-1800*. Cambridge: Polity Press.
Prendini, L., R. Hanner, and R. DeSalle. 2002. “Obtaining, Storing and Archiving Specimens and Tissue Samples for Use in Molecular Studies.” In *Techniques in Molecular Systematics and Evolution*, 176–248. Basel: Birkhäuser Basel.
Price, S. 2007. *Paris Primitive: Jacques Chirac’s Museum on the Quai Branly*. Chicago: University of Chicago Press.
Pyke, G.H., and P.R. Ehrlich. 2010. “Biological Collections and Ecological/environmental Research: A Review, Some Observations and a Look to the Future.” *Biological Reviews* 85 (2): 247–66.
Rabinow, P. 1996. “Artificiality and Enlightenment: From Sociobiology to Biosociality.” In *Incorporations*, 91–111. Princeton: Princeton University Press.
———. 1997. *Making PCR: A Story of Biotechnology*. Chicago: University of Chicago Press.
———. 2002. *French DNA: Trouble in Purgatory*. Chicago: University of Chicago Press.
———. 2005. *Artificiality and Enlightenment: From Sociobiology to Biosociality*. Oxford, UK: Blackwell Publishing Ltd.
Rabinow, P., and G. Bennett. 2012. *Designing Human Practices: An Experiment with Synthetic Biology*. Chicago: University of Chicago Press.
Rabinow, P., and N. Rose. 2006. “Biopower Today.” *BioSocieties* 1 (02): 195–211.
Rader, K. 2004. *Making Mice: Standardizing Animals for American Biomedical Research in America*. Princeton: Princeton University Press.
Rader, K., and V. Cain. 2014. *Life on Display : Revolutionizing U.S. Museums of Science and Natural History in the Twentieth Century*. Chicago: University of Chicago Press.
Radin, J. 2012. “Life on Ice: Frozen Blood and Biological Variation in a Genomic Age, 1950-2010.” Ph.D. Dissertation, Philadelphia: University of Pennsylvania.
———. 2013. ““Latent Life: Concepts and Practices of Human Tissue Preservation.” In *The International Biological Program” in Social Studies of Science, August*, 43:484–508.
Raffles, H. 2001. “The Uses of Butterflies.” *American Ethnologist* 28 (3): 513–48.
———. 2010. *Insectopedia*. New York: Pantheon.
Ratzel, F. 1896. *History of Mankind*. New York: Macmillan.
Ray, J. 1713. *Three Physico-Theological Discourses : Concerning: I. The Primitive Chaos and Creation of the World , II. The General Deluge, Its Causes and Effects , III. The Dissolution of the World and Future Conflagration ..* London: Printed for William Innys.
Revive and Restore. 2013. “Revive and Restore.” http://longnow.org/revive/.
Rheinberger, H.J. 1997. *Toward a History of Epistemic Things: Synthesising Proteins in the Test Tube*. Stanford CA: Stanford University Press.
———. 2000. “Cystoplasmic Particles: The Trajectory of a Scientific Object.” In *Biographies of Scientific Objects*, edited by Lorraine Daston. Chicago: University of Chicago Press.
Richards, T. 1993. “The Imperial Archive: Knowledge and Fantasy of Empire.” *Studies in the History and the Philosophy of Science* 23 (2): 305–31.
Ridley, M. 2000. *Genome: The Autobiography of a Species in 23 Chapters*. New York: Harper Collins.
Riley, C. 1892. *Directions for Collecting and Preserving Insects, Parts 1-3*. Washington D.C.: U.S. Government Printing Office, Smithsonian Institution.
Rival, L. 1998. *The Social Life of Trees: Anthropological Perspectives on Tree Symbolism*. New York: Berg.
Rocha, L.A. A., A. Aleixo, G. Allen, F. Almeda, C. C. Baldwin, M. V. L. Barclay, J. M. Bates, et al. 2014. “Specimen Collection: An Essential Tool.” *Science* 344 (6186): 814–15.
Rogoff, Barbara. 1990. *Apprenticeship in Thinking: Cognitive Development in Social Context*. Oxford: Oxford University Press.
Rohland, N., and M. Hofreiter. 2007. “Ancient DNA Extraction from Bones and Teeth.” *Nature Protocols* 2 (7): 1756–2189.

Rohland, N., H. Siedel, and M. Hofreiter. 2010. “A Rapid Column-based Ancient DNA Extraction Method for Increased Sample Throughput.” *Molecular Ecology Resources* 10 (4): 677–998.
Rosenberg, D. 2003. “Early Modern Information Overload.” *Journal of the History of Ideas* 64 (1): 1–9.
Rose, N. 2007. *The Politics of Life Itself: Biomedicine, Power, and Subjectivity in the Twenty-First Century*. Princeton and Oxford: Princeton University Press.
Rutherford, S. 2011. *Governing the Wild: Ecotours of Power*. Minneapolis: University of Minnesota Press.
Sahlins, M. 1976. *The Use and Abuse of Biology*. Ann Arbor, MI: The University of Michigan Press.
———. 1993. “Goodbye to Tristes Tropes: Ethnography in the Context of the Modern World History.” *Journal of Modern History* 65: 1–25.
Salmond, A. 2012. “Digital Subjects, Cultural Objects: Special Issue Introduction.” *Journal of Material Culture* 17 (3): 211–28.
Sanjek, R. 1991. “The Ethnographic Present.” *Man* December (1): 609–28.
SCBI. 2015. “Sequencing a Honeycreeper | Smithsonian Conservation Biology Institute, National Zoological Park, Smithsonian Institution.” https://nationalzoo.si.edu/SCBI/CCEG/news/genome_sequence.cfm.
Schiebinger, L. 1993. “Why Mammals Are Called Mammals: Gender Politics in Eighteenth-Century Natural History.” *The American Historical Review* 98 (2): 382–382.
Schipper, J., J.S. Chanson, F. Chiozza, N.A. Cox, M. Hoffmann, V. Katariya, J. Lamoreux, A.S.L. Rodrigues, S.N. Stuart, and H.J. Temple. 2008. “The Status of the World’s Land and Marine Mammals: Diversity, Threat, and Knowledge.” *Science* 322 (5899): 225–8075.
Schlanger, N. 1994. “Mindful Technology: Unleashing the Chaine Operatoire for an Archaeology of Mind.” In *The Ancient Mind*, edited by C.Renfrew and E. Zubrow, 143–51. Cambridge: Cambridge University Press.
Seberg, O. 2013. *Biobanking and the Tree of Life*. Natural History Museum of Denmark: University of Copenhagen.
Seddon, P.J., A. Moehrenschlager, and J. Ewen. 2014. “Reintroducing Resurrected Species: Selecting DeExtinction Candidates.” *Trends in Ecology & Evolution* 29 (3): 140–47.
Semenov, S.A. 1964. *Prehistoric Technology, an Experimental Study of the Oldest Tools and Artifacts from Traces of Manufacture and Wear*. London: Cory.
Sennett, R. 2008. *The Craftsman*. New Haven and London: Yale University Press.
Serres, M. 2007. *The Parasite*. Minneapolis: University of Minnesota Press.
Shannon, J.A. 2014. *Our Lives: Collaboration, Native Voice, and the Making of the National Museum of the American Indian*. School for Advanced Research Resident Scholar Book. Santa Fe, New Mexico: SAR Press.
Shapin, S. 1989. “The Invisible Technician.” *American Scientist* 77 (6): 554–63.
Shapiro, B. 2015. *How to Clone a Mammoth: The Science of de-Extinction*. Princeton: Princeton University Press.
Shelton, A.A. 1994. “Cabinets of Transgression: Renaissance Collections and the Incorporation of the New World.” In *The Cultures of Collecting*. Cambridge: Harvard University Press.
Sherkow, J. S., and H. T. Greely. 2013. “What If Extinction Is Not Forever?” *Science* 340 (6128): 32–33.
SIBG. 2015. “Smithsonian Institute for Biodiversity Genomics.” https://biogenomics.si.edu/.
Smith, P.H. 2004. *The Body of the Artisan: Art and Experience in the Scientific Revolution*. University of Chicago Press.
Smith, P.H., and P. Findlen, eds. 2002. *Merchants and Marvels: Commerce, Science, and Art in Early Modern Europe*. New York: Routledge.
Smithsonian Feather Identification Lab. 2015. “Scientists Use Forensic Techniques to Improve Airport Safety.” http://naturalhistory.si.edu/highlight/feathers/.

Smithsonian Institution. 2016. “Smithsonian Institution: About.” http://www.si.edu/about/.
Smithsonian Institution, A Century of Whales. 2016. “Century of Whales at SI: Celebrating 100 Years.” http://naturalhistory.si.edu/onehundredyears/profiles/Whales_SI.html.
Smithsonian Institution Archives, RU7083. 1909. “RU7083 Edgar Alexander Mearns Papers, circa 1871-1916, 1934 and Undated.” http://siarchives.si.edu/collections/siris_arc_217241.
Smithsonian Institution, Living in the Anthropocene Consortia. 2015. “Living in the Anthropocene | The Smithsonian Consortia.” http://consortia.si.edu/story/feature-story/living-anthropocene.
Smithsonian Institution, Museum Support Center. 2016. “Museum Support Center | Newsdesk.” http://newsdesk.si.edu/factsheets/museum-support-center.
Smithsonian Institution, Sant Ocean Hall. 2016. “Modeling Phoenix, Our North Atlantic Right Whale.” http://naturalhistory.si.edu/exhibits/ocean_hall/whale_model.html.
Smithson, J. 1802. “A Chemical Analysis of Some Calamines.” Philosophical Transactions of the Royal Society of London. http://www.sil.si.edu/Exhibitions/Smithson-to-Smithsonian/calamine.html.
Soffer, O., J. Adovasio, J.S. Illingworth, H.A. Amirkhanov, N.D. Praslov, and M. Street. 2000. *Palaeolithic Perishables Made Permanent*. Vol. 74. Antiquity.
Soffer, O., and and P. Vandiver. 1994. “Pavlov I: Excavations 1952–53. E´ Tudes et Recherches Arche´ologiques de l’Universite´ de Lie`ge 66, Dolnı´ Ve˘stonice Studies 2.” In *The Ceramics*, edited by J. Svoboda, 63–173. Lie`ge: Universite de Lie`ge.
Sontag, S. 1966. *Against Interpretation: And Other Essays*. Macmillan.
Soulé, M. E. 1990. “The Real Work of Systematics.” In *Annals of the Missouri Botanical Garden*, 77:4–12.
Soulé, M. E., and B. A. Wilcox. 1980. *Conservation Biology: An Evolutionary-Ecological Perspective*. Sunderland: Massachusetts: Sinauer Associates.
Spary, E. 1996. “Political, Natural and Bodily Economies.” In *Cultures of Natural History*, edited by J. Secord Jardine and E. Spary, 178–96. Cambridge: Cambridge University Press.
Sperber, D. 1985. *“Interpretive Ethnography and Theoretical Anthropology” in On Anthropological Knowledge*. Cambridge: Cambridge University Press.
Star, S.L. 2010. “This Is Not a Boundary Object: Reflections on the Origin of a Concept.” *Science, Technology & Human Values* 35 (5): 601–17.
———. 2014. “Craft vs. Commodity, Mess vs. Transcendence: How the Right Tool Became the Wrong One in the Cse of Taxidermy and Natural History.” In *The Right Tools for the Job: At Work in Twentieth-Century Life Sciences*, edited by Adele Clarke and Joan Fujimura, 257–86. Princeton: Princeton University Press.
Star, S.L., and J. Griesemer. 1989. “Institutional Ecology, `Translations’ and Boundary Objects: Amateurs and Professionals in Berkeley’s Museum of Vertebrate Zoology, 1907-39.” *Social Studies of Science* 19 (3): 387–420.
Stemerding, D. 1991. *Plants, Animals and Formulae: Natural History in the Light of Latour’s Science in Action and Foucault’s The Order of Things*. Enschede, The Netherlands: University of Twente.
Stephens, Z.D., S.Y. Lee, F. Faghri, R.H. Campbell, C. Zhai, M.J. Efron, R. Iyer, M.C. Schatz, S. Sinha, and G.E. Robinson. 2015. “Big Data: Astronomical or Genomical?” *PLOS Biology* 13 (7): e1002195–e1002195.
Stewart, S. 1992. *On Longing: Narratives of the Miniature, the Gigantic, the Souvenir, the Collection*. Durham: Duke University Press.
Stiner, M. 2003. “‘Standardization’ in Upper Paleolithic Ornaments at the Coastal Sites of Riparo Mochi and U¨ C¸ag˘izli Cave.” In *The Chronology of the Aurignacian and of the Transitional Technocomplexes: Dating, Stratigraphies, Culture Implications. Proceedings of Symposium 6.1 of the XIVth Congress of the UISPP (University of Lie`ge*, edited by J. Zilha˜o and F. d’Errico, 49–59. Belgium.

Stocking, G. 1985. *Objects and Others: Essays on Museums and Material Culture*. Madison: University of Wisconsin Press.
Stoler, A. 2010. *Along the Archival Grain: Epistemic Anxieties and Colonial Common Sense*. Princeton: Princeton University Press.
Strasser, B. 2006. “A World in One Dimension: Linus Pauling, Francis Crick and the Central Dogma of Molecular Biology.” *History and Philosophy of the Life Sciences* 28 (4): 491–512.
———. 2008. “Genetics. GenBank--Natural History in the 21st Century?” *Science (New York, N.Y.)* 322 (5901): 537–38.
———. 2010. “Collecting, Comparing, and Computing Sequences: The Making of Margaret O. Dayhoff’s Atlas of Protein Sequence and Structure, 1954–1965.” *Journal of the History of Biology* 43 (4): 623–60.
———. 2012a. “Collecting Nature: Practices, Styles, and Narratives.” *Osiris* 27 (1): 303–40.
———. 2012b. “Data-Driven Sciences: From Wonder Cabinets to Electronic Databases.” *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 43 (1): 85–87.
Strasser, B., and S. De Chadarevian. 2011. “The Comparative and the Exemplary: Revisiting the Early History of Molecular Biology.” *History of Science* 49 (3): 317–36.
Strasser, B., and B.E.T. Fantini. 1998. “Molecular Diseases and Diseased Molecules: Ontological and Epistemological Dimensions.” *History and Philosophy of the Life Sciences* 20 (2): 189–214.
Strathern, M. 1992. *Reproducing the Future: Anthropology, Kinship, and the New Reproductive Technologies*. New York: Routledge.
Strathern, P. 1999. *Crick, Watson, and DNA*. New York: Anchor Books.
STRI. 2016. “Smithsonian Tropical Research Institute.” http://www.stri.si.edu/.
Strohman, R. 1997. “Epigenesis and Complexity: The Coming Kuhnian Revolution in Biology.” *Nature Biotechnology* 15 (3): 194–200.
Suarez, A.V., and N.D. Tsutsui. 2004. “The Value of Museum Collections for Research and Society.” *BioScience* 54 (1): 66–68.
Suchman, L. 2005. “Affiliative Objects.” *Organization* 12 (3): 379–84.
Sunder Rajan, K. 2005. “Subjects of Speculation: Emergent Life Sciences and Market Logics in the United States and America.” *American Anthropologist* 107 (1): 19–30.
———. 2006. *Biocapital: The Constitution of Postgenomic Life*. Durham, NC: Duke University Press.
———. , ed. 2012. *Lively Capital: Biotechnologies, Ethics, and Governance in Global Markets*. Durham and London: Duke University Press.
Sunder Rajan, K., and S. Leonelli. 2013. “Introduction: Biomedical Trans-Actions, Postgenomics, and Knowledge/Value.” *Public Culture* 25 (3 71): 463–75.
Taussig, M. 1993. *Mimesis and Alterity: A Particular History of the Senses*. New York and London: Routledge.
Thomas, J. 1999. "An Economy of Substances in Earlier Neolithic Britain" In *Material Symbols: Culture and Economy in Prehistory*. J.E. Robb, ed. 70–89. Center for Archaeological Investigations, Occasional Paper 26. Southern Illinois University, Carbondale.
Thomas, K. 1991. *Man and the Natural World: Changing Attitudes in England 1500-1800*. London: Penguin Books Limited.
Thomas, N. 1991. *Entangled Objects: Exchange, Material Culture, and Colonialism in the Pacific*. Cambridge, MA: Harvard University Press.
———. 2010. “The Museum As Method.” *Museum Anthropology* 33 (1): 6–10.
Thorsen, L.E., K.A. Rader, and A. Dodd, eds. 2013. *Animals on Display : The Creaturely in Museums, Zoos, and Natural History*. University Park: Pennsylvania State University Press.

Tilley, C., W. Keane, S. Küchler, M. Rowlands, and P. Spyer. 2006. *Handbook of Material Culture*. London: Sage.
Traweek, S. 2009. *Beamtimes and Lifetimes: The World of High Energy Physicists*. Harvard University Press.
Tsing, A.L. 2005. *Friction: An Ethnography of Global Connection*. Princeton: Princeton University Press.
———. 2006. "Unruly Edges: Mushrooms as Companion Species." Ph.D. Dissertation, Santa Cruz, CA: Department of Anthropology, University of California, Santa Cruz.
———. 2015. "Feral Biologies." In *Anthropological Visions of Sustainable Futures*. University College London.
Twine, R. 2010. *Animals as Biotechnology: Ethics, Sustainability and Critical Animal Studies*. London: Routledge.
Tylor, E. 1896. *"Introduction" to Friedrich Ratzel, History of Mankind*. New York: Macmillan.
UNEP. 2010. "What Is Biodiversity? United Nations Environment Program, World Conservation Monitoring Centre."
Viola, H.J., and C. Margolis, eds. 1985. *Magnificent Voyages The U.S. Exploring Expedition 1838-1842*. Washington, D.C: Smithsonian Institution Press.
Viveiros de Castro, E. 2009. *Métaphysiques cannibales: Lignes d'anthropologie post-structurale*. Paris: Presses universitaires de France.
Wandeler, P., P.E.A. Hoeck, and L.F. Keller. 2007. "Back to the Future: Museum Specimens in Population Genetics." *Trends in Ecology & Evolution* 22 (12): 634–5347.
Waterton, C. 2008. "Experimenting with the Archive." *Science, Technology and Human Values* 33.
———. 2010. "Barcoding Nature: Strategic Naturalization as Innovatory Practice in the Genomic Ordering of Things." *The Sociological Review* 58: 152–71.
Waterton, C., R. Ellis, and B. Wynne. 2013. *Barcoding Nature: Shifting Cultures of Taxonomy in an Age of Biodiversity Loss*. London: Routledge.
Weil, S.E. 1995. *A Cabinet of Curiosities: Inquiries into Museums and Their Prospects*. Washington: Smithsonian Institution Press.
White, R. 1997. "Substantial Acts: From Materials to Meaning in Upper Paleolithic Representation." In *Beyond Art: Pleistocene Image and Symbol*, edited by M.W. Conkey, O. Soffer, D. Stratmann, and and N. Jablonski, 93–121. San Francisco: California Academy of Sciences.
Wilkinson-Weber, C.M., and A.O. DeNicola, eds. 2016. *Critical Craft: Technology, Globalization, and Capitalism*. London: Bloomsbury Academic.
Wilson, E.O. 1988. "The Current State of Biological Diversity." *Biodiversity* 521 (1): 3–18.
Winker, K. 2004. "Natural History Museums in a Postbiodiversity Era." *BioScience* 54 (5): 455–3568.
Wonders, K. 1993a. "Bird Taxidermy and the Origin of the Habitat Diorama." In *Non-Verbal Communication in Science prior to 1900*, edited by Renato G Mazzolini. Firenze: L.S. Olschki.
———. 1993b. *Habitat Dioramas: Illusions of Wilderness in Museums of Natural History*. Uppsala: Almqvist and Wiksell International.
Wright, A.V., K. James, J.A Doudna, and J.K. Nunez. 2016. "Biology and Applications of CRISPR Systems: Harnessing Nature's Toolbox for Genome Engineering." *Cell* 164: 29–44.
Ye, C., S. Liang, Z. Yan, M.L. Zepeda, P.F. Campos, A. Missael, V. Velazquez, et al. 2014. "A Phylogeny of Modern Birds." *Science* 346 (6215): 1126–38.
Yong, E. 2016. "Funding Freeze Hits Natural History Museum Collections." *The Atlantic*. . http://www.theatlantic.com/science/archive/2016/03/funding-freeze-hits-natural-history-museum-collections/474981/.
Young, A.M. 2007. *The Chocolate Tree: Natural History of Cacao*. Gainsville: Florida University Press.

Zhang, G., E.D. Jarvis, M. Thomas, P. Gilbert et al. 2014. “A Flock of Genomes.” *Science* 346 (6215): 1308–8075.

Zimov, S.A. 2005. “Pleistocene Park: Return of the Mammoth’s Ecosystem.” *Science* 308 (5723): 796–98.

Zorach, R., E. Rodini, S. Cree, A.M. Korey, L. Markey, and D. Schuld. 2005. *Paper Museums: The Reproductive Print in Europe, 1500-1800*. Chicago: David and Alfred Smart Museum of Art, University of Chicago.