Bird Skin to Biorepository: Making Materials Matter in the Afterlives of Natural History Collections

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Abstract: Examining the material practices of museum genomics, my ethnographic research focuses on the Global Genome Initiative at the Smithsonian National Museum of Natural History in Washington D.C., a project that seeks to preserve vanishing biodiversity for an uncertain future by cryo-preserving half of the families of life in the next six years. Through stuffing a bird skin, taking genetic samples, and sub-sampling tissues for DNA extraction I examine a return to encyclopedic collecting with biotechnological tools, exploring how biotechnology is redefining and preserving "life itself" (Foucault 1970; Kowal and Radin 2015). This article examines one instance of how museum collections are made, standardized, and shared at the Smithsonian. Contrasting perspectives from ethnographic work in the Division of Birds and the Biorepository, I examine the friction and flow of biodiversity as specimens are transformed into data through material-semiotic practices. I analyze how these data and specimens then undergo multiple re-classifications as categories for new types of museum objects—such as genetic samples—are negotiated. Cryo-collections are "made to matter" (Barad 2003) as ontological embodiments through their preservation, multiple uses, and standardization across disciplines. Through attending to the (bio)materials themselves, I argue the practices currently structuring a shared ecological future become legible.

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1.0 Introduction: organizing archives of life in the Anthropocene

In the face of increasing extinction rates, with an estimated 50% of all species potentially heading towards extinction by mid-century (Barrow 2009; IUCN 2017), 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, such as the Smithsonian's Global Genome Initiative (https://ggi.si.edu/), part of a coalition of genomic collecting projects at the National Museum of Natural History in Washington, D.C. Natural history museums have also shifted to echo this perspective of preserving for the future, 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, Corthals, and DeSalle 2009; Graham et al. 2004)—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. Each of these institution's collections of specimens, tissue samples, and data are woven into knowledge organization structures unique to their specific histories (Bowker 2000; Knorr-Cetina 1999; Lampland and Star 2009; Turner and Greene 2014). Within these contexts, communities of scientists (Droege et al. 2014; Ibekwe-Sanjuan and Bowker 2017; Leonelli 2013; Page et al. 2015) are collaborating to standardize data practices across museums to render them discoverable and computable for biodiversity big data projects.

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 these museum-based assemblages of vouchers, tissue samples, and data. By attending to how biodiversity is being standardized in the museum, I focus on the material practices and disciplinary biases that inform making and maintaining collections. I argue that these processes are redefining how life itself is being categorized and archived with implications for collective ecological futures that will be defined through biodiversity data.

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 fifty, years ago—is rapidly shifting the value of collections in the face of these new demands. Valued now as sources of potential insight into historic climate change, population bottlenecks, and extinction events, natural history collections have become "windows into the past" that can potentially provide solutions for our own species' imagined future needs (Smithsonian Institute for Biodiversity Genomics https://biogenomics.si.edu/). Natural history collections are also, perhaps primarily, cultural artifacts of our species' multiple and on-going redefinitions of what constitutes the "natural world"—as defined in the Global North. As the material world of Anthropocenic "nature" becomes a site of contesting interests and values, 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—be they bird skins stuffed with cotton and arranged in drawers, or rows of frozen tissue samples stacked in liquid nitrogen tanks.

"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). However, I would argue that these storehouses of information have been configured in specific ways, based on the specific cultural histories that formed them, which in turn have shaped the kinds of information they can produce, or more precisely, "be conceived of producing." The conceptualization of the collection as a resource that can provide knowledge 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 and their associated data structures. Through collecting, processing and circulating specimens, their parts, and their data, museums remake the natural world, binding the collections to disciplinary pasts while forecasting future uses.

2.0 Folding time: standardizing practices at the Smithsonian

Focusing on negotiations at the Smithsonian National Museum of Natural History between 2014-2016, this article examines the material practices for creating standardized specimens. Through ethnographic engagement with different "communities of practice" (Lave and Wenger 1991) in the Smithsonian National Museum of Natural History's Division of Birds and Biorepository, I learn how a bird's body can come apart in multiple ways—disarticulated into a skin, tissue samples, feathers, bones, and sub-sampled tissues for DNA extraction.

An analytical chain binds together these different parts of a specimen as it is divided into parts and distributed across spaces in the museum: from a whole specimen (a stuffed bird skin in the Division of Birds), to associated pieces (tissue frozen in the Biorepository), to the different kinds of data derived from these pieces (collection data, accession data, and now genomic data). With the integration of genetics into this analytical chain, the relationship between "original and parts" is being fundamentally reconsidered, as debates over whether a tissue sample or DNA extract can serve the same function, for example, as a bird study skin, call into question fundamental concepts about the nature of collecting and preserving life and how the ontological relationship between these parts and pieces should be organized (de Almeida Campos and Gomes 2017). Is the goal to preserve genomes or individual representatives of a species? What kinds of data does each object condense or discard? Further, what capacities or limitations are built into the biomaterials themselves and the ways they are made and remade in the process of crafting specimens and their associated data structures?

Following this thread, I examine making specimens in two distinct spaces within the Smithsonian. In the workrooms of the Smithsonian National Museum of Natural History Division of Birds, I learned to prepare a bird study skin, take tissue samples, analyzing the folding of time between new and old techniques. Exploring the bird collections with specimen preparators and curators, I gathered a layered perspective of the emerging uses for natural history collections. I then follow my bird tissue sample to the Smithsonian's Biorepository, learning the process of removing tubes from the liquid nitrogen tanks to sub-sampling the frozen tissue for later DNA extraction. Among the abstracted bits of preserved biodiversity, developing biotechnological techniques moved hand in hand with the ethical imperative to preserving "life on ice" for an uncertain future. While these processes are entangled with their disciplinary pasts, both practices and policy-level decisions in the Division of Birds and the Biorepository are being reconfigured by the changing material practices of genomics. That is, ways of making molecular specimens influence ways of thinking about their potential utility and value for multiple imagined futures. This is accomplished by folding time in traditional work-flows, extending existing ways of knowing and making (Harris 2007; Pickstone 2001) by incorporating new techniques and technologies into proven specimen preparation practices. "Collections care," according to Carol Butler (Smithsonian Institution 2017), the Assistant Director for Collections at the Smithsonian National Museum of Natural History, "is a hopeful investment in the future." Or, as the director of a genomics project at the Smithsonian often said (Van Allen 2016, 324), "Museums are in the forever business."

As specimens' biologies are unbound into differently valued parts and pieces, spread across the spaces of the museum—from frozen tissue samples to bird skins in cabinets to globally dispersed data—it is important to remember that specimens remain sites of contested classificatory meanings, objects of shifting value, and (dis)embodiments of hand-crafted "natural orders" (Daston 2004) that are being used to mark time in the Anthropocene. Further, a specimen's capacity to carry the heavy burden as an archive of life, ready to be tapped for an uncertain future, is inextricably bound up in the material-semiotic practices of its making.

3.0 Biodiversity inventories as data collections

Over 50% of individual wild animal species are estimated to have gone extinct since the 1970s (Cardinale et al. 2012; WWF 2016), which for scientists' intent on collecting biodiversity "underscores the vital inherent value of museum collections today, tomorrow, and into the future" (Kress 2014, 3010). In the context of massive and continuing losses in biodiversity, museums are being re-evaluated 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 in the museum? Further, how do the evolving museum practices of mining and extending the collections with new specimens and genetic samples shape these forms of life? Or, shifting to a larger context, how do museum practices shape our own species' relationship to the rest of the global assemblage of non-human species?

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. These include 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 both morphological (such as bird skins in a cabinet) and molecular (DNA frozen in liquid nitrogen) specimens. Part of crafting specimens is crafting the data with which they are inextricably entwined. Databases are also artifacts, part of the web of knowledge production within the museum (Leonelli 2012b; Mohns and Geismar 2010), forms of archives (Derrida 1996), that bind up the different kinds of biomatter in chains of relation—voucher specimen to tissue sample to extracted DNA to genetic data.

As scholarship in both the biological sciences (Pyke and Ehrlich 2010; Winker 2004), history of science (Daston 2000; 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, and pressed plants I learned to make during my fieldwork in the various scientific cultures of birds, entomology, or botany at the Smithsonian National Museum of Natural History. However, the application of new technologies to study specimens is expanding, becoming integrated into the traditional practices, or in some cases disrupting them, as I learned through sub-sampling tissues and sorting data in the Smithsonian's Biorepository. Much of the current scientific understanding of several recently extinct species–including 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 (Miller et al. 2009; Rocha et al. 2014; Schipper et al. 2008). 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; Horváth et al. 2005; Rohland and Hofreiter 2007; Nachman 2013).

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 (Bi et al. 2013; Hykin et al. 2015; Janecka et al. 2015) are as high as three billion specimens. "A pressing challenge is to continue to build scientific collections for future needs," writes former Smithsonian Secretary for Science John Kress (2014, 3010).

"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," a curator in the Division of Birds told me as we went through several locked doors into the type specimen collection, on our way to look at a Hudsonian godwit (*Limosa haemastica*, USNM A8074) collected and prepared by Charles Darwin in March 1833. "Now we use them for things they never could have imagined." When I ask her what future uses she can imagine for the collections, she pauses (Van Allen 2016, 217): "We can't know, of course, what direction technology will go … But we can prepare things in different ways—like pickling the specimen [preserving in alcohol] 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."

Predicted future needs 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. 2014; see also the Global Genome Biodiversity Network [http://www.ggbn.org/ggbn_portal/]) 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 (Kress 2014, 3010), 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." 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 it's associated metadata that combine to define its (potential) value as it moves across domains.

4.0 Making materials matter, part I: how to build a bird

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 these 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 2 mL 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 Smithsonian's Global Genome Initiative (GGI)—has deep implications for the disciplines in question. Each Department and Division has its own history of collecting and an existing set of standards that values particular parts of an organism, distinct ways to preserve it based on those evaluations, and specific kinds of data relationships that are deemed vital (Baker 1998; Graham et al. 2004; Marty and Jones 2012). Genomic collecting protocols, such as the Global Genome Initiative's, call many of these practices into question and are in the process of reshaping how, what, and why biodiversity is biobanked across disciplines.

As I learned to make specimens first-hand, this brought into focus various continuities and ruptures in the different disciplinary histories of material practices in the museum. One example of this folding of time occurred in the Vertebrate Zoology Preparation Lab at the Smithsonian National Museum of Natural History's Division of Birds, where in January 2014 I learned 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. Semi-frozen bird on the table in front of me, I measured the distance up from the cloaca 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 I 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 2 mL plastic tube, I carefully labeled each one and put them in the lab's freezer. Returning to my bird skin to stuff it with cotton wool, I used 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 instance, may be an actual heart. As I traced the path of sampled heart tissue frozen in a cryovial, its circulation to the lab and then the biorepository, I saw what different materials and concepts are variously broken apart, brought together and how they change as they move across borders. The same biomaterial from a bird accumulated different meaning and value as they moved across domains and became "legible" to different audiences—the discarded internal organs from the Division of Birds becoming a precious fieldsite for invertebrate zoologists to collect parasites, or the toepad of a nineteenth century bird study skin being sampled by conservation biologists. 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. The knowledge structures underlying these emerging audiences for collections also, in turn, shape the collections themselves as they expand with new types of objects such as tissue samples and DNA extracts, and are reorganized in an attempt to contain new and ever-emerging categories.

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). 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 (2012, 310), "complicates the effort to render flesh as data." 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).

My bird's body and its parts, I suggest, function as boundary objects (Star and Griesemer 1989; Star 2010) between practices, knowledges, and disciplines at the museum. The complicated translations needed to make shifting scientific objects coherent across boundaries underscore how "objects 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?" (Star and Griesemer 1989, 392). As a type of many-to-many mapping, 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 mite extracted from a feather for the Parasite Collection. Yet they are all rendered (semi)legible across these boundaries by the thin threads of (increasingly standardized) data (Wieczorek et al. 2012; see also the Biodiversity Information Standards Taxonomic Working Group http://www.tdwg.org). 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). This "stickiness" in the materiality of my practical encounter 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 and the ways in which they were categorized as either valuable or as biowaste.

5.0 Making materials matter, part II: how to use feathers and bones

More than 640,000 bird specimens are housed at the Smithsonian's various facilities—the third largest bird collection in the world (Smithsonian National Museum of Natural History, Division of Birds http://vertebrates.si.edu/birds/). In the Smithsonian National Museum of Natural History's Division of Birds long corridors lined with white metal cases stretch out into a labyrinth, row after row, stacked three cases high. 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. I asked curators, collection managers, and specimen preparators how they saw the uses of collections change, and to show me different preparation methods that related to those histories. Where these narratives intersected and diverged provided a view into the epistemological spaces within a disciplinary "culture" (such as the Divison of Birds compared to the Department of Mammals or the Division of Invertebrate Zoology) where subtly different practices, and their associated value systems, were in the process of changing. These included how changes in the materials used for specimen preparation influenced their later use to changes in collecting methods in the field.

February 2016—I'm helping pull out a drawer that spans the width of the cabinet. 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 1). Whatever form biodiversity takes, even the 9 foot height of an adult male ostrich, is compressed and folded into the standardized space of the collection drawer. Practices of standardizing specimens take many forms. However, these practices can be obscured by the spectacle of the organism itself—the oddity of a huge bird with ornate plumage folded away like a winter coat takes precedence over the fact that it fits into the same sized drawer as the tiny hummingbirds several corridors over.

I've asked the preparator I'm with 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). There are many more kinds of preparation and subtleties between them than I ever imagined. We talk as we move between the cabinets, opening drawers and handing birds' skins, nests, dried wings, and cleaned bones back and forth. In a drawer of thighbones, a huge bone the size of a baguette takes up the left side of the drawer. Another 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. Looking through the drawers of study skins, I ask him 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 a recognizable "style" that can be "read" across the drawers. Nature is variable but so are the techniques of those who craft it. Practices are changing not only in the preparation labs in the museum, but also in the amount of equipment required when collecting genetic samples in the field:

November 2014—a preparator tells 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. These narratives are echoed in each path I trace through the collection with a different ornithologist, collection manager, or specimen preparator. The collections have become valuable in unexpected ways for new kinds of research, with new categories of researchers from parasitologists to epidemiologists requesting access to the collections:

July 2015—"they're even getting DNA out these nowadays," one of the staff from the Feather Identification Lab tells me as we look at a drawer full of eggs. "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." Resources of a specimen are finite, and decisions about what constitutes proper use are negotiated for every request to take a piece of a specimen.

February 2015—opening a cabinet, a preparator shows me some of the first specimens that had been sampled for genetic projects, their collection of toe tags accreting with each sampling event. "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 actual slicing isn't the hard part, I'm told, it is getting permission to do so. However, some parts of specimens were collected unintentionally and provide new resources in unexpected ways:

March 2015—"[The Division of Birds] has saved feathers from every skeleton prep for at least the last ten years," another preparator tells me. In the process they have accumulated a feather library that has, 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 parasitologist hunting for mites. A parasitologist went through the feathers, "holding each plastic bag up to the light and see if there were any little black dots, which meant there were mites ... She went through the whole collections, 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.

Figure 1. An ostrich collected by Theodore Roosevelt during a 1909 African safari. Note the newspaper still visible through the eye. (Smithsonian National Museum of National History, Division of Birds, March 2015). Photo by author.

More uses of the collection, in effect, validate the existence (and expense) of the collections and its staff and help ensure its future. This orientation to the future shifted across multiple scales, articulating multiple types of time in the museum, including 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 negotiating the incorporation of new types of objects, such as tissue collections and their associated data, into the maintenance of their collections and databases, both preserved for perpetuity.

6.0 Making materials matter, part III: how to build a biorepository

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 large enough I could climb inside of them. 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 2). The rest of the tanks await samples from future collecting expeditions, which hinge on the Global Genome Initiative (GGI) securing funding and Smithsonian scientists securing permits for sites worldwide where desirable 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. 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 are concentrated together in this part of the 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 in a sealed cleanroom, the nation's collection of meteorites is 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. 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.

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 2). Between them sits a tub of liquid nitrogen with a tray of small plastic tubes. 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 to confirm that it is indeed the correct piece of snake tissue from Myanmar, then 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 who are overseeing the procedure.

The younger pair are being taught how to sub-sample tissues, a collaboration between the Global Genome Initiative (GGI) and the Consortium for the Barcode of Life (CBOL), another genetic collecting project at the Smithsonian focused on 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. 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 and carefully slice a tiny piece off. 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 its 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. When the tissue lump is separated from its labeled tube, and from its assigned place in the rack of tubes, it has the most likelihood of ending up losing 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

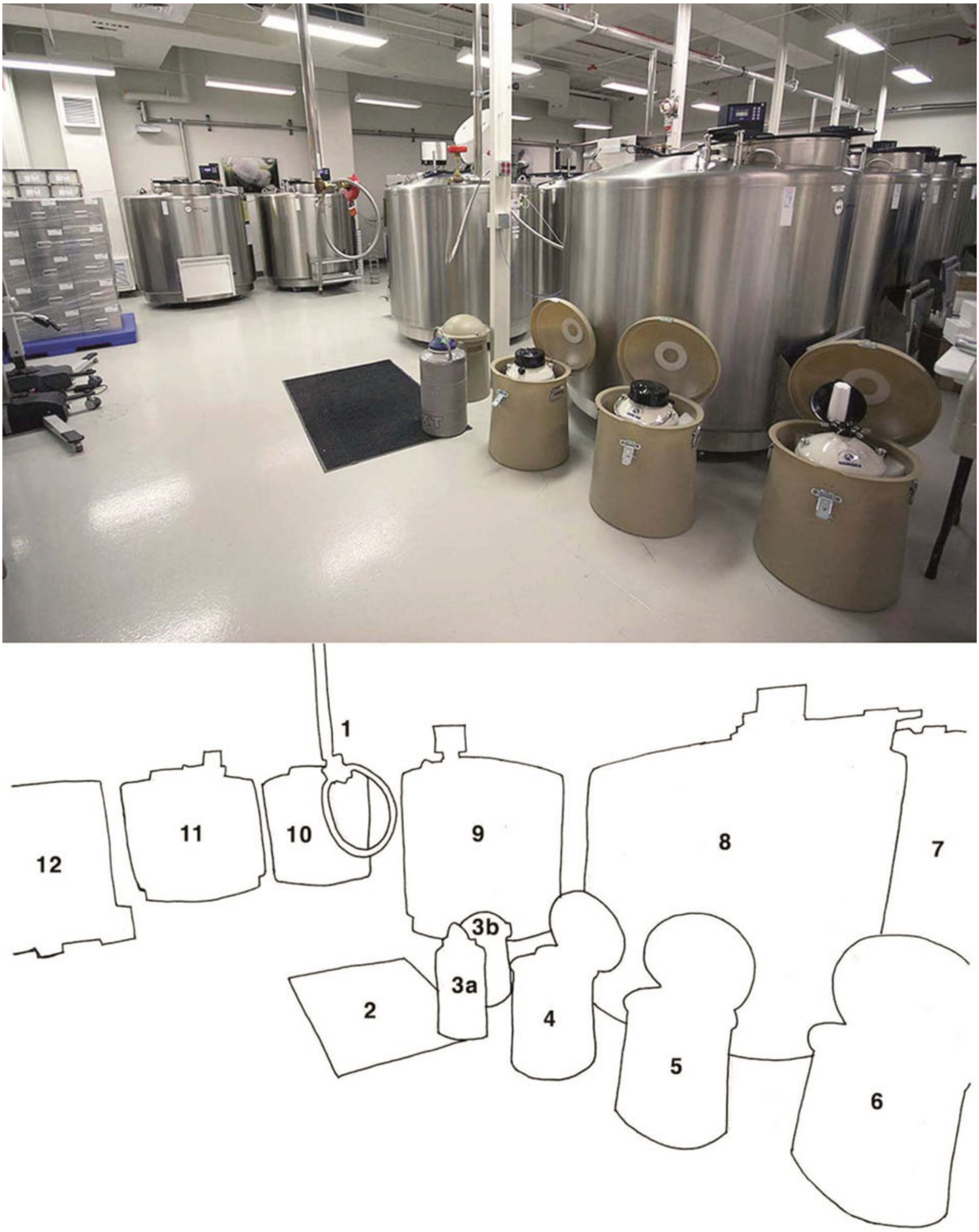

Figure 2. Anatomy of a Biorepository: 1. liquid nitrogen dispensing hose; 2. drip mat; 3a. dewer, inner tank; 3b. dewer, outer transport shell; 4-6 dewers ready for filling; 7-11. the liquid nitrogen tanks holding frozen specimens; 12. empty racks ready to fill up with specimens and store in the tanks.

(Smithsonian Biorepository, December 2014). Photo and illustration by author.

to gain lawful access to the specimen in the first place, a negotiation between nations and their institutional infrastructures. Further parts of the process include 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 this accumulated 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 deeply invested with these values and interests. Keeping these abstracted 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, such as the bird study skin I crafted in the Vertebrate Zoology Prep Lab. Though new uses for old collections of morphological specimens are ever-emerging, 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—a beetle pinned with its legs in perfect symmetry, a bird skin with the feathers neatly arranged, an alcohol-preserved snake coiled to fit into a jar. The molecular specimen is always 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 bit of tissue is categorized as waste or byproduct. Indeed, the demo tissue tubes used to show visitors how the Biorepository system works are standard 2 mL cryovials with biorepository labels, however they are filled with chicken liver scraps from the local supermarket.

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. 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. 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 a very literal version of the "sticky materiality of practical encounter" (Tsing 2005, 3), 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 "really 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 gestured 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 do field collecting. "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 stuff 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. 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 tissue tubes is crucial. 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. The boxes in this freezer represent only what is currently being used in projects, or legacy collections still waiting to be integrated back into the main collections, the genetic portion of which is now (slowly) being centralized in the Smithsonian 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" (Radin 2013) 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.

7.0 Crafting specimens: a view from below

At the intersection of scholarship on the museum (Alberti 2011; Findlen 1994; Thomas 1991) and the life sciences (Franklin 2007; Haraway 1997; Knorr-Cetina 1981; Rabinow and Rose 2006), the emergence of genetic collecting within the museum has only begun to be addressed. While previous scholarship has provided valuable perspectives on the shifting value of genetic collections (Ellis 2008; Hayden 2003; Parry 2004), I suggest that an integrated approach must consider the biomaterial itself, and further, the types of physical and conceptual labor required to create and maintain these categories of valuable "latent life" (Radin 2013). My approach engages the material culture of museum genomics behind-the-scenes, a place usually invisible and inaccessible to the public. Through exploring first-hand the making and re-making of genetic and traditional collections and their data, I ask what is being made, how it is being made meaningful, by whom, and for what purposes?

Attending to the material practices involved in making specimens, genetic samples and data provides a view into the process "from below" (Harding 2008), and I have aligned my ethnographic perspective with the collection managers, specimen preparators and lab technicians who produce and maintain the collections. My experiences in the work rooms of the museum—stuffing birds and subsampling tissues—provides insight into the specific kinds of value, imagined future uses, and shifting epistemologies of ordering (genetic) nature in the museum. What parts of specimens should be preserved? What counts as "genome-quality," and what kinds of labor are involved in creating and maintaining that standard? Finally, what are the implications of these shifting practices for our shared ecological futures?

Importantly for thinking through a material-semiotic approach to museum genomics, I follow Chris Gosden, Frances Larson, and Alison Petch (2007) 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" (Geismar 2009, 1). 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. By contrasting different perspectives gleaned from ethnographic work in two workrooms at the Smithsonian, the National Museum of Natural History's Vertebrate Zoology specimen preparation lab on one hand and the Biorepository lab on the other, I have examined the oscillations and frictions that constitute biodiversity biobanking at the Smithsonian. Examining how "matter comes to matter" (Barad 2003), I have explored the intimate and fluid connections between the minutiae of crafting biological organisms, their tissue samples, their DNA, and embedded within them the vision for shared human and non-human futures. Genetic biobanks—and the power relations embedded in the conceptual frameworks and practices that drive them—have implications that reach far beyond the museum, into research fields as diverse as agriculture, pharmaceuticals, medicine, energy production, national security and potentially de-extinctioning species (Church and Regis 2012; Franklin and Lock 2003; Ong and Collier 2005; Rader 2004). Analysis of the relationship between the classification of nature and the instrumental uses to which it is put has emphasized the co-production of classificatory systems with broader political, economic, social and ethical frameworks. It is through attending to the (bio)materials themselves, I suggest, that the production processes and future limitations of making and organizing scientific knowledge become legible.

8.0 Conclusion: standardizing specimens and the afterlives of collections

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). 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.

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). 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, and the ways in which they were prepared.

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 Carl 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). These physical objects are also part of today's data (Strasser 2012a), which is no less diverse than the data of natural history collections.

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 left-over carcass from the bird I prepared, for instance, became "biowaste" after I took a tissue sample. That cryovial of frozen tissue, a tiny fraction of the bird's original biomass, then became a precious resource to be divvied out in minute pieces.

The process of producing a genome-quality tissue sample, I suggest, is also the process of condensing the value of the specimen into the space of the cryovial. Each discipline within the museum was ingrained with a view of what constitutes a proper natural order, and these in turn determined what was preserved for posterity and, therefore, available for future use. The implications of these daily decisions about what to discard or valorize during the specimen preparation process—that is, how disassembled specimens are made to be valuable through those decisions—determine what kinds of uses can and will be made of these inherently "vital resources" in the future. Materials are made to matter, and each of the objects I have chosen to examine in this article—from a disassembled a bird body, to its tissues, to the array of preparation types in the bird collections, to the emerging types of frozen life in the Biorepository—offers a distinct view into the distinct disciplinary histories they carry with them and are now being challenged by the integration of standardized cross-disciplinary genetic collecting practices. 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 Rheinberger (1997) and Knorr-Cetina (1999) remind us, scientific-epistemic objects are best characterized by their state of continual (re)emergence.

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 data organization (Griesemer and Shavit 2011; Turner 2016). 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 (GGI 2013). Each discipline has its own version of "nature" and "natural order" that is legible in the particular ways it crafts specimens, samples, data, and produces standards to make these objects legible across disciplinary borders. Through analyzing these different modes of crafting nature and crafting standards in the museum, I suggest natural history collections are at a pivotal moment of transformation, where the introduction of genomics is redefining what life is, how it is preserved, and how it should—and could—be used.

The instrumental uses to which a classified and standardized "nature" can be put has emphasized the co-production of classificatory systems within socio-economic and ethical frameworks. I reiterate that it is through attending to the (bio)materials themselves that the choices which structure emerging definitions of life and the conditions of possibility for a shared ecological future become legible. As different visions of life are archived in museums—in the form of stuffed bird skins, their feathers, cleaned bones, recorded bird songs, frozen tissue samples, or genomic data—we must remember that visions for a collective future are also being archived, bound up with each of these specimens and their afterlives.

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