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21st Century Bioarchaeology: Taking Stock and Moving Forward

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ABSTRACT

This article reflects outcomes from a Workshop entitled, "Bioarchaeology: Taking Stock and Moving Forward," which was held at Arizona State University (ASU) on March 6-8, 2020. Funded by the National Science Foundation (NSF), the School of Human Evolution and Social Change (ASU, and the Center for Bioarchaeological Research (CRB, ASU), the Workshop's overall goal was to explore reasons why research proposals in physical anthropology submitted by bioarchaeologists, both graduate students and established scholars, are faring disproportionately poorly and offer advice for changing such outcomes. Therefore, our workshop of 39 scholars and four advanced graduate students with a history of successful grant acquisition, primarily from the United States (US) focused on two related aims: 1) advising on methodological issues for improving research designs; and 2) evaluating topics of contemporary significance that reverberate through history and beyond, as possible trajectories for bioarchaeological research. Among the former were contextual grounding, research question/hypothesis generation, statistical procedures appropriate for small samples and mixed qualitative/quantitative data, the salience of Bayesian methods, and training program content. Topical foci included social inequality, identity (including intersectionality), climate change, migration, violence, epidemic disease, adaptability/plasticity, the Osteological Paradox, and the developmental origins of health and disease (DOHaD). Given the profound changes required globally to address decolonization in the 21st century, this issue coursed through a number of discussions and is also reported here.

1. INTRODUCTION

1.1 Bioarchaeology

Over the past 50 years, bioarchaeology[1] has emerged in as an explicitly interdisciplinary and aspirationally transdisciplinary[2] field of inquiry, with its closest intellectual links to biological anthropology and anthropological archaeology. Although theoretically grounded in the social and behavioral sciences, it also embraces methods and theories drawn from the other sciences and the humanities. This bioarchaeology has matured and diversified into a globally recognized field of study; the term itself is now translated into a number of languages, reflecting a coalescence of older, global bioanthropological and physical anthropological traditions. Thus, the goals and literature in different evolutionary anthropology and archaeology traditions around the world are fusing around an increasingly global bioarchaeology. Several English-language journals are devoted to publishing research in the field including *International Journal of Paleopathology*, *The International Journal of Osteoarchaeology,* and *Bioarchaeology*

[1] In this contribution, we reference human bioarchaeology, the study of human remains from Holocene archaeological and historical contexts, recognizing that the term has also been applied to zooarchaeology (Clark, 1972) and may be used more generally to reference the study of any organic remains recovered from archaeological sites. The more general definition is more commonly used in Europe and the UK than in US. Because of the explicit goals of this Workshop and the primary funding source, as noted later in the introduction, this paper focused upon bioarchaeology in the United States. For this reason, bioarchaeology is considered to include paleopathology (the study of ancient health and disease), which is considered a distinctive field of study in some countries.

[2] "Transdisciplinary," as used here, refers to bioarchaeological research that explicitly addresses contemporary issues that threaten well-being, such as inequality, violence, and epidemic disease. "Bioarchaeology," by its very nature is interdisciplinary.

International. Many other top-tier journals in the field of anthropology frequently publish bioarchaeological studies, the *American Journal of Biological Anthropology* (AJBA)[3]*, Antiquity,* and the *Journal of Archaeological Science* (JAS), *JAS Reports*, for example. Indeed, bioarchaeological and paleopathological research make up the largest proportion (39% in 2020) of research articles published in the *AJPA* relative to other subject areas.[4] Bioarchaeologists have developed two book series devoted to bioarchaeological research: Bioarchaeological Interpretations of the Past: Local, Regional, and Global Perspectives (University Press of Florida) and Bioarchaeology and Social Theory (Springer Publishing Company), edited by Clark S. Larsen and Debra L. Martin, respectively.

The popularity of bioarchaeology among advanced students and young professionals suggests that the current visibility and prominence of bioarchaeology will be sustained into the foreseeable future. Undergraduate bioarchaeology courses are hugely popular in US colleges and universities. Another sensitive indicator of the field's future prospects is the number of excellent students wishing to obtain advanced training and to spend their professional lives as bioarchaeologists. Applications from prospective bioarchaeology graduate students even outpace those of other sub-fields in some prominent US anthropology programs. Each year, advertisements for university and museum positions are posted that specify bioarchaeological training as a desirable or required qualification; bioarchaeological field programs are regularly offered throughout the world as are post-doctoral positions. Again, demonstrating bioarchaeology's popularity, in 2018 an interest group was organized within the Society for American Archaeology dedicated to fostering research and training in bioarchaeology. They held their first meeting in 2019 and by 2021, the group had approximately 1000 active members. Its well-attended inaugural symposium organized by founding Chairs Alexis Boutin and Sabrina Agarwal, "The Future of Bioarchaeology in Archaeology," was held at the SAA Annual Meeting, Albuquerque NM, April 10-14 2019.

Popular culture studies, largely derived from European and Euro-American contexts, find that people are fascinated by bioarchaeology. Seeing and learning from ancient remains can be an excellent illustration of scientific approaches, as represented in television programming, museum displays, or specialized "Body Worlds" (see summary in Buikstra 2019b). Bioarchaeology is an important conduit for the public to engage with the past because they feel a great connection with the remains of past people, finding there stories henceforth untold. We note that we need to balance the desire of some for science-based knowledge with opposition from people from some cultural traditions, such as certain American Indian tribes, to the display of human remains. Members of the Workshop cautioned, however, against imposition of perspectives on repatriation and reburial from North America into parts of the world where there are different perspectives on the viewing and scientific study of the human body, past and present.

Bioarchaeology embraces osteobiographical approaches and the potential for narratives to excite public interest (Hosek and Robb, 2019; Stodder and Palkovich, 2012) and reduce prejudice (Boutin, 2019; Boutin and Callahan, 283-303), yet the difference between well-contextualized inferences and story-telling must be made clear in graduate training so that the potential for bioarchaeology to inform our understanding of the past in ways that benefit living people can be maximized. The relationship of bioarchaeology to its closely aligned (but

[3] Prior to January, 2022, *The American Journal of Physical Anthropology.*
[4] (https://physanth.org/documents/275/2021_Report_of_the_Editor_AJPA.pdf)

distinctly different) field, forensic anthropology, also requires consideration, particularly given the interest generated by the latter at the undergraduate and graduate levels.

Importantly, topics that bioarchaeologists study (e.g., the effects of climate change, the evolution and biocultural context of human health, interpersonal violence) have profound relevance today and the results of our work have the potential to inform the choices of living people now and into the future. An initial effort in addressing such issues is found in *Bioarchaeologists Speak Out: Deep Time Perspectives on Contemporary Issues* (Buikstra, 2019a). Further stock-taking is timely, however, especially for evaluating the central goals and training programs in our field. Formal coursework in ethics and responsibilities to descendent communities and other communities of concern is insufficient or completely absent within many curricula. Appropriate analytical methods for integrating the myriad data forms that excite bioarchaeological interest are underappreciated or underutilized by many bioarchaeologists, and there is a general need to improve the scientific rigor of bioarchaeological research and to enhance and expand training in research design. Hypothesis-testing has been and continues to be a mainstay of bioarchaeological research; we underscore that here, though we appreciate that there are other ways of interpreting the past in systematic and rigorous ways. The need for further standardized methods, data sharing, and data repositories is crucial. Striking a productive balance between methodological specialization and theoretical expertise remains problematic. The Bioarchaeology Workshop reported here represents one step in the collective discussions required for the resolution of such issues. We look forward to other such conferences to further advance the field, preferably in other regions of the globe.

An initial stimulus for the Workshop, as noted in 1.2., was the recognition that bioarchaeology proposals were not faring well within the Biological Anthropology Panel at the US National Science Foundation (NSF). With these and related issues in mind, the 2020 Workshop was designed to 1) seek advice from (primarily US) participants for improving the quality of proposal from bioarchaeologists to the NSF, and 2) in the context of exploring important questions suitable for NSF bioarchaeological research proposal, address 21st century prospects for the field. As profound social justice issues and the COVID-19 pandemic loomed increasingly large during the conference planning, the workshop itself, and subsequent preparation of this article, the second goal became increasingly prominent. The few international voices were included in order to sample global opinion and to explore prospects for further workshops in other world areas. It was not our goal to develop a statement on bioarchaeology from a globally representative group, but rather to use this moment as a stock-taking that would be enhanced in the future by adding other voices from a balanced assembly of international and BIPOC[5] scholars.

An international forum of bioarchaeologists drawn from across professional ranks convened March 6-8, 2020 in Tempe, Arizona for a workshop focused upon stock-taking and planning for the future of this field of study. We limited participants to those involved in advanced, post-graduate educational initiatives in either university or museum settings, as we felt training and curricula to be of prime importance. This Bioarchaeology Workshop was designed to consider unresolved methodological issues, to recognize current bioarchaeological efforts that are especially productive trajectories, and to identify future topics of concern. Especially in the last two categories, we wish to emphasize the increased need for collaborative, interdisciplinary research, noting that this is one of the skills to be overtly encouraged during graduate training.

[5] Black, Indigenous, People of Color

1.2 The Workshop

In some ways, March 6-8, 2020 might seem not so very long ago however, within a week of returning home from the conference, the United States joined most of the rest of the world and pivoted to travel restrictions, sheltering-in-place, and other responses to the COVID-19 pandemic. As of this writing, we gaze back across a deep abyss created by the American response to the pandemic, which was deepened by profound social issues, such increasing awareness of the violence of racism.

_____ and _____ (henceforth, "the organizers") began planning this workshop in 2017 when they were made aware that bioarchaeological proposals were disproportionately unfunded within the Bioanthropology Program at the NSF. The organizers understood this to mean that there were problems with the framing of proposals by graduate students and more senior scholars, including research design and implementation, which in turn implied a need for improvement within graduate training programs in general. This directly influenced choices for participants, whom the organizers identified as experienced researchers with a successful record in funding from NSF, the Wenner-Gren Foundation for Anthropological Research, or The Social Sciences and Humanities Research Council of Canada between 2008-2018. Initially, given budgetary constraints, we limited participation to North America. Late in the process, during proposal review, we were encouraged to add greater international representation so we scrutinized lists of active researchers in Latin America, the Asia-Pacific Region, the UK and Europe select a few additional participants, given limited resources. This conference was envisioned as the first of several on similar issues in other global location, a goal suspended during the COVID-19 pandemic. By March 2020, COVID-19 was already impacting international travel and ultimately, after withdrawals necessitated by the pandemic, 39 participants, in addition to the organizers and four advanced ASU graduate students in bioarchaeology who served as recorders for the break-out sessions, convened at ASU for the two-day workshop.

While our initial vision was a limited-scale "Workshop on Best Practices," we ultimately decided to take advantage of the assembled expertise, realizing that bioarchaeology would benefit from extending our purview to other issues concerning curriculum and future directions of the field. These included such topics as repatriation and ethical concerns; social issues such as inequality, decolonization, and social justice; transdisciplinarity; methodological problems and solutions; social theories and their application; and best curricular practices. This expanded scope served as the basis for successful funding proposals for the Workshop to NSF and the School of Human Evolution and Social Change (SHESC), with support from the Center for Bioarchaeological Research, at Arizona State University. Details concerning the organization of the workshop appear in the Supplemental Materials.

1.3 Organization of this Paper

The following discussion emerges from the Workshop, although it is not an exhaustive report of the breakout sessions and focus groups. We instead synthesize major points from our discussions and add other relevant materials. For example, mindful of an intervening year that included major social upheaval along with the pandemic, this paper begins by considering significant challenges that bioarchaeology should be addressing. These include topics of general importance to academic scholarship and education, e.g., decolonization and transformation, along with the special ethical issues that pertain to bioarchaeology, due to its focus on archaeologically-recovered human remains and funerary contexts. In subsequent sections, we

treat subjects from Breakout Sessions: Social Inequality (3), Identity (4), Climate Change (5), Violence (6), Migration (7), and Epidemic Disease (8), Adaptation and Plasticity (9), the "Osteological Paradox" and the Developmental Origins of Health and Disease (DOHaD) Hypothesis (10), and Research Design and Quantitative Methods (11).

We consider Graduate Training in Section 12, which draws from the Workshop and additional materials prepared during Summer 2020. Given that the majority of workshop participants are based in the US, our discussion is structured through a review of US training programs in archaeology, addressing issues concerning balance between methods and theory, laboratory and field research, and related topics. In our closing section (13), we summarize our results, while providing recommendations for additional significant research directions, methodological and theoretical advancement, and curricula to meet 21st century needs.

Given the focus of this Bioarchaeology Workshop, there are many important topics in bioarchaeology that are beyond the scope of this article, including the details of important developments in analytical techniques and interpretative methods that are applied in bioarchaeology. These include: adult age-at-death estimation (Milner et al 2019, 2021); biomechanics (Ruff, 2019; Longman et al.) cremation analyses (Cerezo-Roman et. al., 2017; Kuijt et al., 2014; Tiesler and Scherer, 2018); DNA (human and pathogen, Nieves-Colon and Stone, 2018; Orlando et al., 2021); evolutionary medicine (Plomp et al., 2022); isotope analyses (mobility, diet, etc., Burton and Katzenberg, 2019; Guiry and Szpak, 2019; Katzenberg and Waters-Rist, 2019; Moffat, 2015).

2. BIOARCHAEOLOGY, DECOLONIZATION, TRANSFORMATION AND ETHICAL ISSUES

While our formal and informal discussions during the March 2020 Workshop ranged widely, many centered on the coming pandemic and social issues roiling beneath the surface of U.S. (and global) politics. Cross-cutting concerns from nearly all sessions were the development of ethical standards, along with decolonizing and transforming bioarchaeology. The following quotation by Rachel Watkins (2020:20), published at the time of the Workshop, is particularly apt: "*Methodological and theoretical developments that do not change the fundamental structural conditions of the discipline will keep it from attaining a proper level of intellectual rigor and social relevance.*" Workshop participants were united in their endorsement of change; some focused upon social issues and ethics, while others concentrated on theoretical and methodological advancement. We also endorsed an active, sometimes activist stance, rather than simply reacting passively to emerging social and biological currents surrounding us.

In light of health care delivery issues that emerged during the COVID-19 pandemic and protests against racially and ethnically-motivated violence across the globe, social science research is once again prominent in public discourse. Bioarchaeologists address fundamental questions about human behavior and adaptation, and our field provides an exceptional long-term view of these topics. Similarly, we also recognize embedded biases based upon our educational and personal experiences. Anthropology, in particular, must wrestle with the ways that our disciplinary roots are entangled with and have encouraged scientific racism and colonialism. It is relatively easy to condemn instances of racist and colonializing science in our past; it is more difficult to acknowledge the covert ways that this legacy invades our discipline today and to plan for and effect a different future. Biological anthropology is now actively engaged in decolonizing efforts (e.g., Bolnick et al., 2019; Marks, 2017; Mulligan and Raff, 2021); bioarchaeology must

also advance this transformative agenda, as we confront and challenge assumptions implicit in our research designs and practice (Blakey, 2021). We must amplify and elevate historically underrepresented and marginalized groups and thus connect critically and meaningfully with our current cultural and political environment, seeking to dismantle white supremacy and achieve global equity and justice for everyone.

2.1 Decolonizing and Transforming Bioarchaeology

Almost three decades ago, Faye Harrison (1991) called for a decolonized anthropology, one that recognized the social context from which science emerges and that was interdisciplinary and inclusive, inviting the public to participate in the production of knowledge and hold scientists accountable for translating their intellectual products into liberation practice. The goal was transformation at a structural level. While support for decolonization has increased, accelerated recently within biological anthropology as a result of sessions held at annual meetings of the national association (Bolnick et al., 2019), the stark 21st century examples of racial discrimination and genocide, especially those happening in concert with the COVID-19 pandemic, have raised awareness and a renewed sense of urgency. Here we focus on decolonization and transformation and ethical issues within bioarchaeology.

What should the decolonization of bioarchaeology look like? There is already a large body of literature on decolonizing higher education (e.g., Gilmore and Smith, 2005; Bhattacharya, 2015; Louie et al., 2017; Parker et al., 2017; Sumida Huaman and Abeita, 2018) and decolonizing anthropology (e.g., Atalay, 2006; Harrison, 1991; Smith, 1999; Allen and Jobson, 2016). The following announcement by the Society of Linguistic Anthropology illustrates a recent, bold step toward decolonizing their publication program (https://anthrosource.onlinelibrary.wiley.com/hub/journal/15481395/about/author-guidelines).

> The *Journal of Linguistic Anthropology* recognizes the foundational work of Black and Indigenous scholars within our discipline. As of July 1, 2020 peer reviewers will be required to evaluate the extent to which a manuscript's cited references are diverse and inclusive of the following categories: race and ethnicity, gender expression and identity, physical and mental ability, institutional affiliation, national origin (i.e., scholars from the country where the research is conducted), and sexual orientation. The journal is especially committed to the inclusion of recent and established scholarly works by BIPOC authors, from within and outside the discipline. The Journal expects evidence of serious engagement with diverse and inclusive scholarship in terms of acknowledging their contributions to theory and content, and will mandate revisions of manuscripts if this requirement is not met.

In another initiative, the Faculty of Social Sciences and Health at Durham University, is working in collaboration with Dr. Nikki D'Souza and Dr. Jason Arday, is beginning their journey in decolonising academic practices and de-centering whiteness. The twin themes for this initiative are "*Turning Words into Action"* and "*If not now, then when?"*. This program is wide-ranging, including interventions to plug the leaky academic pipeline for students and staff of color, and reverberating through curricula, research initiatives, and external relations (see also Arday and Mirza 2018). The impact of intersectionality is also recognized. Dr. Arday recently undertook a review of race equality practices for the British Association for Biological

Anthropology and Osteoarchaeology (BABAO). This resulted in three key recommendations for increasing diversity and representation, cultural competency, and towards becoming an effective anti-racist organisation. Bioarchaeology Workshop participants look forward to many such efforts and their implementation in the near future. A further resource for decolonization efforts in anthropology is the Society for American Archaeology's (SAA) collection of articles on race, inequality, and decolonization[6]. Compiled by the SAA Publications Committee, it is an organic document, regularly documented, and includes bioarchaeology.

Within bioarchaeology, Watkins (2020) has called attention to Sylvia Wynter's (2003) definition of "biocentricity" as a force driving scientifically normative perspectives, ones which a decolonizing discipline should actively question. The singular importance of reflexive perspectives, which emphasize that cultural constructs are not universals, is a point made across a number of the topical foci we discuss in the following sections, ranging from kinship (Section 4) to violence (Section 7). A decolonized, transformed bioarchaeology will doubtless change the way students are trained, alter the manner in which practitioners legitimize their careers (i.e., rebalancing time committed to research and outreach and appropriately recognizing and rewarding the unique demands of BIPOC faculty with respect to mentorship), and renegotiate our relationships to the people we study. Decolonizing bioarchaeology will require significant shifts in our intellectual *and* institutional spaces—it is not merely an intellectual, essentially passive exercise – it needs to be proactive. True transformation will not happen by accident or automatically with time. A bioarchaeology that prioritizes transformation and social justice requires an activist approach to scholarship that is service-oriented and values community stakeholders as co-producers of knowledge (Stottman et al., 2010; Atalay et al., 2014).

A decolonised bioarchaeology also needs to acknowledge that our broader academic institutions are structurally racist. We need therefore to influence and change this at this level, too, examining and transforming everything from recruitment processes, to promotions, to curriculum content and assessments, all of which need to be reevaluated through a decolonial lens. For this process to be effective, it needs to have resources and accountability. We need to look at the academic pipeline that creates barriers for BIPOC students - from primary school onwards - and look at how we can create interventions and disruptions that facilitate engagement and progression for students from marginalised groups, rather than exclusions. Our institutions as a whole need to actively commit to a decolonising agenda otherwise we will be swimming upstream and will not be able to have the transformative impact that we need. As individuals, we need to be more reflexive of our own social identities and positionality and take active steps to addresss our own teaching and research practices. In that spirit, we note that participants in the Bioarchaeology Workshop largely replicated the White, cis-hetero, academic status quo that typifies the field in general, although we note that two of the four ASU bioarchaeological graduate assistants identify as non-White. This represents a positive generational shift, as we move toward decolonization.

We firmly believe that including and truly listening to and taking advice from underrepresented and often purposefully excluded voices is crucial for 21st century bioarchaeology. Professionals and students alike should learn, for example, from the concerns expressed in the important *American Anthropologist*'s Vital Topics Forum (Bolnick et al., 2019), which well illustrates perspectives of those who are marginalized in the evolutionary sciences. Also included are examples of developing collaborations, and conceptualizations of paths

[6] https://www.saa.org/publications/saa-contributions-on-race

forward. This significant, compelling collection is foundational and should be a point of reflection for all concerned about academic futures.

2.2 Ethics: Bodies and Politics

Bioarchaeologists, as social scientists, know that colonial actions frequently manipulate the bodies of the colonized, not only in life, but also by actions directed toward tombs, cemeteries, and their contents (Bargu, 2014, 2016; Mbembé, 2003, 2019[2016]; Verdery, 1999). Within the past half-century, increased awareness of human remains as part of the colonization process has led to public outcry and repatriation legislation. In the United States, while individual state laws vary, national legislation such as the National Museum of the American Indian Act (NMAI, 1989) and the Native American Graves Protection and Repatriation Act (NAGPRA, 1990) has had far-reaching results. For example, the Smithsonian Institution's National Museum of Natural History (US) has repatriated 6,300 individuals, 222,000 funerary objects and 55 sacred objects/objects of cultural patrimony (Bill Billeck, personal communication, September 2, 2021).

Gone are the days, however, of views that repatriation hinders anthropological knowledge (Halcrow et al. 2020, Kakaliouras 2020, Lippert and Sholts 2021, Meloche et al. 2021). Bioarchaeologists now consider collaborative approaches with Indigenous groups as a productive endeavor that enriches methodologies and knowledge of the historical and archaeological context for answering anthropological questions (Ruckstuhl et al. 2016, Halcrow et al. 2020, Weisse 2020). There is also a growing realization of the importance of repatriation and partnerships with the acknowledgement of the cultural trauma and civil rights violations that have been afflicted historically through human remains being unethically obtained and held at Museums and Universities (Halcrow et al. 2020). An example of collaborative research between bioarchaeologists and Indigenous communities was working with the tīpuna (ancestors) from Wairau Bar, an early site in Aotearoa New Zealand, which took a partnership approach between the local *iwi* (tribe), Otago University and the Canterbury Museum. Through this collaboration and repatriation project, researchers have assessed aspects of past life experiences, origins, identity and mobility through multiple bioarchaeological methods (Ruckstuhl et al. 2006).

Because bioarchaeology and related sciences deal with the material remains of the dead, we have a special responsibility to them and their descendants. Thus, decolonization in bioarchaeology is not just about inclusion of different peoples and views, but it is also about the very material work of the field. Repatriation, including the communication and collaboration stimulated by NAGPRA and the NMAI act, are therefore crucial aspects of bioarchaeological engagement (Kakaliouras, 2021a[7]). Similar issues have arisen recently in reference to African American remains from a politically fraught context: the Philadelphia MOVE remains retained and used in teaching by the University of Pennsylvania Museum (Anderson and Hevenor, 1987; Thomas, 2021[8]; Wagner-Pacifici, 1994).

One of the tensions that has developed in implementing NAGPRA and other repatriation initiatives is the definition of "cultural affiliation," which implies a combination of archaeological, biological, folklore, geographic, historical, linguistic, oral tradition, other information, or expert opinion (Buikstra 2006). The weighing of these different categories is difficult and has been contentious, e.g., the Kennewick example (Thomas, D. H., 1999; Owsley and Jantz, 2014). In such evaluations, a 51% preponderance of evidence is generally considered

[7] https://histanthro.org/news/observations/ignoble-trophies/
[8] https://histanthro.org/news/observations/enclosures-and-extraction/

proof. A recent historic period example from the Alameda-Stone cemetery, Tucson, Arizona that did not fall under NAGPRA, but rather Arizona state law proves instructive, as reported in Goldstein et al., (2012). In this example, archaeological (contextual, 10 categories), biological (osteological, 5 categories), and historical (4 categories) are scored independently and weighed equivalently in reaching recommendations. After the excavation and analysis team had evaluated the evidence, a likelihood statement was provided to descendent groups for discussion. As the authors state, "This procedure was unusual for most repatriation contexts for the following reasons: (1) it is rare that all three kinds of information are equally incorporated into repatriation decisions, (2) the descendant groups were actively involved in the process, and (3) there was communication and discussion about the data among all parties involved in the process (Goldstein et al., 2012: 92). This approach appears to be an excellent model for rigor, transparency, and consultation, which may serve well in other contexts.

Bioarchaeologists in Canada and the US have been expressing concern for such ethical issues for decades in reference to Indigenous people (Buikstra, 2006; Cybulski, 2001; Cybulski et al.,1979; Meloche et al, 2021; Pfeiffer, 2021; Reinhard et al., 1994; Walker, 2002; 2004; Williamson and Pfeiffer, 2003). While other Black/African-American descendent communities have also been consulted in the course of or following excavations (www.AvondaleBurial Place.org; see also, Fleskes et al., 2021), the New York City African American Burial Ground has provided a compelling illustration for the significance of consultations and multidisciplinary approaches in the excavation of cemeteries that include enslaved people and their descendants (Blakey, 2010; Blakey and Rankin-Hill, 2009; https://www.nps.gov/articles/ afamburial.htm). Evidence of structural violence against African-Americans, both before and after death is well illustrated in the research of de la Cova (2010, 2011, 2019, 2020a, 2020b) and Nystrom (2011, 2014, 2017b) and is discussed further in Section 7.2. There is consensus, though not unanimity, among bioarchaeologists about responsible, ethical behavior (Kakaliouras, 2021b). A considerable literature now exists concerning ethics in bioarchaeology, much of it focused on the United States, Canada, and the UK (Buikstra, 2019b; DeWitte, 2015a; Lambert, 2012; Lambert and Walker, 2019; Kakaliouras, 2012; Larsen and Walker, 2004; Squires et al., 2019; Walker, 2007). Some have emphasized museums and university settings (Cassman et al., 2007), while other contributions reflect global and non-Western concerns (Halcrow et al., 2020; Squires et al., 2020; Turner and Andrushko, 2011). Finally, Zuckerman et al. (2014: 513) have argued that bioarchaeology has an ethical mandate to speak out for "marginalized, disenfranchised, and impoverished individuals and communities." In advancing such initiatives, the formation of partnerships with descendants and other communities of concern is an ethical imperative.

Much of this discussion centers on archaeological remains from the United States and Canada. This article emphasizes the crucial importance of contexts, representing the profound variation across human communities through time and space. Some of our international participants cautioned that we should not assume communities of concern for ancient human remains are the same globally—or even within the US and Canada. In effect, we should not engage in colonial repatriation efforts, but rather consult, respect and collaborate wherever we work, effectively representing the rich information base that human remains in archaeological contexts represent. We take these comments seriously, but would also remind all bioarchaeologists that our discipline and its membership, while clearly international, largely represents the interests and activities of people of privilege. We acknowledge that there are bioarchaeologists working in many places in the world where the issue of repairing past wrongs is either not pressing, or not part of the sociocultural context in which bioarchaeology is

practiced. Nevertheless, repatriation is no longer just an American, Australian, or Canadian activity. For instance, although not every European country participated in the colonization of the African continent, many did. In 2018, the Sarr-Savoy Report was released from France, which calls for sweeping changes in institutional practices vis-à-vis the repatriation of African cultural heritage[9], Similarly, Germany recently announced the repatriation of the "Benin Bronzes" to Nigeria[10]. Moreover, in Latin America, efforts to gain access to remains and artifacts held in North American museums continue, e.g., the Peru-Yale Partnership in reference to Machu Picchu[11]. Finally, while a national sense of connection to ancient Indigenous pasts is a central cultural and political tenet of many Latin American countries, the voices of marginalized Mexican, Central and South American Indigenous peoples have been represented in literature on repatriation for a few decades now (i.e., Condori 1989). Thus, while we appreciate the particular situations in which our international colleagues work, we find decolonization and repatriation efforts to be on the rise, and we counsel especially our bioarchaeology colleagues to take seriously and honor the direction these efforts may be moving in their countries.

Other ethical issues arise in the conduct of our research on ancient human remains, including many that are common to other scientific disciplines. Materials access and data sharing are particularly important, in that repatriation and reburial means that restudy and verification opportunities are limited. Another related set of issues involves analyses that destroy tissues. While there is the potential for significant information that cannot be recovered in any other manner concerning such topics as biological (genetic) relatedness, diet, pathogens, residential history, destructive sampling for should be carefully justified in terms of problem significance.

2.3 Decolonizing international research and practicing ethical fieldwork

As stated above, most literature on bioarchaeological ethics is focused on the United States, Canada, and the UK; however, much bioarchaeological research and fieldwork is performed outside of those countries. Standards for performing ethical fieldwork in under-resourced countries should minimally include capacity building for local scientists and recognition that national permits and analysis permissions were not granted by descendent or invested communities. Much bioarchaeological research is carried out in countries with stark power and financial differentials to the US, Canada, and the UK. Although not comprehensive, First Nations groups in Canada and Native groups in the United States have legal protections and decision-making authority over the burials of their ancestors. Many Indigenous groups from the Global South, for example, do not have sufficient social or political capital within the national government to make decisions regarding excavation, repatriation, reburial, or scientific analysis of their ancestors. Working with local scientists is an important first step (Haelewaters et al., 2021), but greater efforts should be made to include Indigenous stakeholders.

2.4 Recommendations

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[9] http://restitutionreport2018.com/sarr_savoy_en.pdf

[10] https://www.pri.org/stories/2021-05-17/germany-plans-return-looted-benin-bronzes-nigeria-will-other-countries follow#:~:text=In%20a%20historic%20move%20last,the%20pieces%20starting%20in%202022

[11] https://news.yale.edu/2015/06/04/peru-yale-partnership-future-machu-picchu-artifacts

When considering our mandate to decolonize and transform an ethical bioarchaeology, there are several important points to be made:1) We must make every effort to create a field that is not only open and welcoming to all professionals and students, but also actively seeks to include other communities both as an ethical obligation but also for intellectual enrichment from the diversity of perspectives thus engaged. 2) We should focus on sensitive and ethical engagement with descendent communities, forming partnerships that serve well the needs of community members and scientists alike. 3) We must recognize that we perform research in countries whose Indigenous and descendent communities do not have a voice in national decision-making on cultural resource management, international research permits, or destructive analyses. 4) We should recognize that some of our field's antecedents engaged in unethical activities. Following such recognition, we should focus our energies on creating a future that has overcome the residues of such ancestry. 5) When possible, we should use our knowledge of deep time in relationship to topics such as violence, epidemic disease, and human adaptation to establish humankind's past as a springboard for our global future; 6) Overall, we need a more radical approach to decolonise academia as a whole and a more open acknowledgement that our institutions are structurally racist and continue to perpetuate harm against minoritised groups. We could also look at our funders and our publishers - what research is being funded? Who is on our editorial board? What support is being put in place to publish the work of scholars from the Global South? 7) We must realize that the people we study are often the ancestors of presently colonized, oppressed, or otherwise politically disadvantaged peoples. Bioarchaeologists should recognize not only their privilege in having access to human remains, but they should work together and with descendant groups and other communities of concern on the lawful, proper, and/or humane disposition of such individuals.

3 SOCIAL INEQUALITY

3.1 Bioarchaeology and social inequality

Studies of inequality in the past can reveal how cultural and sociopolitical influences, and associated stigma, e.g., for people with leprosy (Roberts, 2020a) and TB Roberts and Buikstra, 2003, see also Roberts, 2020b) shaped lived experiences and health outcomes, lessons we may apply to modern problems, such as those identified by Ansell (2017), Dorling (2015), Marmot (2015), and Wilkinson and Pickett (2009). Today the gap between rich and poor continues to widen; however, by using the contemporary literature as a baseline, bioarchaeologists can explore and understand the complex factors that result in inequalities (e.g, Roberts, 2020c). For groups that have been historically marginalized, we can examine the sociocultural and structural factors that enforce marginalization to understand how it becomes biologically embodied (see also Section 7.2, Structural Violence). Bioarchaeology can contribute to scholarship on the way that culture becomes biology (*sensu* Gravlee, 2009) by connecting the past and the present to understand, despite shifts in time and cultural changes, how persistent marginalization continues to impact these groups biologically, thus complementing research being conducted by medical anthropologists (e.g., Farmer et al. 2006; Holmes 2013; Singer and Clair 2003). These perspectives, in turn, forces us to think about the inter-generational effects of this marginalization, as is the case with Black/African Americans, who are still biologically impacted by the effects of slavery (see Jasienska 2009). Similarly, Indigenous communities worldwide have suffered the impact of colonization and genocide. Furthermore, as anthropologists, this allows us to illustrate how larger structural forces work against marginalized groups in the

present as they did in the past (de la Cova, 2010, 2011, 2019; Mant et al., 2019). By shedding light on these factors and how they continue to impact marginalized bodies, we can be true agents for change at the social and clinical levels. The past can also reveal alternative social systems to those that prevail today and expose the limits of our current imaginations, which often consider certain forms of inequality inevitable. All of these approaches require careful attention to context and are enriched by interdisciplinary collaborations and engagement with research methods from contemporary social science research.

There are several alternative bioarchaeological approaches to studying social inequality in the past. The first is an historical method that evaluates the nature of inequality today and extends it into the past to understand the archaeological roots of contemporary problems. An alternative, transdisciplinary approach seeks to understand how various sociocultural/ecological factors, including ancient climate change, urban settings, and political systems, led to inequality in the past, and how we can apply those lessons in the present. Similarly, we could conceive of an allegorical approach that allows us to look at past social systems and think about different ways for people to move beyond our own systems in the present. Here, past egalitarian systems and heterarchies show us the range of possibilities of social organization that humans have used.

All these approaches principally rely on our ability to identify social inequality in the past from social/archaeological contexts, including interment structures and health outcomes. Quinn and Beck (2016), for example, have recently attempted to integrate funerary complexity with a variety of other bioarchaeological attributes reflecting political, social, ideological, and economic materialization. Dong et al (2017) similarly integrate contextual and skeletal bioarchaeological evidence in exploring the origins of gender-based inequality in China. Such work well illustrates the challenges in integrating theories of mortuary behavior with social theories surrounding inequality, along with bioarchaeological methods. It is crucial that such research into past inequality does not merely justify *a priori* conclusions based on deterministic and stereotypical beliefs, such as those based in gender, disability, age, ethnicity, etc.

Future bioarchaeological research on social inequality should continue to unite social theory with osteological methods and pursue interdisciplinary collaborations and methods as we work to improve our ability to identify and evaluate inequality in the past. Global health professionals, for example, are profoundly interested in the length and history of social inequality and its impact on health, particularly as we come to better understand the multigenerational effects of inequality. A recent example from Mexico illustrates the potential contribution bioarchaeology can make on this point. Tiesler et al. (2020) examined two documented skeletal series from the Yucatán to evaluate changes in health and age-at-death demographics over the 20th century and found that although the more recent skeletal series had a higher age-at-death, degenerative and metabolic diseases and trauma predominated, reflecting the simultaneous effects of improved healthcare/health interventions and a globalized food system (amputations performed due to the effects of diabetes, for example), sedentism and automobile reliance, and violent crime.

Additionally, contemporary research methods from public health, economics, and social science can be brought to bear on the past. Pitts and Griffin (2012) compared skeletal indicators of chronic stress and inequality as measured by the Gini coefficient, a measure of statistical dispersion used in economics that represents wealth distribution, or in this case, the distribution of grave furniture. Oka and co-workers (2018) have offered a further adaptation of the Gini coefficient termed the Composite Archaeological Index (CAI), which expands its variable base to include life expectancy in an attempt to add wellbeing to the mix. The Capability Approach

(CA), another methodological loan from economics, has also been used archaeologically, but this theoretical framework deemphasizes income (or wealth) and focuses on wellbeing, namely that income differences among individuals do not inherently translate into differential abilities of "doing and being". Adapting a construct developed by the Nobel Laureate in Economic Sciences, Amartya Sen, Arponen et al. (2016) proposed a two-step method to apply the Capability Approach in archaeology. The first stage identifies social differentiation and the second connects that variation to differential access to critical goods or capabilities. The Capability Approach may be particularly useful in identifying and evaluating heterarchies, where unequal status does not imply power imbalance. Finally, public health tools like the World Health Organization's "Dirty War Index" (DWI), used to evaluate undesired and prohibited outcomes in a given conflict (e.g., child mortality), can be applied to bioarchaeological datasets. Using an integrated skeletal, archaeological, historical, and ethnographic approach, Zuckerman and Banks (2017) calculated the DWI values for a historical massacre site and emphasized the utility of this index for quantifying suffering and the biological cost of past conflicts and its ability to help challenge prevailing narratives about those conflicts. Not only do these efforts improve our ability to research social inequality in a bioarchaeological context, but they connect our work to contemporary social science research and help us forge additional interdisciplinary links and further improve public outreach. Although quantifying inequality with these methods or with archaeological approaches (e.g., Quinn and Beck, 2016) may not capture the spectrum of inequality at all archaeological sites, systematic data collection may help us better evaluate inequality on a broad temporal and geographic scale and develop testable models following Ortman (2019). Nystrom and Robbins Schug (2020) emphasize that the human cost is absent from several of the economic approaches as originally conceived and that adaptations that include health measures are advantageous.

3.2 Recommendations

By examining mortuary context and skeletal remains that preserve embodied evidence of cultural ideas about class, gender, violence, etc. and their impacts on health, social identity, and wellbeing, bioarchaeological research can address several key questions about inequality in the past, with implications for today's world. These include 1) Under what conditions did inequality emerge in the past? 2) Who held power in the past? Under what conditions? For what purposes? 3) What were the embodied consequences for those without power? 4) How did these social formations change? 5) What social/ecological formations existed in the past without our current forms of inequality? 6) How does the study of past inequalities and marginalized people help inform present and future remediation efforts?

4. INFERRING ANCIENT IDENTITIES

Today, our social, political, and economic landscapes are built upon individual and group identities, such as gender, age, religion, political affiliation, ethnicity, and social status. These structure our daily existence as they also keenly influence global events. Social news media reinforce the existence of differences across these dimensions, frequently reinforcing value judgments; violence too often ensues. Thus, the origins, maintenance, and manipulation of identities is a research theme of significance in which bioarchaeology has an important role to play.

The anthropological study of identity is anchored by investigations of ethnicity, beginning with Barth's (1969) influential monograph and the work of the Manchester School

during the 1960s and 1970s. Archaeological and bioarchaeological studies have followed, expanding the purview to explore multiple dimensions and their intersection, as we illustrate in this section. Bioarchaeology being ideally suited to this enterprise, focusing upon the manner in which identities are embodied in the human skeleton (Knudson and Stojanowski, 2008, 2009a, 2009b) Gowland and Knüsel, 2006; Sofaer, 2006).

Here we will focus upon three bioarchaeological aspects of identity – gender, social age, and kinship – along with intersectionality. The challenge is moving from biological attributes, frequently evaluated via osteological data, that, along with contextual variables, allow us to estimate these social constructs, many of which are fundamental to interpreting past lives. The degree to which social age, gender, and kinship structured power relations, for example, is a significant question to explore in multi-scalar contexts across space and through time.

4.1 Linking the skeletal to the social categories: sex to gender, biological age-at-death to social age, and inherited features to ethnicity and kinship

Individual and group identities are keenly important in the contextualized study of human remains (Knudson and Stojanowski 2009a; 2020; Gowland and Thompson, 2013). Fundamental aspects of identity include social age, gender, and ethnicity, as well as their intersections. Bioarchaeologists begin their estimations of these social parameters with assessments of biological sex, age-at-death, the timing of earlier life events as represented osteologically, and phenotypic expressions of genetic variation. Such osteological observations may be supplemented by information based in proteomics, ancient DNA (amelogenin gene) and observations of mummified soft tissues, when available. As discussed at the Workshop, students and practitioners of bioarchaeology are well aware of the current state of play in estimating these skeletal parameters. The persistently elusive goals of accurate estimates of biological sex appear imminently achievable through minimally invasive proteomic procedures (Buonasera et al., 2020; Gowland et. al. (2021); Parker et al., 2019; Stewart et al., 2017; Ziganshin et al., 2020) and genetic analyses (Mittnik et al., 2016; Skoglund et al., 2013). Efforts to improve macroscopic approaches to sex estimation in juveniles also continue (e.g., Stull et al., 2017).

Responses to late 20th century critiques of paleodemography, paleopathology, and paleoepidemiology (Bocquet-Appel and Masset, 1982; Wood et al., 1992) have stimulated increased attention to developing bias-free and more accurate methods for estimating age-at-death in adults, especially older adults (Caussinus and Courgeau, 2010; Hoppa and Vaupel, 1999; Milner and Boldsen, 2012; Milner et al., 2019). With advances in imaging, cemental annulus evaluations offer important options, when minimally destructive methods are appropriate (Naji et al., 2016, 2021). Studies of phenotypic features in documented genealogies are refining our knowledge of the genetics of complex morphological structures (Paul and Stojanowski, 2015; Paul et al., 2017; Stojanowski et al., 2017, see also Section 6).

These advances in fundamental demographic and biodistance methods are welcome, as they provide important building blocks for estimates of population structure, which are crucial for broad-scale interpretations of health, disease, migrations, and violence. We must also recognize, however, that it is the sociocultural and contextual interpretations of biological parameters that shape the lived experience of individuals across the life course. Gender, social age, and ethnicity influence diet, activity patterns, the work people did, their socioeconomic status, and health, which are reflected in metric, morphological, and biogeochemical features of the skeleton. Notably, these variables can also influence the rate and patterning of skeletal degeneration, which is frequently used as an index of chronological age. We also note that close

attention must be paid to the specific cultural contexts from which the skeletal sample or individual skeleton derives, as these give meaning to our biological sex and age estimates. While accurate biological sex and age estimates may be the key to opening the door to representing past lives, only when we can better understand how these aspects of identity were shaped culturally, perceived socially, and experienced personally can we cross the threshold into truly reconstructing past lifeways (Gowland, 2006).

4.2 From Skeletal Age-at-death to Social Age

One of the tensions in research on the biological estimators of age-at-death is between the development of widely applicable standards for estimating biological parameters in the face of knowledge of dietary and activity-based influences on aging, which vary across and within groups. While the development of general standards is important, the influence of social and cultural factors on aging merit further attention (Agarwal, 2012). Workshop participants were particularly mindful of research concerning the natal event, the timing of adolescence, and recognizing old age.

Further refinement of methods for estimating the timing of the natal event is necessary, as in utero, childbirth, and neonatal deaths provide important information concerning the health of the infant and the mother (Gowland and Halcrow, 2020; Han et al., 2018). Studies of mothers and infants as entangled units are important future directions for investigation of community health, nutrition, cultural factors influencing childbirth, and cultural perspectives on the roles and relative positions of women and children in society. Thus, bioarchaeology would benefit from greater focus on the earliest stages of the life course, i.e., fetal and neonatal development and the social construction of conception, childbirth, and neonatal life (Halcrow et al., 2018; Han., et al., 2018; Smith-Oka et al., 2020). Related to this would be social understandings of pregnancy and cultural constraints on pregnant women that may have health implications (Lewis, 2017). Greater consideration should also be given to the impact of reproductive loss on societies. Biological sex ratios of non-adults could also extend knowledge of health and treatment biases. DOHaD should be considered more explicitly (Gowland 2015; See Section 10.2) in relationship to impacts on growth, adult skeletal dimensions, and later life health and mortality patterns (Roberts and Steckel, 2019). The implications of the Barker (2003) hypothesis (DOHaD) for morbidity and the skeletal expression of disease would be important investigative pathways.

Linked to the focus on the life course is also a growing interest in understanding the social and biological transitions from childhood through adolescence and adulthood (Halcrow and Tayles, 2006; Inglis and Halcrow, 2018). Some researchers are starting to explore skeletal indicators of adolescence to understand variability in pubertal timing and social attitudes towards this key life transition (Shapland and Lewis, 2014; Lewis et al., 2016), as well as what pubertal timing indicates about standards of living in pre- or non-industrial contexts (DeWitte and Lewis, 2021). More research on older ages and social definitions of the elderly is also required (e.g., Boutin and Porter, 2019). Older age groups are the most neglected demographic in archaeology, mostly due to the misconception that people in the past did not live to old age. Given the prevailing negative sterotypes surrounding older age in the presence, it is important that bioarchaeologists understand the social construction and experences of older age in the past (Gowland, 2007). Identifying hormonal fluctuations from bones and estimating the timing of menopause would assist in studies of fertility. We should also consider the life course as it extends agency after death (Buikstra, 2019b; Crandall and Martin, 2014).

4.3 Skeletal Sex to Gender

Throughout most of bioarchaeology's past, practitioners have focused upon the accuracy of biological sex estimation methods, with those for adults emphasizing the bony pelvis. Other, more variable expressions of skeletal sexual dimorphism are less accurate, but may be useful in specific populations, especially with prior knowledge developed in documented collections. The degree of skeletal sexual dimorphism has also been used to infer health and adaptation through time and space (Clark, 2013; Clark et al., 2014; Vick, 2005). While accuracy in estimating biological sex continues to be a matter of concern, bioarchaeologists have extended their interests to non-dichotomous definitions of biological sex and social expressions of gender. From this develops, for example, a concern that division of labor in ancient groups may have been over-interpreted (Bolger and Wright, 2013). Knowledge of non-binary biological and social expressions of sex and gender should anchor forensic anthropological observations, as well (Jones, 2014; Schultz, 2021).

The media eagerly and increasingly report inferences about gender and alleged departures from the normative male-female dichotomy. Stories about doomed prehistoric Romeo and Juliet lovers have gone viral (Geller, 2017: 1, 89). Such headlines, frequently based upon preliminary archaeological conjecture, are rarely supported by the necessary contextual information and seldom survive peer review. Similarly, National Geographic reported, with apparent amazement, a burial from Nakum, "Maya Royal Tombs found with Rare Woman Ruler" (Geller 2017: 145**).** "'Blinged out' female ruler may be evidence of powerful women during Bronze Age," wrote journalist Michael Price for *Science* magazine (March 10, 2021). Titles such as "Viking Warrior Women?" (Price et al., 2019) are also guaranteed readership in the public sphere. Such studies of powerful women are persistently newsworthy. The 21st century has witnessed notable revisions of received wisdom concerning powerful women in the past, frequently revealed in bioarchaeological studies (Buikstra et al., 2004; Knüsel, 2002; Lull et al., 2021; Price et al., 2019). We might perhaps wonder why the presence of powerful women in the past should be news, but such androcentric extensions of today's world into the past persist (Conkey and Spector, 1984; Geller, 2017, 2019).

There are therefore many reasons to expand our studies of biological sex into the more challenging domain of gender (Ghisleni et al., 2016; Gilchrist, 2004; Sofaer, 2012). Among the most central are that our appreciation of past lives is thus enriched, (e.g., Bolger and Wright, 2013, Tung, 2021; Section 7) and examples of gender flexibility counter the heteronormative, essentialized vision of the past that all too often informs visions of binary sex categorization today (Geller, 2017, 2019). An important archaeological example of moving beyond the heteronormative perspective of the past has been voiced by Gabby Omoni Hartemann (2019), a transgender PhD student from Brazil. They discuss the importance of drawing attention to non-binary identities in the past because to not do so is a form of erasure, which contributes to transphobia and violence against non-binary individuals today. Recognizing past non-binary identities in the past helps legitimize them today.

4.4 Skeletal Morphology to Kinship

Bioarchaeologists and their intellectual predecessors have long used phenotypic variability to infer the history of ethnic groups, especially migrations at global and continental scales. These have largely given way to focused studies of regions, communities and the family. Questions have expanded from mobility and migrations to issues of residence and the manner in which kin relations structured the political, economic, and social lives of past peoples.

Small scale bioarchaeological studies of kin relationships began with attempts to explore post-marital residence patterns, such as the pioneering work of Lane and Sublett (1972). Similar small-scale foci by researchers such as Alt (Alt and Vach, 1992, 1995; Alt et al., 1997); Konigsberg (1988; Konigsberg and Buikstra, 1995) and Schillaci and Stojanowski (2002, 2003) have continued to be productive, if occasionally contentious. (Peregrine and Ember, 2002). Today. "biodistance" is the term we apply to the inference of inherited relationships through the study of skeletal morphology and dental features (Buikstra et al., 1990). Such small-scale foci are crucial in our explorations of human history in that family and kin relations structure how an individual learns and is socialized. Many of the factors that structure human existence, such as socioeconomic status, diet, and health are linked to early life experiences and the family, broadly and flexibly defined (Johnson, 2019). Kinship and family histories are fundamental to understanding the inequalities that plague our world today. Studying the development of these differences over the long term and at various scales is important to understanding today's complexities.

Investigations of human mobility and large-scale migrations can also be accessed through the study of phenotypic variation and kinship, as the latter frequently structures the nature of migrating groups. To fully and accurately interpret mobility through biodistance methods, studies should be grounded in the anticipated population genetic impact of human movement, as represented in the work of anthropological geneticists (Fix, 1978, 1979, 1999, 2011), and migration recognition thresholds when using various classes of bioarchaeological data (Frankenberg and Konigsberg, 2011). Similarly, we should be aware of the myriad anthropological studies of kinship and mobility, e.g., Amorim, et al., (2018); Walker and Hill (2014).

We emphasize here in our discussions of ancient DNA, ethics, and migration, kinship is a malleable category, situational, contingent, and context-specific. Johnson (2019; see also Johnson and Paul, 2016) presents reviews of the need for contextual grounding for studies of kinship, which is a social construct. As with other social categories mentioned in this section, bioarchaeological studies of kinship contribute to our appreciation of past lives, and they should also inform about the flexibility of kin categories beyond those essentialized in today's world (e.g., Gregoricka, 2013; Pilloud and Larsen, 2011.

Insofar as DNA can elucidate relationships of biological kinship, it has proven an especially challenging topic for bioarchaeologists collaborating with Indigenous communities, especially those in the U.S and Canada (Bolnick et al., 2016; Claw et al., 2017; Reardon and TallBear, 2012; TallBear, 2013, 2015). Commodification of heritage and bodies as property underlies many increasingly vocal and politically powerful concerns. From such tensions, has emerged Kim TallBear's (2017, 2019) proposal for a "Relational kinship" for partnering in a decolonized world. TallBear, a citizen of the Sisseton-Wahpeton Oyate Tribe and a Professor and Canada Research Chair in Indigenous Peoples, Technoscience, and Environment at the University of Alberta, aligns with the many scholars who recognize the power of non-Western ontologies in arguing against the Western binaries of human/not human, natural/unnatural worlds. Emphasizing an Indigenous concept of relationality, TallBear (2019: 37) promotes "making kin" as a 21st century solution that emphasizes reciprocal relationships of caring and trust, which extend to all people and all that surrounds us, rather than Western constructs of nation-states, sovereignty, and negotiation. Such relational, non-genetic models well illustrate the fundamental differences between Indigenous and Western notions of "kin-based" relationships and belonging.

Today many aspects of human lives today are structured by kinship, including daily interactions, religious celebrations, interpersonal violence, and migration events. The basis for establishing kinship in the past includes a complex interaction of genetic relationships with individual and group histories. Twenty-first century bioarchaeology has many tools for estimating genetic relationships, natal locations, and social status. Combining these with other information available from the archaeological record should provide the tools for investigating past kinship relationships and the manner in which past lives.

4.5 Intersectionality

Developed within a Black feminist activist paradigm, intersectionality holds promise for advancing bioarchaeology's analytic and transdisciplinary agendas. The concept was formalized by Kimberlé Crenshaw (1989), although its history extends into the 19th century. Intersectionality refers to multiple identities interacting within an individual at a given time. As sociologist Patricia Collins (2015:2) states, the "general contours" of "[t]he term intersectionality references the critical insight that race, class, gender, sexuality, ethnicity, nation, ability, and age operate not as unitary, mutually exclusive entities, but as reciprocally constructing phenomena that in turn shape complex social inequalities." There are two crucial implications of this and similar definitions: 1) a person's identity is constructed by multiple interacting identities (the cumulative effects of which on lived experiences are greater than the sum of those associated with individual axes of identity); and 2) these same factors also operate to structure social inequalities. Other social scientists explicitly recognize that these are two important (intra-group vs. inter-group) distinctions in intersectional studies. Discussions focus on definitions of axes of marginalization, power structures, and the utility of atheoretical vs. theoretical approaches (Evans 2019; Sen and Iyer, 2012). Such discussions are highly relevant to developing intersectional studies within bioarchaeology, using a focus on power structures and inequality through time and across space to address mechanisms that stimulate migration, violence, climate change, and pandemic disease. Factors promoting resilience in the face of these challenges should also be sought.

Intersectionality has become increasingly visible in bioarchaeology, emphasizing knowledge gained by conceptualizing interacting, mutually constituted identities within individuals and groups. Two recent treatments of intersectionality summarize background information, the current status within bioarchaeology, and possible future trajectories for bioarchaeological research employing this construct (DeWitte and Yaussy, 2020; Yaussy, 2021). As many of the public health, psychological, and economic applications of intersectionality theory today focus on health as an independent variable, this approach would seem appropriate for exploring intersectional interactions in the past. For example, Yaussy (2019) explored frailty, age-at-death, gender, and socioeconomic status (SES) for 18th and 19th century England. Other intersectional studies focus exclusively on disadvantaged SES contexts, such as Byrnes' (2017) investigation of the Erie County Poorhouse in Buffalo, New York. Similarly, Mant et al., (2021) have explored trauma in biohistorical contexts through an intersectional approach.

Earlier contexts, without written records, can also be productively analyzed through intersectionality. For example, working with Middle Horizon (500-1100 CE) and Late Intermediate Period (1100-1400 CE) remains from the Chilean *altiplano* oases of San Pedro de Atacama and the neighboring Loa Valley, Torres-Rouff and Knudson (2017) explored multi-scalar dimensions of identity. Their skeletal observations include data marking both mutable and immutable aspects of individual life histories: isotopic evidence of residence, phenotypic proxies

for ancestry vs isotopic indicators of diet, and culturally modified crania, for example. Their multi-scalar approach, moving from the group to the individual, identifies a homogenizing of identity across the *altiplano* as the influence of the distant Middle Horizon Tiwanaku state waned. Previously distinct communities and individuals became much more alike, apparently a symbol of local resilience and regional power. This example is not linked explicitly to broader, theorizing agenda, though one could probe further the mechanisms accounting for local resilience in the face of waning colonial influence. In a more recent intersectional study, Knudson et al. (2020) recast San Pedro de Atacama data from two Middle Horizon cemeteries (Solcor Plaza and Solcor-3) and thus moved the conversation toward a discussion of power structures and inequalities in relationship to trade and foreign influence. These examples indicate how the multidimensionality of intersectional studies can strengthen bioarchaeological investigations of external political and economic influence and local inequalities and community resilience.

The social scientists and researchers from public health who have employed intersectionality emphasize difficulties in defining the limits and focus of the field and its subject-matter. One concern is that intersectionality has extended its earlier activist agenda that focused on disadvantaged communities, now including the advantaged in comparisons. This would appear an analytical strength, to be encouraged in bioarchaeological studies. We address this issue later, in reference to structural violence (Section 7.2). Even so, we can certainly sympathize with Collins's (2015:17) concern that the creative edge may be lost as the field becomes mainstream.

While bioarchaeology must always be mindful of quality scholarship in knowledge production, we should also seek creative inspiration from contemporary voices of practitioners (*sensu* Collins above) and others whose lived experiences and voices lend power and creativity, which has been so vital to prior intersectionality initiatives. Thus, collaborative, intersectional studies of past identities, whether focused on individuals or on communities, would seem poised to provide insight into the structures that initiated and reinforced inequalities in the past. Temporal depth and cross-cultural insights should emerge from these investigations in a manner significant for 21st century interventions, as they also enlighten our perspectives upon past lives. Bioarchaeology's engagement with various theoretical perspectives and lenses in the interpretation of trauma and violence in the past reveals the inherent complexities of the biosocial factors of lived experience that not only expose individuals to risk for injury and experiences with violence but produce and reproduce them. Mant et al. (2021) compare osteobiographical case studies of two unclaimed individuals from different geographical and temporal contexts and frame their methodological evaluation and interpretation of the trauma evidenced on these remains' bodies using a cross-disciplinary, intersectional methodology). This four-step methodology incorporates all available anthropological, biological (e.g., clinical), historical, and sociopolitical datasets into the interpretation of observed traumatic injury on individual skeletal remains. By contextualizing age, sex, socioeconomic status, and traumatic injuries in 19th century London, particularly in the context of England's Poor Law legislations, a more nuanced understanding of the risks for and lived experiences of poverty for older working women during this time is revealed. The authors demonstrate how the differences and variable intersections of the assorted biosocial axes of these individuals' identities (e.g. age, sex, gender, socioeconomic status, race, physical and mental health, etc.) and their life histories affected their osteological health, overall health outcomes, and resulted in their traumatic injury patterns, deaths, and unclaimed status. In doing so, Finally, the author's show how the broken bones

observed on the individuals' skeletons are a product of the intersection of the unique biological, histomorphological, sociocultural, environmental, and behavioral factors framing these individuals' lived experiences in the context of structural inequality. This study highlights the importance of theoretically informed trauma analyses and utility of osteobiographical approaches for identifying the presence and mechanisms of traumatic injury and inferring the unique biosocial factors that precipitate the physiological and sociocultural events that underwrite broken bones.

4.6 Conclusions

As we have seen in this section, the study of identities in the past is a challenging adventure in linking numerous classes of archaeologically recovered data. For the bioarchaeologist, this means studying human remains, not only in their funerary contexts, but within the larger residues of their lives, their homes, their shrines, and their monuments, necessitating collaborative efforts with other scholars and descendent communities. The study of identities – however arduous – is essential in exploring how and why past peoples changed their relations to others and to their environments. Intersectionality studies hold potential for identifying the institutions that maintain structural violence (Section 7.2). Questions that emerge for further study include, 1) How can we further refine methods for estimating biological sex, age-at-death, and genetic relationships? 2) How best do we move from biological to social categories of gender, social age, and kinship? 3) How can we identify non-essentialized examples of variation across social categories and use this information to inform the present; 4) How best to approached intersectionality in the past and use this information to identify the institutions than initiate and maintain structural violence? 5) How can we best bring this information to contemporary problems.

5. CLIMATE CHANGE

The archaeological record reflects the impact of past climate and environmental changes, which have been persistent forces framing the human condition since our species first emerged in the Pleistocene. The 21st century is already witnessing extreme climate events—floods, fires, and heat advisories—related to global warming; CO_2 levels and annual mean surface temperatures are approaching levels not seen since our genus, Homo, evolved in the Pliocene (Burke et al., 2018). For the past 12,000 years, humans have benefitted from a relatively stable climatic condition, but for at least half that time, we have directly and significantly manipulated the "natural" and increasingly anthropogenic world (Stephens et al., 2019). The pace and the magnitude of contemporary anthropogenic climate change is arguably the most important challenge our species has ever faced. On Thursday, May 9, 2013, we officially passed 400 ppm average daily concentration of carbon dioxide in Earth's atmosphere, a level that was last matched on Earth 3.5 million years ago, when the arctic was around 8° C warmer, covered with pine forests, and sea level was as much as 16 meters higher than today (Dumitru et al., 2019). By the end of the present century, we can expect 3-7° C of warming above the mean annual surface temperatures we have enjoyed throughout most of the nineteenth and twentieth centuries (IPCC, C. C., 2007), from a current mean of 16° C (61° F) to somewhere between 19° to 26° C (66° to 79° F), or more if we continue unabated to emit fossil fuels into the atmosphere (IPCC, 2014). This magnitude of warming in such a short time is unprecedented for our species.

Climate change undoubtedly has had, is having, and will have substantial effects on human communities, and it will lead to profound changes across the spectrum of life on Earth. The sixth mass extinction event is already underway (Barnosky et al., 2011). This biological

annihilation will "have negative cascading consequences on ecosystem functioning and services vital to sustaining civilization" (Ceballos et al., 2017: 6089). It is difficult to make predictions about exactly how climate change will proceed, particularly given the unprecedented magnitude and pace of recent changes (Quintero and Wiens, 2013), but our best option for prediction is to rely on historical sciences, primarily reconstructions of past environments. To plan for the future of our planet we also need to understand how human communities perceive and understand climate and environmental changes; the meaning of climate changes cross-culturally and over time; the role of history, culture and society in shaping short-term responses to climate change; and the long-term consequences of adopting different strategies. To imagine the full range of possibilities and impacts of climate change and environmental crises, particularly in terms of the human response to these kinds of events, requires global knowledge of human history (Robbins Schug, 2020; Robbins Schug et al., 2019).

In this section, we shall first briefly review resilience models and climate change, emphasizing the significance of integrated biological and cultural resilience perspectives on long term change, as in socioecological systems (SES) models. Examples drawn from the archaeological record illustrate the importance of bioarchaeological evidence. In so doing we shall touch on topics, including several considered in other sections of this article: diet, violence (Section 7), migration (Section 8) and pandemic disease (Section 9), as well as diet. Sections 5.1 5.2, and 5.3 are directly relevant to Nystrom and Schug's (2020: 159) observation that bioarchaeologists have potential for informing on the impacts of climate change on health in relationship to the three ways the Intergovernmental Panel on Climate Change (IPCC) specified that climate change will affect human health worldwide. These include 1) direct impacts of climate and weather on health (e.g., heat waves, flooding); 2) impacts mediated by the ecosystem (e.g, changes in distribution of vector-borne diseases, air and water pollution); 3) impacts heavily mediated through human institutions (e.g., changes in food production, population displacement).

5.1 Climate Change and Human Resilience

> The archaeology of climate change offers opportunities to identify the factors that promoted human resilience in the past and apply the knowledge gained to the present, contributing a much-needed, long-term perspective to climate research. One of the strengths of the archaeological record is the cultural diversity it encompasses, which offers alternatives to the solutions proposed from within the Western agro-industrial complex, which might not be viable cross-culturally.
>
> Burke et al., 2021, 1

The long-term perspective required to document climate change necessarily engages the archaeological and historical records. For example, Holling's (1973:8) now classic statement on resilience and stability in ecosystems discussed the Roman "construction of the Via Cassia about 171BC, which caused a subtle change in the hydrographic regime" of a small Alpine crater lake in Italy. Although the aquatic system had established a trophic equilibrium throughout marked environmental changes, from grassland to fir and mixed oak forest, the construction of a nearby Roman highway exceeded its limits, and a new condition was reached. Such accounts of anthropogenic effects are unfortunately all too familiar in the 21st century.

Discussions of resilience continue to crosscut academic and political discourse about climate change and humankind's future upon this earth. As defined by Holling (1973:14) and generally accepted, resilience "is a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables." Importantly, as indicated in Holling's original definition, resilience does not necessarily mean stability - systems can be modified. Butzer's (2012) treatment, cited in at least one policy paper (World Health Organization, 2017), focuses upon collapse but in the context of a resilience model and emphasizes the significance of cultural identity, as Burke et al (2021) and Temple and Stojanowski (2019a) have subsequently advocated. In parallel to the ecological literature's emphasis upon diversity as an attribute associated with resilience, Burke et al. (2021), emphasize the importance of cultural diversity in promoting resilience in human systems.

The issue of cultural resilience figures heavily in Temple and Stojanowski's (2019a) bioarchaeological treatment of hunter-gatherers. They argue that the persistence of ethnic identity is of particular significance, buffering again external stressors through the maintenance of support networks. Similarly, in human contexts, resilience should be measured using worldviews, historical contingencies, and perceptions (Temple and Stojanowski (2019b). Thus, as we think about human resilience in response to climate change (and other stressors) our definition of resilience should be modified to include cultural attributes. A useful working definition *for cultural resilience* therefore becomes, "the capacity to maintain hallmark characters of identity during periods of disruption to cultural and socioecological systems." The Point Hope hunter-gatherer example (Justice and Temple, 2019) serves well to illustrate this perspective. Ipiutak (350—850 CE) groups moved away from the Point Hope Peninsula due to climatic deterioration, returning later as the Tigara (1150-1550 CE) with a transformed socioecological system that maintained persistent reciprocal relationships with nature illustrated in burial patterns and inferred ontology of personhood. That is, these groups transformed food acquisition strategies, but their relationships with the natural world and mutual ways of "becoming" in the natural world persisted. While there were key changes in material attributes that archaeologists use to define cultures, the persistence of these people's worldview signifies significant cultural resilience in the face of climate change, including a flexible socioeconomic system. Archaeologists exploring resilience of ancient groups in the Greater North American Southwest who faced climate and environmental change (Hegmon et al., 2008; Nelson et al., 2006) have included dimensions of human behavior amenable to bioarchaeological measures, such as population structure, health, violence, and funerary behavior. The significance of flexible responses, some including mobility but not necessarily migration is underscored in this research.

We agree with Burke et al (2021) that cultural resilience is the core concept for modeling human resilience in response to external stressors such as climate change. We further argue that aspects of cultural identity, whether individual or group (kinship, religion, social standing, ability status), crucial in studies of resilience, are (perhaps uniquely) accessible through bioarchaeological study (See also Section 4). Similarly, as health and quality of life are persistent measures of positive, adaptive outcomes, we again see bioarchaeology in a key role. Finally, missing in most archaeological, ecological, and socioecological scenarios is the role of religion and worldview, which is an important aspect of a people's identity (Buikstra, 2019d); Martin and Harrod, 2020; Temple and Stojanowski, 2019b). Evidence gained through the study of funerary rituals and mortuary sites is keenly important in this regard.

One of the many attractive aspects of resilience models is their adaptability. As Holling (1973:21) expressed it, the "resilience framework . . . does not require a precise capacity to

predict the future, but only a qualitative capacity to devise systems that can absorb and accommodate future events in whatever unexpected form they may take." As we have witnessed in the 21st century, even widely expected disruptive forces, such as pandemic disease, can test cultural resilience in remarkable ways.

5.2 Exploring the effects of climate change on migration and violence

Violence (see Section 7) and migration (Section 8) are often seen as inevitable and maladaptive human responses to climate change (Robbins Schug et al., 2019). Bioarchaeology is replete with studies that contradict such generalizations. For example, Harrod and Martin (2014) examined variable responses to climate and environmental change among Ancestral Pueblo people of the Southwestern United States, including but not limited to migration and warfare. Some of the alternate strategies included formation of cooperative alliances with other communities, with exchange networks and critical resource redistribution. Flexibility and diversity of possible responses appears to have been the resilience response under these circumstances. Violence precipitously increased in populations that experienced drought and had constructed socioecological and cultural systems more rigid than their counterparts who engaged in alternative pathways.

Thus, flexibility in socioecological and cultural systems facilitates resilience. For example, shifting to different trade networks of food sources when drought challenges the environment, while maintaining essentially the same feedback systems within a population. This promotes reduced violent conflict when climate challenges emerge. Alternately, the system may be designed around a narrow set of interdependent components with high levels of inequality. These systems must drastically transform during periods of climate change, and transformation increases stress and violent interaction

Turning to a society more complex than the Ancestral Pueblo context, Robbins Schug and colleagues have also conducted research on human-environmental interactions over the past 4500 years in South Asia (Robbins Schug, 2011, 2016, 2017; Robbins Schug and Blevins, 2016; Robbins Schug and Goldman, 2014; Robbins Schug et al., 2012, 2013). They found variation in the experience of climate and environmental change in urban societies versus rural, agrarian villages. Human skeletal remains from cities such as Harappa or Mohenjo Daro demonstrate the effects of environmental and political changes on human communities. Interpersonal violence, infection, and infectious diseases were rare at the height of what is known as the Indus civilization (Robbins Schug et al., 2013). However, the skeletal remains of people who stayed behind and lived in these cities during the "post-urban" period demonstrate that the prevalence of traumatic injuries and infectious diseases increased over time with the onset of climate change and social instability and that the risk for interpersonal violence and disease was shaped by social inequality (Robbins Schug et al., 2012). In this case, the more resilient response indeed appears to have involved migration. Thus, flexibility again facilitated resilience, as homeland and place were flexibly defined, population survived challenges of climate change better than the more rigid group that remained in the urban area.

Though there are examples wherein the adaptive response was indeed migration or at least enhanced mobility (Buzon et al. 2007; Buzon and Simonetti, 2013; Thompson et al., 2005), other long-term histories report that migration is only one of many alternatives in the face of external stressors. Rather than assuming that mobility and migration are maladaptive, we should focus upon the factors that make population movement a resilient response For example, Beekman (2015) found that the archaeological evidence from the Guanajuato and Jalisco regions

of Northern Mexico in the Epi-Classic period demonstrate large-scale migration events coincided with prolonged drought in the period from 700-1200 AD. Drought and socio-political changes were triggers for large-scale migration, which in turn led to more socio-political instability. On the other hand, Stojanowski and Knudson (2011, 2014) also examined mobility in the context of environmental change in human populations from Niger, in the Sahara region of North Africa. In that case they found more subtlety in human migration patterns in the face of a harsh environment and climate changes. Early Holocene populations settled in the region and raised their children but sedentism corresponded to a high prevalence of biocultural stress markers (signs that suggest a period when homeostasis and/or growth were disrupted during infancy or childhood) in the bones and teeth of the younger generation. In the Middle Holocene, climate change led to aridification and these environmental changes were associated with higher levels of mobility. Responding to increasing aridity through an increase in population mobility in this case led to fewer signs of growth disruption in childhood. Importantly, there is no evidence that this increase in mobility resulted in socio-political instability or inter-personal violence.

Bioarchaeologists working in other areas of the world have found that there are a variety of historical and socio-cultural circumstances where the relationship between climate change and migration breaks down (e.g., Knudson and Torres-Rouff, 2015; Gregoricka 2016; Robbins Schug 2011; Tung et al., 2016). Importantly, bioarchaeology is able to identify how history and sociocultural variation shape the likelihood of climate and environmental change leading to migration and this allows our discipline to explore other pathways to resilience.

5.3 Climate and disease

Bioarchaeology has a key role to play in understanding the antiquity of modern observations of associations between climate change and infectious disease outbreaks. McMichael (2015) notes that extreme weather events, which are projected to increase with human-driven climate change, are often followed by disease outbreaks, as these disrupt social conditions and infrastructural elements relevant to public health and affect the distribution and/or demography of pathogens, vectors, and animal reservoirs. Global warming has led to an expansion of the areas that are hospitable to some pathogens and vectors, altering global distributions and prevalence of diseases such as cholera (Chowdhury et al., 2017). Understanding how climate change has shaped the distribution of pathogens and facilitated the emergence and spread of new diseases, and how humans have both contributed to climate change and suffered through or exhibited resilience in the face of climate-associated disease events in the past is important for prompting change today.

Bioarchaeological examination of the links between climate change includes recent work on historical plague epidemics. The mid-14th century plague epidemic, often referred to as the Black Death, that inaugurated the Second Pandemic of Plague (periodic epidemics of plague in Afro-Eurasia until as recently as the 19th century in some locales (Varlık, 2020)) emerged in the context of changing global climatic conditions associated with the end of the Medieval Climate Anomaly (also called the Medieval Warm Period) in the 1270s and the transition to the Little Ice Age (Brooke, 2014). Historians such as Campbell (2016) have suggested that climate change might have played a role in the emergence and spread of the Black Death. In England, the site of several bioarchaeological studies of the pandemic, the end of the Medieval Climate Anomaly was characterized by unstable and unseasonable weather that caused the back-to-back harvest failures that, in turn, produced famine conditions (Campbell, 2017). Bioarchaeological research in London has examined how severe famine events produced by those climate changes – in

syndemic interaction with intense population pressures, increasing urbanization, and dramatic social inequality – might have exacerbated vulnerability to plague, leading to higher mortality rates than might have otherwise been the case (for more details, see Section 9.1) (DeWitte, 2015b, 2018, 2021; DeWitte and Slavin, 2013). Associations have also been suggested between climate conditions and other historical pandemics, such as the Antonine plague in the 2nd century CE (Elliott, 2016) and the Plague of Justinian (also referred to as the First Pandemic of Plague) that began in the 6th century (Harper, 2017; McCormick et al., 2012). These have not yet received extensive bioarchaeological attention, but the availability of skeletal remains as have been used in aDNA studies of the Plague of Justinian (Harbeck et al., 2013; Wagner et al., 2014) suggests such work might be possible.

Not only does the Black Death provide an opportunity to examine the effects of climate change on the emergence and experience of disease, it is also relevant to our understanding of resilience. Following the Black Death, there were improvements in standards of living across status levels (Dyer, 1989) and in levels of health on average (DeWitte, 2014b) in England. From the perspective of resilience theory, these dramatic transformations might have occurred because the massive depopulation caused by the Black Death interfered with inertia in social and economic systems in England that had existed beforehand, such as little innovation and low investment in improving agricultural production (DeWitte et al., 2016). As bioarchaeological engagement with resilience theory continues to increase, we look forward to improved resolution regarding the variation that might have existed in resilience responses to disease in the past.

5.4 Diet and Adaptation

Global climate change has drastic impacts on local ecosystems, which influence modes of production and resource availability and, thus, human diet. Even small changes in ambient temperature by 2-3 degrees Celsius can transform ecosystems and dietary practices (Turner et al., 2020). As our planet faces the challenge of increasing temperatures, changes in precipitation patterns, and increasing intensity storms, ecosystem turnover and precarity in human diet are increasingly likely (Brown and Funk, 2008; Hanjra and Qureshi, 2010). Food scarcity attributable to global climate change already challenges human communities and threatens communal existence (Connolly-Boutin and Smit, 2016; Gregory, Ingram, and Brklacich, 2005). As anthropologists, we recognize that diet is more than mere sustenance – it is reproduced through cultural transmission and forms the basis for symbolic modes of communication. Archaeological and bioarchaeological studies demonstrate that changes in ambient temperature, droughts, and storminess have resulted in drastic transformation in diet that may have prompted deeper consequences such as increases in stress and disease, violence, and regional abandonment, whereas flexibility within socioecological and cultural systems have facilitated resilience in diet (Harrod and Martin, 2014; Hegmon et al., 2008; Nelson et al., 2016). Bioarchaeological studies of diet provide a contextual and longitudinal understanding of human diet during periods of climate change. Within these studies, it is possible to understand how population adaptability provides mechanisms for survival during climate change, and specifically, the ways in which flexible behaviors help facilitate resilience in diet. Finally, many of these studies also illustrate the ways in which resilience in ideological systems may be facilitated by dietary transformations that are required for surviving climate change, or alternately, introduce rigidities that increase precarity within socioecological systems.

A compelling example of flexibility within socioecological and cultural systems is associated with dietary resilience in Late/Final Jomon communities during a period of climatic

cooling. This has been documented archaeologically and bioarchaeologically in Southwestern Honshu, Japan, at around 4100 BP (Temple, 2019a). Stable isotope analysis and carious lesion frequency indicate that populations increased consumption of cariogenic plant foods, reduced consumption of terrestrial and aquatic animals (Kusaka, Ikarashi, Hyodo, Yumoto, and Katayama, 2008; Kusaka, Uno, Nakano, Nakatsukasa, and Cerling, 2015; Temple, 2019a). This dietary transition was facilitated by socioecological practices that drew upon long-standing memory in plant cultivation indicating resilience in Jomon diets. Animal remains appear in grave goods following this period of climatic change suggesting that these residual elements became incorporated into the intergenerational symbolic communication systems between the living and dead (Temple, 2019a). While these grave goods are consistent with emerging inequality (Kiriyama and Kusaka, 2017), the use of animal remains as tools for symbolic communication uphold the reciprocal relationships with nature that are found in hunter-gatherer communities hinting at a further mechanism for dietary resilience within ideological systems.

The importance of ideology is also emphasized by Temple and Kusaka (2022), who report that flexibility in dietary practices facilitated resilient occupation of Yoshigo Shell Mounds (Japan). During climatic cooling events around 2900 and 2800 BP, emphases on ancestral affiliation through spatial patterning and grave goods persisted. Similarly, shell mounds in Brazil were occupied for several thousand years, and during this time, ritual communication through burial and feasting remained static, despite clear evidence for changes to local ecosystems (Fish et al., 2013). The El Monton site on Santa Cruz Island of the Channel Islands, California, was occupied by populations across a 4000-year span. During this extended period, ritual power and ancestral affiliations were used to maintain persistent occupation of the landscape despite shifting dietary practices and climatic challenges (Gamble, 2017). Such case studies provide examples for long-range, resilient occupation of landscapes by shifting dietary practices in response to climate change, yet maintaining ancestral affiliation with place.

Another example of climatic cooling occurred at around 8.2 kya across Northern Europe (Thomas et al., 2007); resultant environmental changes led to distinctly different responses for Mesolithic hunter-gatherers from Oronsay Island off the west coast of Scotland (Wicks and Mithen, 2014) and the contemporaneous groups from south Wales (2019). The former abandoned their homelands, while the sites from Wales present evidence of continued occupations in the face of notable climate change. Stable isotope analyses suggests that the groups from Oronsay Island had been heavily reliant on maritime resources and that increased environmental instability may have impeded access to these foods, leading to abandonment (Schulting and Richards, 2002). By contrast, stable isotope analyses for contemporary people in Wales, points toward a more diverse socioecological system associated with dietary resilience and population survival across the 8.2 kya event in the region (Schulting, 2019). These studies support hypotheses derived from resilience theory that emphasize flexibility within socioecological and cultural systems to facilitate greater resilience in diet, which have tremendous import as adaptability becomes a hallmark component of survival in a rapidly changing global climate.

Archaeological and bioarchaeological evidence underscores the fact that diet should be considered an independent variable, not necessarily inherently linked to other sociocultural variables. For example, Stojanowski (2019a), using carious lesions, antemortem tooth loss, periapical abscesses, and dental calculus, argues for the persistence of a core diet at the Gobero site in Niger during and after climatic aridification at around 6500 BP. Despite a relatively stable diet across this time period, transformed sociopolitical structures are visible, include large-scale

cemeteries, specialized disposal areas, and funerary pendants, perhaps signaling the emergence of ethnic distinctions. Berger and Wang (2017) interpret decreased rates of stress markers across the Bronze Age in the Hexi Corridor of Gansu in the context of fluctuating climate conditions as reflecting the resilience of the agropastoral subsistence strategies that existed at the time. On the other hand, marked changes in diet are also found independent of climatic and or environmental change. The European Mesolithic-Neolithic transition is one example of a marked dietary change independent of climate change where transformation in patterns of migration, diet, ancestry, and ritual practices swept across a landscape (Schulting, 2019).

5.5 No Grand Narratives

Governmental and non-governmental organizations are developing plans to cope with and respond to climate change. Unfortunately, policy and planning professionals are not relying on archaeological sources to inform their decision making (Rockman, 2012; Sabloff, 2009, Van de Noort, 2011). The most prominent sources for the public and, unfortunately, policy makers are authors like Jared Diamond and Steven Pinker, whose discourse about human adaptation and "human nature" in the face of external stressors is underinformed anthropologically (Robbins Schug et al. 2019). Thusly apprised, the Human Security field has reached erroneous conclusions about human behavior in the context of climate change, specifically that resource scarcity, social inequality, and environmental migration will inevitably result in increased conflict and inter-personal violence, e.g., Adger, 1999; Alvarez, 2016; Carleton et al., 2016; Cramer, 2002; de Soysa et al., 1999; Ehrlich and Ehrlich, 2013; Gilgan, 2001; Gough, 2002; Hsiang et al., 2013; Matthew, 2010; Mochizuki, 2004; Nordås and Gleditsch, 2007; Oels, 2012; Ohlsson, 2000). This perspective—that climate change always leads to migration, competition, and violence leads to narratives emphasizing US isolation and military power (Hartmann, 2013; Lane, 2010).

Broadly speaking, bioarchaeology challenges such simplistic Grand Narratives of human history. Small scale societies are often resilient in the face of environmental change; mobility, flexibility, and adaptive diversity is a largely successful strategy for avoiding negative consequences (Berger and Wang 2017; Gregoricka, 2016; 2021; King et al., 2018; Robbins Schug, 2011; Snoddy et al., 2020a; Sohler-Snoddy et al., 2017; Stojanowski and Knudson, 2011; 2014; Temple and Stojanowski, 2019a; but see also, Bartelink 2006, 2009; Bartelink et al., 2014; 2019). However, complex societies are often much less flexible, often falling into the "rigidity trap" (Holling and Gunderson, 2002). They are too frequently built on structures of social inequality that can become fault lines for further marginalization when crises arise, including longstanding and rapid climatic change events (Nystrom and Robbins Schug, 2020).

Thus, bioarchaeological research on human health in the context of global climate change demonstrates that sometimes the social and cultural changes that people employ in the short-term may ultimately not be enough to buffer them from long-term consequences of environmental change. However, grand narratives concluding that climate change always leads to migration, competition, violence, and collapse are overly simplistic and do not account for the important historical, social, and cultural forces that actually shape human perceptions of climate change, decision making, and the consequences of different choices.

5.4 Conclusions

In bioarchaeology, we have denaturalized natural disasters such as climate change by recognizing that moments of crisis and chaos are also windows for socio-cultural change and biological adaptation (e.g., Robbins Schug, 2016). When reframed in this way, we remove the

tendency to think of change as bad and to inadvertently reify pre-existing structures as somehow "good" or "natural" for that time and place (Moore and Baldwin 1993). This de-essentializing is similar to that seen when we emphasize bioarchaeological evidence for alternative, humane responses to human variety, whether in shape, size, color. sexual orientation or health (see Section 4).

One of the challenges we face as scholars interested in contributing to broader discourses about climate change is creating a narrative that captures cultural diversity without becoming so rife with details that no conclusions emerge. If, for example, flexible responses are more resilient than rigid ones, we should say so without becoming lost in descriptive minutiae, however "interesting" these may be. To ensure that our research relates to broad issues of significance begins at the level of the research design and ensuring that the questions we as are important in understanding the past as they also relate to issues of significance in today's world (see Section 11).

6. MIGRATION

On the 4th of July, 2021, the United States –itself a settler colonial nation – celebrated nearly 250 years of independence; meanwhile, global news was awash with stories of contemporary migrants and the human drama that both stimulates and follows human movement. Migrations and human mobility have been prominent throughout humankind's history, from the original dispersal of our species "out of Africa" to our current ability to cross continents in a matter of hours. Bioarchaeologists and their intellectual predecessors have long studied this phenomenon by scientifically investigating variation in our species across time and space, dating back at least to the Italian Renaissance studios of Leonardo da Vinci and Albrecht Durer, where scientific studies of bodily proportions anchored art.

Many discussions at the Workshop focused on the link between the discipline's deep history of studying human variation and scientific racism. The names of Aleš Hrdlička, Georg Neumann, and Earnest Hooton and racialized science have become synonymous in many minds. Rather than reviewing this well-trod history, as we discuss "decolonizing bioarchaeology" elsewhere in this essay, we will address here a number of ways in which 21st century bioarchaeology can and should engage with migration and the manner in which it can be studied through the embodied signatures of heritage, residence, and cultural modifications. We begin by emphasizing that "words matter" and argue in the strongest possible terms against the typological terminology (and thinking) that continues to characterize some studies of migrations and heritage, both bioarchaeological and molecular. We also emphasize the multi-scalar nature of migration studies and the manner in which multi-disciplinary approaches to population movement should emphasize both the "bio" and the "archaeology" of our name.

6.1 Words Matter

Following the lead of bioarchaeologist Stojanowski (2019b), biological anthropologist Kenneth Weiss (Weiss and Lambert, 2011, 2014; Weiss and Long, 2009), forensic anthropologist Ann Ross (Ross and Pilloud, 2021; Ross and Williams, 2021), and molecular anthropologist Deborah Bolnick (2008), we must advocate against the use of typological language in discussions of the history of humankind and human variation, frequently found today in reference to migration. Changing the use of ingrained, typological terms will not be easy, as they reflect a way of thinking closely meshed with categorizing humankind in terms of races, either implicitly or explicitly. Racist political groups frequently use poorly chosen words from

scientific reports to justify their dogma. As Stojanowski (2019b:183) emphasizes, "[t]his is unacceptable, and it is time for bioarcheologists, those who study ancient migrations with nuance and context, to speak out".

6.2 **Bioarchaeology, Genomics, and Migrations**

While migration remains a highly visible topic in the public eye, there have been relatively few attempts by bioarchaeologists to publicly engage "big picture" questions, such as the Great Migration[12], the Lapita-Polynesian Colonization, and the Peopling of the Americas. Bioarchaeologists have written authoritatively about the Great Migration (de la Cova, 2011, 2014, 2019) and continental migrations (e.g, Neves and Hubbe, 2005; Hubbe, et al., 2011, and Powell, 2005), but we are seldom viewed as the "go to" authorities on the topic. The most notable bioarchaeological exception is the African Diaspora, writ large in the research of Michael Blakey (2001, Blakey and Rankin-Hill, 2009). Today's broad-scale syntheses tend to either be by molecular geneticists (Reich 2018) or molecular anthropologists in collaboration with archaeologists or museum specialists (Lamnidis, et al., 2018; Willerslev and Meltzer, 2021).

Tensions between those favoring migration, as opposed to diffusion, in explaining sequences of distinctive material culture assemblages have beset archaeology since it emerged from the mists of antiquarianism. Mid-20th century archaeologists, however, armed with Libby's (1955, see also Renfrew, 1973) revolutionary chronometric discovery soon realized that they need not explain the changing patterns of humankind's residues within a very narrow time frame. Models that invoked *in situ* change were posited and explored. Drilling down on non-migration explanations thus freed those studying the past to explore paradigms that did not require population replacement. Stable, complex systems models of processual archaeology focused regionally rather than explicitly addressing mechanisms for change through time (or space). Subsequent post-processual archaeology similarly avoided migration, despite the potential for re-energizing this topic given its criticism of universal paradigms and emphasis placed on individual agency (Barrett, 2012; Hodder, 2004).

Migration's passage from visibility to invisibility during the 20th century has been recounted by various archaeologists, including Adams et al., 1978; Anthony, 1990; Burmeister, 2000; and Harke, 1998. In turning away from migration, archaeologists risked, as anthropologist and student of Indo-European migrations David Anthony's classic 1990 article suggested, dispensing with the baby along with the bathwater. Migration persisted as an explanatory model for change only among some archaeologists in Europe who continued to work within cultural-historical frameworks, many of whom simplistically equated material culture with supposedly discrete biological and cultural groups (Furholt, 2018; Heyd, 2017).

In parallel, bioarchaeologists, reeling from critiques of the "old physical anthropology" focused on searches for better biodistance methods, such as the so-called "non-metric traits" (e.g., Buikstra, 1972; Finnegan, 1972; Ossenberg, 1970; Spence, 1974, see also Buikstra et al., 1990, Hefner et al., 2016). These were frequently used to argue against population replacement in regional contexts where changes in material culture were *de facto* explained by migration. Inspired by the "new archaeology," many bioarchaeologists turned away from biodistance studies, as they focused upon research questions more in line with the adaptationist concerns of processual archaeologists, many of which related to health and diet (Armelagos, 1969; Cook, 1979). This shift in bioarchaeological emphasis led to the immensely productive health-related

[12] Movement of six million African-Americans from rural southern United States to the urban North between 1916-1970. https://en.wikipedia.org/wiki/Great_Migration_(African_American)

studies associated with food production (Cohen and Armelagos 1984), as mentioned in the Introduction (see Section 1).

As with radiocarbon dating in the 20th century, the 21st century has seen remarkable technological advances in genomics and bioinformatics, which facilitate new insights in the study of archaeological migrations. Approaches generally take two basic forms, the study of contemporary variation, which is projected into the past, and the study of ancient DNA, sometime replicating the full genome of very ancient materials (Pickrell and Reich, 2014). The former may include quite large samples although they may reflect only relatively recent events (Pickrell and Reich, 2014; Stojanowski, 2019b). Ancient DNA, although limited by taphonomic factors, holds potential for inferences at global-to-local scales (Calloway 2018). That we have several high-quality Neanderthal genomes as well as from their sister group Denisovians are achievements unleashed through the power of genomic analysis (Mafessoni et al., 2020; Prüfer et al., 2014, 2017; Reich et al., 2010; Slatkin and Racimo 2016). Similarly, stimulated by new methods for data collection, capture, and analysis, 21st century bioarchaeologists are exploring documented genealogies in studies of complex dental structures in a manner that should improve biodistance models and promote renewed emphasis on bioarchaeological studies of migration (Paul and Stojanowski, 2015; Paul et al., 2017; Stojanowski et al., 2017, 2019b).

Disputes have developed, however, over general genomic models for migration, such as those proposed by Haak et al. (2015) and Allentoft et al. (2015) for the Yamnaya Culture pastoralists from the Russian and Ukraine steppes as they apparently replaced earlier Neolithic farmers in Europe (Calloway, 2018). Such models, pronounced with authority of what biological anthropologist Ann Horsburgh (2015) terms "molecular chauvinism," may serve relatively well as maps for characterizing global or continental scale migrations, but when we focus on people and processes, as Horsburgh (2015: 142) emphasized, "privileging the genetic data over all the other classes of data available impoverishes the nature of the reconstructions available to us." In the case of the Yamnaya model, archaeologist Martin Furholt (2018: 164) reminds us that genetic data needs to be better contextualized using archaeological theory, and that "anthropology shows us that material culture may be linked to diverse and changing layers of identities, may be actively used for different purposes by social actors, and may have a different and changing impact on social interaction," echoing issues raised by TallBear in Section 4.4. These are lost when monolithic linkages between cultural and biological units, so similar to the outdated archaeological tropes of the early 20th century, are newly attired in white coats and promoted today (Furholt, 2018, 2019a, 2019b).

To date, even if samples are painstakingly chosen by bioarchaeologists, the migration debates have most visibly involved molecular or archaeological scientist-spokespersons. Biodistance and mobility studies are not commonly included in this work, sometimes added later but not really integrated into the research design, although this may be changing with Furholt's (2019a) polythetic approach. More anthropologically satisfying, at the other end of the scale, is an earlier study of people also associated with the third millennium BCE Corded Ware Culture (Haak et al., 2008). Biological profile information along with DNA and strontium isotope studies of mobility, lineage relationships, and sex-based residence were combined to explore the circumstances of life and death of 13 individuals, apparently the result of a massacre that took place near present-day Eulau, Germany, approximately 4600 years ago (Meyer et al., 2009). This integrated, interdisciplinary effort speaks to the manner in which Neolithic people lived, and their deaths speak compellingly to political tensions and violence associated with regional culture change.

Another impressive example of interdisciplinary research designed to address population structure and mobility by Amorim et al., (2018) focused on the European "Migration Period" of the early Middle Ages (4th-6th centuries, CE), following the dissolution of the Roman Empire. Supplemented by archaeological contextual information and by isotopic signals of diet and mobility, deep genomic characterizations of 63 individuals from two cemeteries illustrated organization around biological kindreds, structured also by sex. The authors argue that their results illustrate that "long-term shared common descent can shape social identity and that this is reflected in material culture" (Amorim et al., 2018, 8). Each of the two cemeteries contained burials of two distinctive ancestral groups also defined in terms of their funerary contexts. In addition, results are consistent with migration models, as proposed historically and through material culture. Such nuanced, focused and interdisciplinary studies are convincing and compelling snapshots that reveal much about larger historical processes well beyond their precincts.

6.3 Bioarchaeological Approaches to Migration

Recent, edited volumes on migration (e.g., Cabana and Clark, 2011; Baker and Tsuda, 2015) have included bioarchaeologists, who made significant contributions to regional histories, methodologies, and theoretical issues (Frankenberg and Konigsberg, 2011; Knudson, 2011; Knudson and Torres-Rouff, 2015; Zakrzewski 2015;). In these collections, bioarchaeologists have tended to focus on subtle, but important, relationships in local regions., e.g., the following examples.

> The bioarchaeology traces aspects of these different models of Iberian history. The very fact that religious practice imprints upon the body suggests the distinctiveness and separation of the Islamic peoples from the autochthonous individuals. It further suggests that religion might act as a disruptor to social cohesion.
>
> This model suggests a large migration associated with an initial period of social, cultural, and religious disruption, followed by transformation, as both religion and the populations are incorporated to form the Andalucían history.
>
> Zakrzewski, 2015, 66

> During and after environmental and political disruptions and the resulting changes in social and economic networks in the south-central Andes, Atacameños perhaps chose to stay put and tie their success to local endeavors as a means of surviving and possibly even prospering during the Late Intermediate Period. Like Morrissey (chapter 9), we argue that human responses to environmental disruptions vary, and may or may not include migration from one environmental zone to another, presumably less affected, zone.
>
> Knudson and Torres-Rouff, 2015, 136

These carefully argued conclusions imply more general questions: Are religious differences introduced by immigrants typically more disruptive to social cohesion than other customs? How do religious differences affect local transformations? How do communities at the edge of distant state political control respond to the withdrawal of foreign influence? How is resilience in the

face of such changes demonstrated? Certainly, these studies are regionally significant, but how may they expand to address larger issues?

An important step moving forward may be seen in Lesley Gregoricka's (2021) review of migration studies in bioarchaeology, which defines a number of topical areas wherein bioarchaeological studies have been prominent: social and ethnic identities; kinship analyses and post-marital residence; forced migration and enslavement; contact, interaction and admixture; and climate change and disease transmission. If bioarchaeologists and their colleagues can regularly report a common suite of parameters relevant to such a focused set of issues, then comparative studies may generalize accordingly. Gregoricka (2021) also urges, as do we, that bioarchaeologists develop a habit of disseminating both their local and more general results on these and related issues to the public.

The long-term perspective afforded by bioarchaeology has the potential to reveal whether the patterns of health among migrants observed in some contexts today also existed and thus shaped variation in health within and between populations in the past. Specifically, several studies of contemporary populations have revealed that individuals who successfully migrate are, at least temporarily, healthier on average than individuals in both their sending and receiving populations (the so-called "healthy migrant effect" or "migrant selectivity) (e.g., Chen, 2011; Lu, 2008; see also Groves et al 2013 where a mobility study of an Anglo-Saxon site in northeast England found that migrant individuals appeared to have had a better overall state of health than the local population)). The long-term perspective of bioarchaeology is also ideal for addressing social theories about migrations, including, for example, Manning's (2006) hypothesis that cross-community migration is the most transformative force of all forms of migration, which he defines as a "subcategory of mobility in general" (Manning, 2006: 31).

> Cross-community migration, in which human individuals and groups move to join an existing community and learn its language and customs, is a consistent, species-based form of behavior that systematically structures human life. Colonization, in which existing communities expand to new territories, is quantitatively significant in human migration, but has been less productive of social change than cross-community migration.
>
> Manning, 2006, 28

Manning's (2006) perspective emphasizes process in a behavioral model, which focuses on human motivations and impacts, rather than an ecological focus on locations of origins and destination.

Individual and group identities associated with migration have been investigated by bioarchaeologists in a variety of contexts, frequently facilitated by biodistance and bone chemistry studies of mobility, such as those reported in Knudson and Stojanowski (2009a, 2020). Perhaps studying identities, as they change across migrating and recipient communities, would be a way to characterize the human experience of immigration effectively. Stojanowski's (2010) pioneering study of Seminole ethnogenesis is a useful model in this regard, as is Zakrzewski's (2015) study of Islamic Iberia during the Medieval Period, discussed above. Identity and migration studies would thus seem ideal venues for bioarchaeology to play a central role. After all, the human body in motion is the core of migration, wherein new identities may be embodied in association with new materials and language forms.

Bentley et al. (2009) assessed identity, kinship and mobility through the comparison of strontium, carbon and oxygen isotopes in human teeth with burial artifacts at a Bronze Age site in northeast Thailand. Among the females at the site, different groups were identified through isotopic signatures and these groups also had distinctive types of pottery. The authors argue that their social identity is therefore drawn from place of origin (in this case different villages) and is represented by material culture in the mortuary context.

The relative lack of research on Pacific migration is indicative of the small number of sites that have been excavated with human remains. However, from the sites that have been excavated with human remains there has been extensive bioarchaeological work, particularly over the past 15 years exploring human colonisation and adaptation, including Lapita colonisation (Clark et al. 2017, Buckley et al. 2010; Kinaston et al. 2013; Walter et al. 2017). However, recent aDNA work, including genomic research, is expanding knowledge and understanding of the complexities of migration into the Pacific including the early settlement by Lapita people, to the settlement of distant islands, including Aotearoa New Zealand (Knapp et al. 2012, Lipson et al. 2018, Skoglund et al. 2016). Because of the political and cultural complexities of working with human remains in the Pacific, some of the previous biological anthropological research on migration focused on aDNA and DNA analysis of commensal animals as proxies for human colonisation (Matisoo-Smith 2015).

Thus, migration and mobility studies are ideal contexts for bioarchaeologists to contribute to scientific advancement of knowledge and also to shape public awareness of past human group and individual transformations in the course of migrations. Changes in the human landscape – whether biological or cultural – can be invigorating, as they are inevitable. Bioarchaeologists have contributed to the study of migrations at a number of scales, ranging from the individual experience of those enslaved (Blakey and Rankin-Hill, 2009) to an economic underclass (Beaumont et al 2013; Harrod et al., 2012). The motivations for migrating, as well as definition who migrates are important questions, amenable to bioarchaeological stud. As families and other kin groups are frequently the core of mobile units, we urge, along with Johnson (2019; Johnson and Paul, 2016) that in the study of kinship, at any level, bioarchaeologists extend their view of families from normative, biological definitions to encompass nonnormative conceptions, which will require focus up context and nuanced analyses to characterize human behavior along multiple scales (see also Section 4.4).

6.4 Conclusions

In sum, our discussions of migrations lead us to a number of significant conclusions, some related to the fraught history of bioarchaeology in the study of human migration and mobility. While we encourage bioarchaeologists to continue to engage in the study of human variation in relationship to human movement, we also urge that terminology eschew typological language and focus on the people whose bodies moved across the landscape. Words matter, and nowhere more importantly than in studies of the human past. In research on migration, at whatever scale, we should engage with sufficient contextual information to characterize the process of human behavior before, during, and as a result of human migration and mobility, including impacts within the receiving region. By exploring details, we can establish those attributes that are of more general significance, beginning to answer questions about, "under what conditions do individuals and groups move?" These conditions may be environmental, political, economic, social, or, most likely, a combination. Ethnic groups are fluid, and ethnogenesis is an important, vital process in human history. In migration models, ground

truthing with bioarchaeological, archaeological, and historical evidence is essential for knowledge to truly advance. And finally, the public should be partners in this endeavor, especially when they compose a descendent community, but also as they respond to the research we present in public venues, as is our responsibility.

7. VIOLENCE

> . . .bioarchaeologists are ideally positioned to explore the causes of violence in earlier societies. Human remains from archaeological sites are a unique source of data on the environmental, economic, and social factors that predispose people to both violent conflict and peaceful coexistence.
>
> Walker, 2001, 574

In this epigram from two decades ago, Phillip Walker reviewed the status of violence studies in bioarchaeology, challenging researchers to generate data that represent fracture frequencies, rather than reporting isolated examples, to address a number of questions significant for interpreting ancient contexts. He also moved seamlessly between contemporary and archaeological examples as he illustrated the relevance of bioarchaeology for addressing fundamental questions about the nature of aggression in our species, its patterning, and its distribution across time and space. He closed by noting the frequent association of climatic instability with violence, when viewed at a global scale. We will return to that issue later in this essay.

In the two decades since Walker's review, bioarchaeologists have published widely on violence, including expanding the availability of frequency data that was lacking at the time of his writing. The Bioarchaeology Workshop's discussion of violence centered on both direct evidence of physical violence in trauma analyses, and Galtung's (1969) and Farmer's (2004) notion of structural violence and how we could investigate this powerful construct in the bioarchaeological record. The group concluded that the subtle yet impactful forces of structural violence stemming from long standing power inequalities could indeed be critically examined—at least partially—with a bioarchaeological lens. To achieve deep insights into direct physical violence and structural violence, our group emphasized the need for nuanced analyses of temporal trends and regional examples were emphasized, as were prospective partnerships with colleagues in both violence and peace studies. Participants cautioned against monocausal explanations for violence, emphasizing relationships with other variables, such as climate change, migration, social and gender norms, and inequality as well as the context-dependent reasons for and repercussions of violence.

In this section, we consider trauma and violence from several perspectives, beginning with a brief methodological stock taking, followed by a review of general conclusions, and ending with a projection of where future studies of past physical violence may be most helpful in conceptualizing humankind's future. Recognizing that there are inextricable links between these two forms of violence in human groups, due to their distinctive osteological signatures, this essay will consider interpersonal and structural violence separately. In turn, the latter section will be subdivided between aspects of structural violence as it affects the living individual and the body as it is treated following death.

In considering the dissemination of knowledge about trauma, we recognize, for example, that studies of early hominin violence are both important and engaging case studies that also

provide the foundations upon which to build humankind's history of inter-personal aggression. The public is often drawn to such reports, which can serve to anchor broader discussions. In these contexts, however, it is crucial that our primary case studies must be accurate, and we therefore must recognize both the strengths and limitations of our current methodologies.

7.1 Trauma and Interpersonal Violence

Through the study of intravital bone trauma, bioarchaeology contributes to our understanding of physical violence across humankind's past. Bioarchaeologists also explore the intricate, complex relationships between the factors that predispose to interpersonal and group violence, and they infer day-to-day activities that increase the risk of broken bones. For example, antemortem and perimortem[13] fractures, frequently exciting public interest and also stimulating controversies, have been identified in ancestral hominins (e.g., Berger and Trinkaus, 1995; Kappleman et al., 2016; L'Abbé et al., 2015; Weidenreich, 1939, 1943). Counter arguments have focused on probable postmortem causation and the limited nature of monocausal arguments (Binford et al, 1985; Binford and Stone, 1986; White, cited in Hersher 2016[14]; Trinkaus, 2012). In response to critiques, interpretations of fractures in Neanderthal remains have moved from proposing unicausal, global explanations to recommending context-specific arguments (Trinkaus, 2012). As we shall see here, the search for causation continues in studies of more recent, Holocene human communities, with researchers generally agreeing with Trinkaus about multiple causes. Many bioarchaeologists, including those at the Bioarchaeology Workshop, however, argue that key interacting, predisposing variables may indeed be identified through nuanced contextual studies.

Projectile and sharp force trauma to the bony skeleton are readily recognized by bioarchaeologists, as are distinctions between antemortem, perimortem, and postmortem examples. Less obvious are the effects of blunt force trauma, with distinctions between perimortem and postmortem changes due to taphonomic factors, especially ground pressure, subject to dispute, e.g., Lahr et al., 2016, Stojanowski et al., 2016. As some of the more visible, attention-getting examples of trauma require distinctions between perimortem blunt force trauma and post-depositional changes (Lahr et al., 2016, Kappelman et al., 2016; Ingvarsson and Bäckström, 2019), developing accurate standards for distinguishing perimortem trauma from postmortem alterations based upon forensic and funerary archaeological excavation expertise is essential. The methods created and applied by Sala et al., (2015a, 2015b, 2016) for remains from the Middle Pleistocene site of Sima de los Huesos (Atapuerca, Spain) appear promising for resolving this significant problem. Knowledge drawn from forensic anthropology about fracture biomechanics, fracture healing rates, and the role of taphonomy in altering bone to mimic antemortem and perimortem processes is essential in bioarchaeological studies of trauma.

Other important methodological concerns require the researcher to distinguish bony reflections of non-violent, frequently occupational accidents, from those truly reflecting interpersonal violence. Arkush and Tung (2013), for example, present an extensive compilation of expected skeletal correlates for certain forms of violence behaviors. Other recent reviews of bone fracture and causation appear in Wedel and Galloway (2014) and Lovell and Grauer (2019). An abundance of bioarchaeological treatments of violence include Anderson et al., (2018), Domett et al., (2011), Martin and Frayer (1997), Knüsel and Smith (2014), Martin et al. (2012), Martin and Anderson (2014), Harrod and Martin (2014), Klaus and Toyne (2016), and

[13] defined as occurring at or around the time of death

[14] https://www.npr.org/sections/thetwo-way/2016/08/29/491841003/scientists-divided-over-how-lucy-died

Redfern (2016, 2018, 2019). Attention to data recording systems is also important so that comparisons can be make and etiology assigned**, e.g.,** Magalhães, B. M., et al., 2020.

For much of the 20th century, archaeological interpretations of the past largely ignored evidence of violence in small-scale societies, ultimately reconsidering this stance due to evidence provided by Keeley (1996) among others. Keeley's volume, *War Before Civilization: The Myth of the Peaceful Savage* (1996)*,* illustrated the deadly force expended by warriors in small scale societies and convincingly countered the argument that conflict was something that peaceful Indigenous communities learned from colonists. Bioarchaeologists have a long history of addressing inter-personal violence in groups of small size, including topics such as cannibalism (Turner and Turner, 1999; White 1992) and torture (Osterholtz 2012). Even so, the popular and frequently cited treatments of temporal trends in violence are commonly published outside our field. A recent example by Pinker (2011) uses a number of sources, including a global sample of bioarchaeological reports, to argue that violence was more prevalent in the past than it is today. As Milner (1999, 2007, 2019) and others have emphasized, generalizations about humankind's violent nature require nuanced regional sequences, rather than samples collected from across the globe with little regard for archaeological, historical, and cultural contexts.

As with studies of health and disease (cf. Cohen and Armelagos, 1984; Cohen and Crane-Kramer, 2007; Steckel and Rose, 1997; Steckel et al., 2018), bioarchaeologists studying violence have both developed knowledge across temporal spans and focused on detailed analyses of specific communities delimited in time and space. Comparison of the results of studies of temporal sequences across vastly different regions have underscored the lack of directionality implied by popular writers such as Pinker (2011). For example, a detailed study of cranial trauma and fortifications among pre-contact Andean groups from 8000 BCE to 1532 CE revealed considerable evidence of violence during the late Early Horizon (400 BCE-100 CE) and then again during the Late Intermediate Period (1000-1400 CE) with an apparent lull in between (Arkush and Tung, 2013). For Western Europe, Baten and Steckel (2018: 320) report that over the past 2000 years a combination of factors, including "population increases, climate change, interstate conflict, political fragmentation, religious intolerance, and disease—contributed to the unusually high levels of violence during the Late Middle Ages" (14th-15th centuries CE). The Late and Early Medieval Periods (5th – 10th centuries CE), however, presented the most elevated frequencies of healed and perimortem trauma, along with weapon wounds, which were the criteria used for recognizing violence in the 4738 (4726 >50% observable) crania that served to anchor the Baten and Steckel (2018) study.

Redfern's (2020) overview of bioarchaeological evidence from European contexts from the Neolithic Period (c. 7000 – 1700 BCE) through the 17th century CE highlights convincing evidence for violence directed at both children and adults during a climatic *optimum* between 5600-5000 BCE, and more generally that there is no necessary directional link between climate change and violence. Similar conclusions are also drawn by other bioarchaeological case studies in *The Routledge Handbook of the Bioarchaeology of Climate and Environmental Change,* edited by Gwen Robbins Schug (2020). Specific regions may be environmentally buffered by a diversity of resources and a culture sufficiently adaptive to take advantage of alternatives. The topic of human adaptation is considered in a later section of this essay, while resilience theory, adapted from ecology via archaeology (Buikstra 2019d), is being applied in bioarchaeology (Temple and Stojanowski, 2019a). Environmental buffering is discussed in a bioarchaeological example by Pilloud (2020), who found that a Central California response to climate change between 1000-1200 CE (Early Medieval Warm Epoch) did not include the violence and other

evidence of skeletal stress, reactions which are seen in contemporary groups from more southern portions of the same region. Non-lethal violence, perhaps as a mode of conflict resolution, did increase for adults of both sexes during the Middle Late Intermediate Period in the Atacama Desert highland oases in present-day Chile during a "volatile moment in Atacameño prehistory" (Torres-Rouff, 2020: 339). In nearby Bolivia, across 3000 years, Lake Titicaca's water levels have fluctuated, but not all such changes correlate with the increased violence largely explained by political developments. The significance of cultural flexibility is underscored by the failure of the Greenland Norse to adopt coping mechanisms honed by the Inuit, which served the Inuit well during the Little Ice Age (1300-1850 CE) and ultimately drove the Norse from Greenland (Redfern, 2020).

These patterns pertain to local regions, some with more limited time scales than Pinker's (2011) survey of archaeological data inferring violence/warfare in a combined global sample of previously reported perimortem trauma and projectiles within bones. Other arguments for decreases in violence, in this case homicides, have been developed from historical records, e.g., Eisner's (2003, 2014) History of Homicide Database. Bioarchaeological studies, on the other hand, emphasize that time trends are not unidirectional, with multiple contextual factors evoked in explanation. Bioarchaeological critiques, however, are largely limited to academic language and scholarly publications. Our goal should be to reach broader non-professional audiences in a professionally-responsible manner.

As Robbins Schug (2020, in a non-technical treatment of her larger compendium, emphasizes, "the deterministic view that climate change invariably causes migration, competition, violence, and collapse is overly simplistic. Bioarchaeology shows us that human responses are far more complex and diverse."[15] Resilient reactions that involve flexibility in the face of difficult alternatives are amply documented across the archaeological record, as is the human cost of failing to plan for managing both short pulses and long-term challenges to contemporary lifestyles. The lessons from bioarchaeology suggest that even resilient responses may involve difficult choices among varied alternatives, such as a different menu and food production system, or more drastically, migration. Even non-lethal violence as conflict management appeared in cultures as diverse as the those living in the San Pedro de Atacama oases and the Chumash of southern California (Torres-Rouff ,2020; Torres-Rouff and Costa, 2006; Walker, 1989)

7.2 Structural Violence

Although we have separated physical violence from structural violence in this discussion, we clarify that they are inextricably linked; the forces of structural violence greatly impact the frequency, pattern, and effect of physical violence and also contribute to other forms of bodily and psychological harm (Tung 2021). Briefly, Galtung's (1969) definition of structural violence includes the institutional, societal, and political limitations of an individual's ability to achieve This is a useful construct for bioarchaeologists, as the impact of structural violence may be recorded in a variety of acute and chronic stressors, such as dietary inadequacy, disease, trauma, and pathogen load (Zuckerman et al. 2021) (Section 7.2.1). Trauma is another way in which structural violence may be embodied. A second aspect of structural violence, as applied bioarchaeologically, relates to post-mortem treatment of the body, especially autopsies and recovery for reference "documented collections" of human remains (Section 7.2.2).

[15] https://www.anthropology-news.org/articles/the-long-view-of-climate-change-and-human-health/),

Various other theoretical approaches to the expression of power differentials, such as biopolitics/biopower (Foucault, 1976), dead body politics (Verdery, 1999), necropolitics/ necropower (Mbembé, 2003), and the poetics of violence (Whitehead, 2002, 2004) are being adapted today in bioarchaeological examples. Some, such as biopolitics and necropolitics, focus upon the violence experienced by individuals and groups under conditions of power differentials. The poetics of violence is more broadly based, as it references the performative aspects of violence, as well as its generative potential and functions within cultural contexts (Osterholtz, 2020). Political functions and the experience of violence by those participating as actors and observers are embedded in these many approaches, which tend to be applied by bioarchaeologists in exquisitely detailed and nuanced contexts.

Bioarchaeological studies of embodied structural violence underscore the significance of a broad definition of violence that extends beyond the bodily trauma to the creation of socio-political power structures that create and reinforce inequalities, ultimately leading to violence, poor health and inadequate nutrition for the disadvantaged living, while also predisposing to destructive, sometimes illegal, and disrespectful treatment of the dead body. Exploring the dynamics that create and reinforce such inequalities underscore that these are not "natural" states; by identifying the factors that lead to such structural inequalities, perhaps we may avoid their creation in the future.

7.2.1 Structural Violence Embodied in the Living

In bioarchaeology, structural violence has been invoked most frequently to explain evidence of trauma and poor health in historical contexts. This research has focused largely on remains recovered from three types of contexts; cemeteries associated with almshouses, asylums, and sanatoria, anatomical ("documented") collections representing those whose bodies were autopsied, sometimes illegally, or macerated and thus retained (Atwell and de la Cova, 2018; Blakely and Harrington, 1997; Crist et al., 2017; de la Cova, 2010, 2011, 2012, 2014), and lastly burial grounds for other economically disadvantaged individuals or those previously enslaved individuals (Blakey and Rankin-Hill, 2009; Bright, 2020; Geber, 2016; Tremblay and Reedy, 2020).

Studies of embodied structural violence have revealed gendered and racialized experience of violence in the 19th and early 20th centuries. For example, in a comparative study of Euro-American and African American males from the Cobb, Hamann-Todd, and Terry anatomical collections, de la Cova (2010) hypothesized that African-American males would present more evidence of trauma, due to conditions associated with enslavement. In fact, the Euro-American males presented significantly more post-cranial trauma and a trend toward more cranial trauma. Partitioning her sample of males by birth date, de la Cova (2011) discovered that African Americans, especially during the reconstruction period suffered disproportionately from tuberculosis (TB) and syphilis. De la Cova (2011:526), contextualizing the study in historical sources, attributed the differences to "environmental conditions related to enslavement, postliberation migration to the industrialized North, crowded urban living conditions, and poor sanitation." A subsequent. comparative study of African American and Euro-American females (de la Cova, 2012) from the Terry Collection used the term "structural violence" for the first time in exploring the reasons for patterned differences in fracture patterning across the two groups. In a review of her research results, de la Cova (2021: 155-156) recommends a four step, rigorous research approach, which includes hypothesis-testing and interpretation only after the scientific

protocol in complete. This work stands as a model for interdisciplinary rigor in exploring the embodiment of structural violence.

Structural violence can be much more difficult to investigate in the archaeological record when there are no ethnohistoric or archival sources. Martin and Harrod (2015:134) provide a model that charts a pathway for examining data sets within a more nuanced and data-rich context drawing on the archaeological record, which is adapted here as **Figure 1**. Qualitative and quantitative data from skeletal material is the beginning point, and the other data add layers of context that can be provided by archaeological and ethnohistoric sources provide ways to empirically support the presence of social structures within which violence is embedded.

[Insert Figure 1 here]

One of the issues that emerges in the interpretation of health-related impacts as a measure of structural violence is the lack of comparative data from those who were known via independent measures to have not been disadvantaged. The skeletal indicators of cribra orbitalia, porotic hyperostosis, stunting, and so on are often assumed by scholars focusing on the topic to reflect structural violence, based on historical or other contextual data. Even more convincing are comparative data from contemporary groups in privileged positions, age-sex-context matched. As Klaus (2012, 35-37) points out, given the historically contingent nature of structural violence, there are several concerns in bioarchaeological applications to contexts without archival records:

1. Extending the concept to non-Western premodern settings may seriously problematize a bioarchaeology of structural violence.
2. Structural violence may likely be a feature that only a rigidly hierarchical society can achieve.
3. Its relationship to other forms of violence and power must be examined in tandem to prevent analysis from becoming too linear, deterministic, or reductionist.
4. We must be on guard against portraying recipients of structural violence as passive victims.
5. The key to a bioarchaeology of structural violence is a thoroughly and deeply embedded engagement with archaeological and historic contexts.

These are important issues, and as Klaus (2012: 44) also points out, comparisons with "members of archaeologically defined supra- and subordinate social formations" are the ideal way to examine health indicators for evidence of structural violence. Barring that, a "contextualized diachronic sequence of health outcomes" is appropriate, leading Klaus to compare the lives of temporally sequential pre-colonial and colonial Muchik people from the Lambayeque Valley from the north coast of Perú. Klaus's results are rendered robust due to the comparison.

7.2.2 Structural Violence and the Dead Body

Human cadaveric dissection has a long history, extending to 3rd century BCE Greece (Ghosh, 2015). Over the intervening centuries, legal, social, and religious issues have shaped anatomizing, especially contentious regarding those selected for anatomization. Obtaining cadavers for such purposes, with the rise of formal medical education during the 19th and 20th centuries in Europe and North America, for example, frequently led to bodies being obtained either clandestinely from very recent graves or disproportionately from criminals or those dying in disadvantaged circumstances. While earlier bioarchaeological reports of surgical

interventions, with special interest in trepanation had appeared, Blakely and Harrington's (1997) volume on the remains recovered from the basement of the original building of the Medical College of Georgia Building in Augusta, Georgia set a new standard for contextualizing dissected remains and the people whom they represent. Cited in review as a "thought-provoking, innovative, and, in short, a significant contribution to our field" (Grauer, 1999:199), this volume was followed by a number of 21st century efforts to explore social status through the body's post-mortem life. Interestingly, even though this volume is obviously the start of an important trend in the bioarchaeological study of structural violence (Nystrom, 2017a), a review by medical historian Edward T. Morman (1999: 157) argued that the subtitle of the book—*Postmortem Racism in Nineteenth-Century Medical Training* – was "overly sensationalist." By contrast, *The Journal of Blacks in Higher Education* (1998) embedded the volume in a discussion entitled, "White Medical Students, Black Cadavers," which detailed the long history of anatomization of black people.

Shifting her focus to be more firmly focused on the marginalized histories of the people represented in the documented collections, de la Cova (2020, 2021) has further emphasized the structural violence represented in such contexts. The association of dissection/anatomization and marginalization has also been emphasized by Nystrom (Hodge and Nystrom, 2020; Nystrom, 2011, 2014, 2017b, 2017b) and Watkins (2018; Watkins and Muller, 2015). The Nystrom (2017b) edited volume makes the important distinction between anatomization/dissection and autopsy, both methodologically and socially (see also Dittmar and Mitchell, 2015). The socially marginalized have been subjected to anatomization/dissected, with their identities all too frequently subjugated to the educations needs of the White elite (Watkins and Muller, 2015). In contrast, elite bodies have been opened in order to explore cause of death; identity is retained during autopsy and in final interment.

7.3 Combining Physical and Structural Violence

Learning about construction and maintenance of violence in the past holds powerful lessons for today's world. Male violence (lethal and nonlethal) is expressed cross-culturally in diverse and complex ways because it is associated with social spheres of power and influence, and it is embedded within culturally specific ideologies, histories, and collective memories (Martin 2021). Bioarchaeologists such as Tung (2021) and Harrod (2017) have explored the ways that violence can be seen as both a chaotic and transgressive force as well as a generative and transformational social process. These works demonstrate how violence plays a key role in creating, maintaining, and transforming social processes. Using an interpretive approach that focuses on the ritualized aspects of male violence provides rich insights into the social processes that help to normalize and institutionalize violence.

One compelling example of this form of study is Tiffiny Tung's (2021) discussion of masculinity and violence during late Andean prehistory and the early colonial period. Following nuanced study that combines bioarchaeological, art historical and archival sources, Tung (2021, S125) emphasizes that "naturally violent man" is in truth the product of social, political, and other culturally-mediated processes that "make and mark" gender. She argues that this bioarchaeology of embodiment with the body at its core provides key markers of structural violence, such as malnutrition, meanwhile also recording the physical impact of interpersonal aggression. Importantly, Tung (2021) also addresses broader issues, including the degree to which the link between masculinity and power are essentialized in various cultures, thus naturalizing the link between men and violence today. This is an important example wherein

received wisdom should be interrogated through a critical reading of long-term histories. In her detailed and wide-ranging study, she critically reviews other commonly held beliefs, such as a "natural" link between meat-eating and masculinity, which is de-coupled in the Andes, as maize consumption assumes prominence, presumably through *chicha* as a "power drink" that reinforces masculinity in social displays.

7.4 Conclusions

Richly contextualized studies, compared across time and space argue compellingly against notions of "natural" violence and essentialized time trends. Causes of violence in societies of any scale are invariably so complex that identifying factors for deterring violence will similarly be a complex task, requiring time depth and both pre-and post-pulse samples. Climate change, for example, is indeed correlated with violence on some occasions, but other risk factors in the face of climate change are also important. Mitigations today should address all factors, not assume unicausality. Regarding histories of violence, bioarchaeologists should also argue for nuanced perspectives on the conquered and the conquerors on any landscape, writ large in misconceptions about the North American colonial experience. A mosaic landscape of Indigenous cultural differences in social, political, and economic structures should be appreciated in terms of agency as they encountered the overpowering other. Finally, members of the Bioarchaeology Workshop envisioned future, temporally controlled studies of conflict situations wherein a detail pre-conflict baseline is created. This would afford a fundamental, crucial point of comparison from which to view the impact of war on interpersonal violence.

8. EPIDEMICS AND PANDEMICS

In the months following the Workshop as the COVID-19 pandemic intensified, many participants saw a growing recognition by journalists and the general public of the relevance of bioarchaeology for understanding the origins, contexts, behavior, and consequences of epidemic and pandemic diseases in human history (see, e.g., the Wade (2020) *Science* article, written for a general audience, that highlights the work of and includes commentary from some Workshop participants). In particular, numerous parallels have been drawn between COVID-19 and the Second Plague Pandemic (sparked by the 14th-century Afro-Eurasian pandemic now commonly referred to as the Black Death), the 1889-1891 pandemic (commonly called the Russian flu, but which might have been caused by a coronavirus (Brüssow and Brüssow, 2021)), and the 1918 influenza pandemic. Correspondingly, however, it is important to avoid making direct false analogies between the COVID-19 pandemic and the Black Death or the 1918 flu, as there are many important differences between the pathogens that caused these pandemics and their pathophysiologies, potential for long-term sequelae, and social, political, public health, and medical contexts. Because of these, and other differences, we cannot use past epidemics as models for making direct predictions about how COVID-19 will affect us (e.g., morbidity and mortality rates), nor what the long-term outcomes will necessarily be. Context is crucial to understanding individual and population-level experiences and outcomes of disease, and we should not expect COVID-19 to behave in the same way as historical pandemics. However, there are parallels that can and should be drawn between COVID-19 and past pandemics in order to contribute to positive changes that benefit people in the future; these include the xenophobia and racism that is revealed or amplified by these crises (Cohn, 2012; Hoppe, 2018; Rambaran-Olm, 2021), challenges in slowing or stopping the spread of disease, and the role that social inequality can play in worsening the outcomes of a pandemic (Abrams and Szefler, 2020; Nelson, 2021).

8.1 Social determinants of infectious disease morbidity and mortality outcomes

Over the last year, we have witnessed the effects of social inequality on outcomes of COVID-19. Greater income inequality within countries is positively associated with numbers of COVID-19 deaths (Davies, 2021), and higher poverty rates are associated with faster spread of the disease (Bargain and Aminjonov, 2021). Frontline workers are drawn disproportionately from socioeconomically disadvantaged groups (Blau et al., 2021). Effective, non-pharmaceutical preventative measures, such as social distancing and self-isolation, have often not been feasible for frontline workers, so they face higher risks of exposure to the disease. Lower-income people are also more likely to rely on mass transportation and experience crowded living conditions, which can elevate risk of exposure to and promote the spread of disease (Almagro et al., 2021; Truong and Asare, 2021). Lower-income people are also more likely to live in multigenerational households, which elevates risks of exposing vulnerable elderly people to the virus (Nafiyan et al., 2021). They are more likely to experience reduced access to good health care services and generally seek health care at more advanced stages of illnesses, increasing risks of poor outcomes (Patel et al., 2020). Several health conditions have been identified as increasing the risk of severe illness with or risk of death from COVID-19, all of which disproportionately affect people with low incomes (Truong and Asare, 2021) for a variety of reasons, such as poor nutritional status because of food deserts and/or swamps, reduced access to health care services and education, or the inability to take time away from work to seek health care (Miranda et al., 2019). People of lower socioeconomic status experience higher rates of chronic stress, which might negatively affect immune responses (Dowd and Aiello, 2009; Owen et al., 2003). Poor communities are more likely to be exposed to higher concentrations of indoor and outdoor air pollution (Hajat et al., 2015; Perlin et al., 2001), which is associated with elevated risks of infection and death from COVID-19 (Conticini et al., 2020; Travaglio et al., 2021; Wu et al., 2020). Now that effective vaccines against COVID-19 are available and supplies are improving, particularly in wealthier nations, there are emerging disparities in vaccine access between wealthy and poorer nations (Hyder et al., 2021) and socioeconomic disparities in rates of vaccination within populations even though the vaccination is free in many countries (Hughes et al., 2021; Whiteman et al., 2021).

This general pattern of disproportionate negative effects for impoverished people during epidemics is not new. As described below, analyses of human skeletal remains from medieval London cemeteries have revealed evidence of worsening health, in general, prior to the 14th-century Black Death (DeWitte, 2015b, 2018). These changes in health occurred in the context of increasing social inequalities in England. Population growth prior to the Black Death outpaced agricultural production, and by the end of the 13th century, an estimated 70 percent of the English population was living at or below the poverty line (Campbell, 2016). Conditions for poorer households were made worse by recurrent, often severe, famines, including the Great Famine of 1315-1317 CE. Declines in health for a large portion of the population might have exacerbated mortality outcomes during the Black Death. Further evidence gathered from the remains of people who died during the Black Death in London suggests variation in risk of mortality during the epidemic; specifically, people who had experienced growth disruptions during childhood or episodes of infectious disease at any age prior to the Black Death appear to have faced higher risks of death during the epidemic compared to people who had been relatively healthy beforehand (or at least had been spared exposures to stressors capable of producing skeletal markers) (DeWitte and Hughes-Morey, 2012; DeWitte and Wood, 2008; Godde et al., 2020).

Such variation in risk of mortality is perhaps not entirely unexpected, as most causes of death are selective with respect to frailty or underlying health condition. Importantly, some of the variation in health status that existed prior to the Black Death might have been shaped by social status or wealth inequality. Documentary evidence of variation in mortality by wealth, social position, or household size (which likely reflects socioeconomic status) during the Black Death and later plague outbreaks in England and other locations has indicated that in some cases medieval and early modern plague disproportionately affected lower status and poor people (e.g., Alfani and Bonetti, 2019; Carmichael, 1986; Cummins et al., 2016; DeWitte and Kowaleski, 2017; Galanaud et al., 2020). Though this is not necessarily a universal nor temporally consistent pattern during the Second Plague Pandemic (see, e.g., Alfani and Murphy, 2017), in the interests of working toward alleviating some of the burden of disease today, we should perhaps take note of evidence of the existence of wealth inequalities during epidemics and pandemics, rather than the absence thereof. Regardless, from bioarchaeological studies it is noted that following past pandemics, health for the remaining population improved (e.g., see Baten et al., 2019 and the impact of the 6th century Justinian plague on European populations).

In addition to, and likely interacting in a syndemic fashion with, the clear negative effects of economic inequality during the pandemic, there have been striking racial disparities in exposure to and morbidity and mortality from COVID-19. Numerous studies have highlighted the disproportionate infection and mortality rates for citizens of Native Nations and Black, Hispanic, Latinx, and Asian people in the US and the UK (Abedi et al., 2021; Chen and Krieger, 2021; Lopez et al., 2021; Mackey et al., 2021; Nazroo and Bécares, 2020). Similarly, globally, some migrants have experienced disproportionate rates of COVID-19 disease and mortality and have been disproportionally affected by the economic consequences of the pandemic (Greenaway et al., 2020; Guadagno, 2020; Guijarro et al., 2021; Mukumbang, 2021), as have people with specific health conditions (e.g. leprosy: Mahato et al 2020). To date, there have been no published bioarchaeological studies of the possible effects of racism and xenophobia on outcomes of past bubonic plague pandemics (though work has been done on leprosy and stigma in the past, see, e.g., Robbins Schug, 2016). However, given the increasing application of biogeochemical analyses to confirmed or suspected historic plague burials, there is certainly the potential for bioarchaeologists to integrate demographic, aDNA, isotopic, and morphometric data to examine whether disparities across population affinities, ethnic minorities, or migrant statuses existed during past plague epidemics.

Many of the mechanisms linking wealth or racial inequality and health and disease have been well-established in the medical anthropological, public health, and epidemiological literature, but the COVID-19 pandemic is dramatically highlighting the implications, not just for those directly affected by poverty and racism, but also for the population at large, i.e., interfering with measures to control the spread of the disease within and between populations. Importantly, because the social and economic factors affecting morbidity and mortality at the time of the Black Death and currently in the context of COVID-19 are (at some point during the lifetime of an individual or their ancestors) exogenous to the individual body, it is theoretically possible to prevent or change them. Some of the outcomes of social inequality are not immediately reversible, given the effects of economic disparities and psychosocial stress on long-term immune function and risk of chronic disease, and the possible intergenerational effects of poverty via epigenetic mechanisms (McEwen and McEwen, 2017). Nonetheless, we should be driven to do whatever is possible to reduce the negative consequences of inequality.

Bioarchaeological research has an important role to play in these efforts given its potential to reveal the deep history of structural conditions that shape human health and that continue to be reproduced today, such as racism, xenophobia, economic inequality, and other forms of structural inequality and marginalization. Clear, contextualized documentation of this deep history can be leveraged to undermine the idea that health, disease, and risks of death are all a matter of individual biology or responsibility, i.e., that people are inherently at higher risks because of their genetic makeup or that they put themselves at elevated risk of disease and death because of deliberate choices they make or have made (see, e.g., de la Cova 2011, 2014, 2019). It is all too easy to blame individuals, particularly those viewed as "other", for their poor health rather than to recognize and rectify the structures that are ultimately responsible for creating the embodied conditions that put people at risk; bioarchaeological research may help to counter this tendency. This is by no means a novel insight nor is it unique to bioarchaeology. There is, for example, a huge body of literature on the social determinants of health, which emphasizes the conditions in which people are embedded (e.g. income level, educational opportunities, food insecurity, racial segregation, access to housing) rather than individual biology and behavior (Marmot, 2005). For example, with respect to the COVID-19 pandemic, Tan and colleagues (2021) provide evidence that higher levels of measured structural racism are associated with higher rates of disease and death, even after adjusting for access to healthcare, population density, and other factors that contribute to exposure, morbidity, and mortality. Scholars who engage with intersectionality to promote health equality and social justice have long pushed against "blaming the victim" (see e.g., López and Gadsden, 2016), while syndemic perspectives, rooted in anthropology but more widely influential, highlight the role of adverse social conditions in determining poor health outcomes (e.g., Singer and Clair, 2003). Bioarchaeology can contribute to this discussion and to efforts to promote health equality by providing a wider view of how the social conditions operating within populations today produce health inequality that also operated in the past. These structures are not a historical anomaly, and the negative effects of deeply entrenched systems of oppression and privilege, and evidence of their production through deliberate actions, can be documented bioarchaeologically. This deep perspective can provide a compelling counter to complacency by those in positions of privilege in the face of inequalities today.

8.2 Ancient DNA and bioarchaeology: a symbiosis

In addition to yielding insights on the context-dependent nature of the interaction of human biology, socioeconomic and political conditions, and disease, as well as the production and reproduction of axes of power and marginalization across time and space, bioarchaeological research, when integrated with ancient biomolecular (e.g., aDNA) analyses, also promises to improve our ability to detect undocumented past pandemics and transform our understanding of the microevolutionary consequences of past pandemics and the evolution of pathogens.

The threat of emerging infectious diseases will continue to grow as climate change shifts ecological dynamics and human populations encroach further on animal habitats. The global rise in temperature and human population growth will lead to unprecedented risks of zoonotic diseases. Since most human infectious diseases have resulted from zoonotic infections, there is much insight to be gleaned from tracking these zoonotic transmissions through time. In what contexts did zoonotic jumps lead to infectious and virulent human-adapted pathogens, and vice versa? For how long did major human infectious diseases exist as isolated spillover infections before adapting to human-human transmissibility? Hundreds of ancient pathogen genomes have

been recovered (Duchêne et al., 2020), and improvements to aDNA methodology and accessibility will ensure this successful recovery rate increases. These ever-growing time-series datasets present an invaluable opportunity for bioarchaeologists to fully engage with the origins and impact of zoonotic infections. For example, the earliest *Yersinia pestis* genome, the causative agent of plague, was recently recovered from a 5,000 year-old skeleton from Riņņukalns, Latvia (Susat et al., 2021). This genome represents a lineage that diverged recently after *Y. pestis* shared a last common ancestor with *Y. pseudotuberculosis*. *Y. pestis* was only identified in a single individual from a burial of four, which, combined with the observation that most Bronze Age *Y. pestis* genomes have been recovered from single burials, lead the authors to suggest that these early Neolithic and Bronze Age strains caused terminal or low transmissibility zoonotic infections in humans (Susat et al., 2021). Identifying archaeological sites with early zoonotic spillovers is instrumental for bioarchaeology to integrate the One Health concept, which views human health as directly linked to animal health (Mackenzie and Jeggo, 2019; Zinsstag et al., 2011).

Extraction of DNA, including from more recent burials of known epidemic victims, has enabled the positive identification of causative pathogens, exploration of genetic differences between historic and currently circulating strains of pathogens, and characterization of microbiomes and microorganism ecologies (e.g., Bos et al., 2011; Bos et al., 2016; Devault et al., 2014; Spyrou et al., 2019; Tito et al., 2012; Warinner et al., 2014). Such burials also allow for a "real-time" examination of changes in human genetic variation in response to past epidemics (Barquera and Krause, 2020). For example, Kerner and colleagues (2021) found evidence of negative selection against the P1104A polymorphism of *TYK2* (which increases risk of clinical forms of TB in homozygotes) starting ~2,000 years ago, which suggests a significant role for the disease in shaping European health since that time. Recent work focused on 16th-century burials in Germany has begun to explore the possible selective effect of catastrophic mortality caused by epidemics during the Second Pandemic of Plague on human immune loci **(**Immel et al., 2021); extracted DNA from individuals buried in a 16th- century mass grave in Ellwangen, Germany, a the findings might reflect the effects of historical epidemics on genes involved in innate and adaptive immune responses to pathogenic bacteria, such as *Y. pestis*. Future work focusing on the 14th-century Black Death, which produced higher rates of mortality than any subsequent outbreak during the Second Pandemic (DeWitte and Kowaleski, 2017), will be important for understanding the immediate microevolutionary effects of the pandemic at the moment of its emergence into medieval populations of Afro-Eurasia.

Human genetic data may also reveal the effects of past pandemics on patterns of migration, for example, allowing us to test hypotheses regarding whether and how pandemics produced push or pull factors driving migration. In England, for example, there is historical evidence that rates of migration increased following the Black Death and that, in general, females predominated among rural-to-urban migrants during the medieval period (Dyer, 2005; Kowaleski, 2013). However, genetic work from well-dated bioarchaeological assemblages is crucial for examining the actual extent and the age/sex patterns of that migration and what effects it might have had on human genetic variation or disease ecologies. Work along these lines has begun with respect to the Black Death. Recently, Klunk et al. (2019) analyzed temporal trends in mtDNA from human skeletal remains from medieval London and cities in medieval Denmark and found high mtDNA diversity in these contexts before, during, and after the Black Death. These findings might reflect consistent, high levels of female migration into these particular cities before and after the epidemic. Further, Kendall et al. (2013) identified, via

isotopic analysis of people who died during the Black Death in London (East Smithfield/Royal Mint site), some migrants, including females, to London who could have originated from the city's surrounding hinterlands or further afield in northern and western Britain, thus showing that London was an attraction for migrants at that time.

8.3 Conclusions and recommendations

Well-dated, contextualized bioarchaeological data can also contribute substantially to reconstructions of pathogen phylogeographies, including clarifying the role of human economic, demographic, and social behavior in the spread (and maintenance) of diseases at regional and global scales (Bravo Lopez et al., 2020; Mühlemann et al., 2020, Bos et al., 2014; Spyrou et al., 2019). Contextually rich bioarchaeological datasets with temporal control also have much to offer evolutionary biology and population genetics. Time series datasets spanning hundreds to thousands of years present an unparalleled way for tracking evolution in real time. Securely dated pathogen genomes can be used to calibrate molecular clocks, and datasets of ancient human genomes enable evolution to be tracked directly though time via allele frequency changes.

In summary, Workshop participants viewed bioarchaeology as having made important contributions to our understanding of disease epidemics and pandemics, with a tremendous potential to contribute even more, particularly as we improve efforts to integrate multiple lines of evidence. As we have emphasized elsewhere in this paper, it is clear that we need to assume greater responsibility for more effectively disseminating our findings to scholars in other fields, policy makers, and the general public so that the lessons we learn from past pandemics can actually generate positive changes in living populations.

9. HUMAN ADAPTATION and PLASTICITY

9.1 Adaptation

Bioarchaeology can make substantial contributions to the study of human adaptation, referred to here as changes in form or function that reflect natural selection acting on heritable variation. For example, bioarchaeology may explore the morphological substructures of physiological adaptations to altitude and climate that have long been studied by human biologists (Baker, 1984; Stinson et al., 2012). Thermoregulatory adaptations conforming to Bergmann's and Allen's rules regarding surface area relative to volume (Allen, 1877; Bergmann, 1847; Roberts, 1953; Katzmarzyk and Leonard, 1998) can be assessed via brachial and crural indices (as scale-free measures of surface area) and bi-iliac breadth (as a hard-tissue constant representing volume) (Ruff, 1994). Brachial and crural indices as well as limb shape have been key in understanding migration and adaptation during the Holocene in the Western Hemisphere (Holliday and Hilton, 2010; Auerbach, 2012), Japan (Yamaguchi, 1989; Temple et al., 2008; Temple and Matsumura, 2011), Siberia (Stock et al., 2010), Africa (Shea and Bailey, 1982; Ruff and Walker, 1993; Migliano et al., 2007; Bleuze et al., 2014), and Europe (Holliday, 1999; von Cramon Taubadel et al., 2013). However, bioarchaeologists should heed the warnings raised by Roseman and Auerbach (2015), whose modeling indicates that patterns of variation in skeletal traits typically used to assess adaptation to climate are also shaped by population structure (arising from genetic drift, gene flow, and mutation) and are not solely attributable to the effects of natural selection. In addition, it is important to understand which of these traits evolve via natural selection versus those that change through pleiotropic pathways (Savell et al., 2016).

Human biologists have recently demonstrated selection signals in association with adaptation to high altitude (and thus hypoxia) in terms of blood-oxygen transport and lung surface area, though physiological mechanisms of these adaptations vary between regions (Bigham, 2016; Brutsaert et al., 2019; Moore, 2004; Frisancho, 2013; Yang et al., 2017). One physiological advantage found in populations with long-standing occupation of high-altitude environments is greater efficiency in blood-oxygen saturation (Frisancho, 2013) via alterations of lung surface area: populations from higher altitudes have greater lung surface area than those from lower altitudes. Bioarchaeological studies have explored the morphological scaffolding of these adaptations. For example, studies of pre-Hispanic Peru reveal that populations from isolated, high-altitude locations have greater rib curvature and wider sternal and clavicular proportions in association with a deeper, wider thoracic morphology, while populations from more isolated regions of the lowlands express comparatively shallow and narrow thoracic volume (Weinstein, 2015). However, sex differences in these patterns suggest that long-term adaptation combined with migration contributed to local variation in thoracic morphology and demonstrate that the contextual approach of bioarchaeology is valuable in documenting both the morphological scaffolding underlying selective processes and the context under which deviations from ecogeographic predictions may occur.

The jaws and supporting bony structures provide some of the best examples of phenotypic plasticity in relation to human behavior. The jaws are the foundation of the face and their size and morphology affect facial proportions and shape. Our faces are at the centre of our expression, behavior, social position and relationships, and there is a growing psychological literature (Zebrowitz *et al.*, 2015; Foo *et al.*, 2017; Hu *et al.*, 2017; Nakamura and Watanabe, 2019; Kachur *et al.*, 2020) on their social significance. Many people today have personal experience of the plasticity of the jaws and supporting stuctures through orthodontic work, which relies on adaptation of the alveolar process to the forces which are applied to the teeth. This takes place through remodeling of the bone which, in the jaws, is rapid in comparison with the rest of the skeleton. Patients notice changes in the position of teeth within months. Rapid jaw remodeling is an essential process which keeps the teeth in occlusion as they wear down or are lost, or modified. There is an adaptive significance because in most mammals a functioning dentition is essential for survival. This constraint is modified by human behavior with tool use and social organisation which allow survival even without a completely functional dentition. Altogether, the teeth, jaws, supporting skull structures, toolkit and behavior work as a coordinated whole. A bioarchaeologist would argue that consideration of artefactual evidence for behavior is incomplete without a consideration of teeth and jaws.

Today, on all continents of the world, more than half of children and adolescents are diagnosed with one or more form of malocclusion (Lombardo *et al.*, 2020). The high prevalence contrasts strikingly with the rarity of occlusal anomalies in many archaeological assemblages and in fossil hominins. This has led to much discussion amongst dentists on just what it is about the nature of modern life, diet, childrearing and behaviour that has led to the current situation (Peres *et al.*, 2018; Boyd *et al.*, 2021). Corruccini (1984; 1990; 1999) has proposed that the soft modern diet requires less forceful chewing and therefore places less load on the masticatory apparatus, which in turn leads to the development of a smaller muscle mass, reduced dimensions of the jaws and less robust bony supporting structures. In this interpretation, the potential for developing an alveolar process that will accommodate a given size of teeth exists in the genotype, but phenotypic plasticity in response to the forces applied creates a jaw which is too small and the teeth become crowded. Evidence from clinical CT scans shows that there is a clear relationship

between masticatory muscle mass and jaw size and robusticity (Sella-Tunis *et al.*, 2018). Laboratory animal experiments also show that the hardness of the diet affects jaw size (Lieberman *et al.*, 2004; Ravosa *et al.*, 2008; Anderson *et al.*, 2014). Archaeological assemblages of human skulls show differences in shape between people whose diets were based mostly on meat or fish and those based on plant foods (Holmes and Ruff, 2011; Noback and Harvati, 2015). There is also discussion about differences in cranial morphology between hunter-foragers and agriculturalists (von Cramon-Taubadel, 2011; Katz *et al.*, 2017). A much older (Begg, 1954) interpretation of malocclusion focusses instead on the heavy tooth wear seen in archaeological dentitions, which rapidly reduced the size of teeth during childhood as well as adulthood. It is suggested that tooth size and jaw size are adapted to heavy wear and, in effect, the teeth when they first develop are bigger than needed in order to fall into proper occlusion when worn (Kaifu *et al.*, 2003). There is little doubt that the remains of many young adults in archaeological contexts display teeth which have been reduced in size by wear and the jaw has been remodelled around them to adapt to the shorter tooth row. Living people wear their teeth to a much lesser extent, through diet, behavior, and habits, which creates a mismatch between tooth size and the jaw's potential to adapt. These two explanations of the current malocclusion epidemic are not mutually exclusive, and the answer probably lies somewhere in between. Thus, the plasticity of the jaws, skull and face lies at the centre of a debate which is relevant outside bioarchaeology and which touches the lives of ordinary people.

At present, results suggest that evolution, and in particular natural selection, has substantially affected human bodies over the past 10,000 years, with important and interesting contingencies in these processes attributable to local behavior. The application of increasingly sophisticated population genetic models to evaluate pleiotropic effects and deeper explorations of archaeological context to explore dietary behavior and migration portend enormous potential for the continued role of bioarchaeology in the study of human adaptation.

9.2 Phenotypic Plasticity

Phenotypic plasticity refers to the range of phenotypes (behavioral, morphological, or physiological) that may arise in response to environmental stimuli (West-Eberhard, 2003, 2008). Scholars in evolutionary ecology and genetics have explored phenotypic plasticity for decades, using experimental and natural conditions to understand the array of phenotypes that may be produced in response to environmental conditions and the possibility for traits to alter the genotype (Johansen, 1911; Waddington, 1953; Suzuki and Nijhout, 2002), the adaptive versus non-adaptive value of phenotypic plasticity (DeWitt et al., 1998; Ghalambor et al., 2007), and the limits of adaptive plasticity (Stearns, 1992; Charnov, 1993; DeWitt et al., 1998). Early anthropological and sociological research argued for a remarkable degree of plasticity in development, highlighting the convergence of phenotypes within shared environments and the detrimental impacts of racism and inequality on health and well-being (Boas, 1912; Dubois, 1914; Cobb, 1936). Bioarchaeologists have the advantage of studying phenotypic plasticity in terms of temporality, ecology, and social conditions.

Plasticity in skeletal phenotypes provides bioarchaeologists with the capacity to understand behavior, ecology, and biology in the past (Armelagos et al., 1982; Goodman et al., 1984; Larsen, 2015). For example, depositional patterns associated with bone (re)modeling principally reflect highly dynamic structural optimization in response to mechanical demand that is influenced by systemic conditions, a process now referenced under the broader paradigm of functional adaptation (Ruff et al., 2006). Bioarchaeologists evaluate changes in long bone

diaphyseal morphology to better understand changes in behavior that were attendant with the transition to agriculture (Larsen, 1982; Ruff et al., 1984; Bridges et al., 2000). In addition, adaptive plasticity is inferred from patterns observed during European colonization in the Americas, acting both as an embodied signal of the extractive and exploitive economic structures imposed on Indigenous North American populations and as a testament to the adaptive capacity of these populations to survive under circumstances of disease, dispossession, and death (Ruff and Larsen, 1990; Larsen et al., 1996). Plasticity in long bone diaphyseal morphology has also been used to resist the monolithic conceptualization of hunter-gatherer subsistence economies, and instead point towards highly adaptive behavioral practices that reflect long-standing environmentally directed beliefs, knowledge, and skill sets (Stock and Pfeiffer, 2001, 2004; Holt, 2003; Stock and MacIntosh, 2016; Ruff and Holt, 2018; Temple et al., 2021).

Studies of skeletal adaptive plasticity can also contribute to broader discussions of developmental stability (the capacity for a genotype to produce near-similar phenotypes under consistent environmental conditions) as well as the limits to variation imposed by functional constraints, which limit morphological variation in association with the function of the structure in question (Futuyma, 1998), and canalization (the capacity for a genotype to withstand environmental perturbations) (Waddington, 1953). Studies consistently demonstrate higher levels of asymmetry and variance in diaphyseal breadths compared to lengths and articular surface dimensions (Ruff et al., 1991; Auerbach and Ruff, 2006; Buck et al., 2010; Reeves et al., 2016). These results are consistent with the responsiveness of diaphyseal morphology to habitual activity, and greater developmental stability in articular surface and length dimensions (Lieberman et al., 2001; Ruff et al., 2006). These findings suggest limits placed on plasticity through developmental stability, while highlighting the relationship between diaphyseal breadths and mechanical strain (Auerbach and Ruff, 2006; Buck et al., 2010; Reeves et al., 2016). Taken as a whole, plasticity in diaphyseal morphology is directly observable in bioarchaeological contexts and provides important information on the habits, dispositions, and practices of past populations. In addition, the study of asymmetry and variation in diaphyseal structure helps reveal limits on plasticity associated with functional constraints.

Stress has been defined in bioarchaeology, following Selye (1936), as a non-specific physiological response to any external perturbation that threatens homeostasis (Goodman et al., 1988). In general, stress is considered a "shadow image" of adaptation, reflecting circumstances where populations fail to thrive in a given environment (Goodman et al., 1988, page 192). Accordingly, skeletal and dental indicators of stress are assumed to act as long-standing evidence of this failure to thrive (Goodman, 1994). In this approach, exposure to chronic stress has been associated with a range of variations (including lesions and disruption to skeletal and dental growth and maturation) that might reflect dietary deficiency, disease, and relationships between these factors with social and ecological conditions, most frequently through comparison of lesion frequencies (Buikstra and Cook, 1980; Huss-Ashmore et al., 1982; Goodman et al., 1984). This assumption reflects the idea that the presence of these conditions may act as a barometer for stress experiences in the past. However, this assumption has been critiqued in light of the Osteological Paradox (Wood et al., 1992) described in Section 10. In response to this critique, some bioarchaeologists now use stress markers in association with quantitative demography to explore the relationship between stress and selective mortality in past populations (DeWitte and Stojanowski, 2015). More recently, the incorporation of life course and evolutionary life history into studies of stress has provided new perspectives on human lifespans (Temple and Goodman, 2014; Gowland, 2015; Agarwal, 2016; Temple, 2019b). These works emphasize life history

theory combined with social and environmental context in the study of stress in archaeological contexts. These considerations move stress concepts away from binary indicators of health, and instead focus on the trade-offs related to short-term survival and physiological constraints through attention to the lifespan.

A process may be considered adaptive if the invocation of the stress response (via the hypothalamic-pituitary-adrenal (HPA) axis) promotes short-term survival through alteration of the phenotype (Cannon, 1915; Selye, 1936; Crespi and Denver, 2005; Worthmann and Kuzara, 2005; Crespi et al., 2013), with more recent studies arguing that additional systems involved in the regulation of stress and short-term survival also require consideration in this relationship (Edes and Crews, 2016). The capacity for phenotypic alteration after the developmental phase represents a long-standing hallmark of vertebrate evolution. If it does indeed promote short-term survival in response to stress, this suggests the response may be tethered to adaptive plasticity. It is, however, important to point out that natural selection is balanced by evolutionary trade-offs – negative correlations between traits that prevent simultaneous optimization (Futuyma, 1998). Physiological constraints are one type of evolutionary trade-off that occur in association with limits placed on energetic investment (Stearns, 1992; Charnov, 1993). Thus, investment in short-term survival of stress events may be met with exhaustion when energetic resources are spent (e.g., Selye, 1936), or alternately, result in reduced investment in future growth and maintenance in organisms with limited energetic allocation (Worthmann and Kuzara, 2005). This relationship is well documented in individuals who survive early life stress but experience reduced growth in body size, reproductive energy, immunosuppression, and early mortality (Kuzawa, 2007). In the United States, the experience of systemic racism provides a stark example of plasticity in the capacity to survive stress carried over multiple generations, while simultaneously producing substantial inequalities in long-term health and well-being (Gravlee et al., 2009; Kuzawa and Sweet, 2009), all ideas alluded to more than a century ago when scholars of color argued for the detrimental, long-term consequences of racism on individual development (Dubois, 1914; Cobb, 1936). Taken as a whole, the exploration of stress as a consequence or shadow concept of adaptation has moved from a linear, comparative process towards one focused on individual lifespans where tremendous transformative potential exists when applied to contexts including inequality, marginalization, and racism.

The study of stress is, however, an intensely debated topic in psychology, clinical medicine and biology, as well as bioarchaeology, and critiques surrounding the meaning of developmental variation or lesions seen in the dentition and skeleton must be considered (Wood et al., 1992; Goodman, 1994; DeWitte and Stojanowski, 2015). Hillson (2014) argues that the physiological conditions related to infection and dietary insufficiency may not trigger the stress response and that there exists scant evidence for a direct relationship between the dental or skeletal indicators used in bioarchaeology and the physiological changes associated with stress, either as originally defined by Selye or with more recent, broader definitions. This critique suggests that bioarchaeologists should consider carefully the physiological pathways that follow stress and the way in which these might influence plasticity during development or adult life (Gosman, 2011; Klaus, 2014). Stress experiences are now associated with more than five dozen biomarkers suggesting that the traditional biological principles associated with Selyean models need to be expanded (Edes and Crews, 2017). While many of these biomarkers do not have direct influence over bone, dentine or enamel formation, there are potential downstream cellular consequences such as mineral depletion, energetic imbalance, immunological damage, inflammation, hemorrhaging, cellular disruption, and vasoconstriction that might influence

skeletal and dental tissue (Chen et al., 2000; Chyun et al., 1984; Guder et al., 2020; Macrae et al., 2007; Martinelli et al., 1994; Parsons, 1992; Resnick, 2012; Sasaki et al., 2007; Riesenfeld, 1973; Seow et al., 1989; Stockman and Fandrey, 2006; Tsukasaki and Takayanagi, 2019). In addition, recent work in biology (Schulte, 2014) considers a wide range of responses to environmental stressors, such as climate change, or interruptions to food and water supply, that parallel issues addressed in bioarchaeology. If bioarchaeologists are to take part in this wider development of the stress concept, then it must develop a firmer basis of evidence for the physiological basis of variation and features observed in archaeological human remains.

Bioarchaeologists have a tremendous opportunity to explore relationships between adaptive plasticity and physiological constraint by leveraging the contextual nature of human skeletal remains from archaeological mortuary contexts (Temple, 2019b). Skeletal indicators of stress (particularly compromised growth of bones and teeth, including dental enamel and vertebral neural canals, and reduced adult body size) represent instances where individuals survived. Bioarchaeologists thereby directly interact with evidence for adaptive plasticity in human skeletal remains. Factors such as the presence of chronic infection, relative adult body size, and mortality may act as evidence for physiological constraint, or negative correlations with the capacity to survive stress events at earlier stages in the life course. Bioarchaeologists first referenced plasticity in the context of biological compromise during the transition to agriculture in prehistoric Illinois (Buikstra, 1988). Bioarchaeologists have begun to apply the concept of adaptive plasticity as the capacity to alter phenotypes towards an optimal value (Temple, 2014, 2019b; Gowland, 2015; Agarwal, 2016) and have also defined it in intergenerational contexts, where maternal stress experiences may be transmitted to offspring, most especially when the nexus of dependence between mother and infant is accentuated (Gowland, 2015; Gowland and Halcrow, 2020). The life course paradigm in bioarchaeology unified these concepts as one of cumulative experience prior to entry into the mortuary assemblage (Agarwal, 2016). Physiological constraint was introduced to bioarchaeological research with the attendant goal of expanding the life course paradigm to the full context of death, with the understanding that human plasticity is limited and that the context of bioarchaeological research may be leveraged to understand the conditions under which these constraints may be enacted (Temple, 2019b).

Bioarchaeologists have explored adaptive plasticity and constraint by comparing skeletal indicators of stress with mortality risk across differing environmental conditions such as in the presence of disease epidemics, in normal (non-crisis or "attritional") mortality cemeteries, climatic disturbances, and with European colonization (Clark et al., 1986; DeWitte and Wood, 2008; DeWitte and Hughes-Morey, 2012; Wilson, 2014; Thomas et al., 2019; Ham et al., 2021). Bioarchaeologists address intragenerational challenges of maternal stress (Section 4.2) using isotopes that target periods of nutritional insufficiency in the early life environment in the dental enamel of non-surviving subadults and compare these values to early life and adult diet in individuals who survived to adulthood (Beaumont et al., 2015). Concepts such as developmental sensitivity have been incorporated into bioarchaeological research using incremental microstructures of 1) enamel that demonstrate relationships between earlier stress events, formation of later growth disturbances, and risk of death (Temple, 2014; Gamble, 2017; Lorentz et al., 2019; Garland, 2020), and 2) dentine that allow for high-resolution examination of the timing of early life nutritional stressors (Beaumont and Montgomery, 2016; Brickley et al., 2020).

Bioarchaeologists have more recently sought to interact with social justice movements by demonstrating intersectionality (Section 4.5) between sex, socioeconomic status, and stress

experience with mortality hazards (Yaussy, 2019). European colonialization in the Americas and racism in the United States are indeed associated with greater frequencies of skeletal indicators of stress and disease (Larsen and Milner, 1994; Murphy and Klaus, 2012; de la Cova, 2011, 2014). Bioarchaeologists are beginning to record evidence for surviving these environments at early ages and navigating physiological constraints at later stages of the life course during traumatic encounters with European colonialism (Ham et al., 2021; see also Geber's (2014) work attesting to the effects of English colonialism in the context of Irish workhouses during the 19th-century Great Famine). Future studies may push these limits further by documenting survival of early life stress and consequences at later stages of the life course in relation to systemic racism and colonialism. It is, however, important to point out that a substantial lack of diversity in bioarchaeology (Section 2.1) suggests that such studies will result in subjectification until marginalized voices are included in the exploration of these questions (Watkins, 2018). The framing of questions towards plasticity, constraint, and context in bioarchaeology also requires inclusion of marginalized voices in research design as well as training a diverse generation of scholars to do future research. The value of inclusion and restorative justice has been demonstrated in bioarchaeological research (e.g., successful repatriation efforts by Yaqui of massacre victims, see Perez, 2010). Expanding this approach to bioarchaeological studies of adaptive plasticity and constraint would yield potentially transformative results.

9.3 Epigenetics

One highly promising avenue for exploring human adaptation and developmental plasticity is epigenetics. Epigenetic modifications of DNA, via mechanisms such as methylation, post-translational alterations of histones, and binding of non-coding RNA, can occur in response to physiological and psychosocial stressors (Mulligan, 2016). In turn, they can modify gene expression and thus individual phenotypes. Epigenetic changes can be passed on to offspring, transforming individual experiences into intergenerational phenotypic alterations. Epigenetic analyses have the potential to clarify the mechanisms that link early life stressors to health outcomes later in life and may allow us to better understand what skeletal markers of stress actually indicate about health and frailty (cf. Section 10). Bioarchaeologists are well positioned, for example, to explore the intergenerational effects of structural violence (Section 7.2) in terms of maternal-fetal health, as recently explored by Gowland and Halcrow (2019) (see Section 4.2). Epigenetic research has surged recently, but it remains an almost totally untapped source of evidence for bioarchaeologists. However, the work of Gokhman et al. (2017, 2020) has demonstrated the feasibility of bioarchaeological applications of epigenetics. There are limitations currently to bioarchaeological applications in the effects that can be inferred from bone, as epigenetics is often tissue specific and most of the anthropological epigenetics studies focus on blood (for a review of epigenetics of bone disease, see Michou, 2018). Nonetheless, as with other technological advancements mentioned in this paper, interdisciplinary research leveraging epigenetic data from archaeological contexts can not only clarify patterns of stress and health in the past, but also put our field in better conversation with human biologists and other scholars with a deeper history of engagement with epigenetics.

9.4 Summary and Recommendations

As scholars working at the nexus of human biology, evolution, and culture, bioarchaeologists can contribute substantively to our understanding of their interplay and the relevance of past events and behaviors for living populations today. We are at an advantage,

compared to other fields, in having both a deep temporal perspective that is crucial for clarifying human evolutionary trends as well as contextual details (from experiences embodied in the skeleton, archaeological data, and historical documents) that enrich our understand of the cultural causes and consequences of changes to human anatomy, physiology, and genome. As is true of other topics of interest in the field, advances in this area will benefit from increased integration of emerging technologies, advances in evolutionary theory, and increasing diversity of scholars.

10. OSTEOLOGICAL PARADOX, DOHaD, and HEALTH

10.1 Osteological Paradox

Several Workshop participants indicated in the responses to the preparatory questionnaire an interest in bioarchaeological approaches to studying health in the past, and several, more specifically, expressed concern that the Osteological Paradox has been insufficiently addressed in bioarchaeological studies despite the original paper by Wood and colleagues (Wood et al., 1992) having been cited over 1700 times since its publication [similarly, subsequent review papers of the Osteological Paradox, by Wright and Yoder (2003) and DeWitte and Stojanowski (2015), have each been cited hundreds of times]. Briefly, the Osteological Paradox describes fundamental issues affecting assemblages of human skeletal remains that interfere with reconstructing health in the once-living populations from which they derive. Wood and colleagues focused primarily on heterogeneous frailty and selective mortality. Heterogenous frailty refers to variation in one's age-standardized relative risk of death, and selective mortality acts on that variation such that individuals who die at each age are disproportionately those with the highest frailty (Vaupel et al., 1979; Wood et al., 1992). Of particular concern is the fact that most sources of, and expression of variation in frailty are undetectable in human skeletal remains (what Wood et al. call "hidden heterogeneity in frailty"), making it difficult to infer individual or sub-population patterns of health from aggregate cemetery data. One of the arguments put forth by Wood and colleagues (and, indeed, what is from the perspective of many people synonymous with the Osteological Paradox), is that it is possible that pathological conditions or skeletal indicators of stress observable in human skeletal remains might, in some cases, indicate relatively good health or low frailty, contrary to the more common interpretation that skeletal lesions reflect poor health.

Workshop participants noted that while some scholars have engaged productively with the Osteological Paradox (Hughes-Morey, 2016; Marklein and Crews, 2017; Milner and Boldsen, 2017; Usher, 2000; Wilson, 2014), the majority of the citations of the original Wood et al. paper are firmly in the vein of passively mentioning that it exists and might have some effect on findings, but without actively addressing heterogeneous frailty and selective mortality with data at hand. Some scholars seem to feel obligated to acknowledge the Osteological Paradox (sometimes solely in response to reviewer suggestions to do so) but do not engage with it during research design or analysis, nor do they substantially alter interpretations of data in light of it. The consensus of participants is that many scholars do not address the Osteological Paradox, even when they are interested in it and it is seemingly relevant, beyond (at most) paying lip service to it. This is because they are at a loss regarding how to do so, particularly in cases where they face limitations such as fragmentary skeletal remains, poor age estimates, or lack of good chronological control. We see a need to promote building engagement with the Osteological Paradox into research from the design stage, rather than applying it in a post-hoc manner. Scholars who are addressing the Osteological Paradox should be as explicit as possible in their

publications regarding how they are doing so in order to facilitate dissemination of promising approaches.

In general, age-structured data can facilitate the study of selective mortality, including evaluating the association between skeletal stress markers and risks of death or survivorship (e.g., Boldsen, 2007; Boldsen et al., 2015; DeWitte and Wood, 2008; Temple, 2014; Watts, 2015; Wilson, 2014) and the integration of data from incremental dentine analyses of dietary isotopes to examine the outcomes of nutritional stressors during key developmental periods (Beaumont and Montgomery, 2016; Miller et al., 2020). There is also potential information about variation in frailty present in lesion "activity" data – i.e., maintaining distinctions in data analysis between people who died before healing of lesions occurred and those who survived beyond the commencement or completion of lesion healing (e.g., DeWitte, 2014a; Mays et al., 2005; O'Donnell, 2019). The use of age-structured data, of course, hinges on accurate age estimates. Emerging approaches for improved age-estimation include the third version of transition analysis (Milner et al., 2021), which includes dozens of skeletal indicators, most of which are postcranial, and can be applied to incomplete and fragmentary remains. This might better allow people working with fragmentary and otherwise poorly preserved skeletal remains to link age (on an individual basis) to other variables of interest. Lastly, clarity regarding the mechanisms that lead to the formation of skeletal lesions and their association with heterogeneous frailty, and of expressions of co-morbid conditions (see, e.g., van Schaik et al., 2014), can be improved through further, ethical use of documented collections and dissemination of information about such collections available around the world (see, e.g., http://forensicanthropology.eu/osteological-collections/#page-content).

10.2 Developmental origins of health and disease (DOHaD)

Workshop participants were equally interested in bioarchaeological studies of the developmental origins of health and disease (DOHaD) and had parallel concerns that while there has been an increase in the number of papers that mention it, much of this is lip service rather than substantive analysis or interpretation using the DOHaD framework (for exceptions, see e.g., Armelagos et al., 2009; Garland, 2020; Ham et al., 2021; Lorentz et al., 2019; Reitsema et al., 2016; Temple, 2014; Weisensee, 2013). The DOHaD framework (also referred to as the Barker, fetal origins, and fetal programming hypotheses) addresses the later life health outcomes of early life stress events, such as the long-term effects of malnutrition *in utero* or during infancy on risks of disease and mortality later in life (for more detailed overviews of DOHaD and bioarchaeology see: Gowland, 2015; Temple, 2019b).

Participants argued that more work should be done in bioarchaeology linking indicators of early life stress to specific diseases that occur later in life and that are clearly identifiable in the skeleton. Such efforts are facilitated by a growing body of literature generated by studies in living populations that integrate demographic, medical history, psychosocial, epigenetic, and/or cause of death data. Much of the research in living populations on DOHaD focuses on non-communicable diseases such as cardiovascular disease and diabetes (e.g., Barker, 1990; Gomez-Verjan et al., 2020), but developmental insults also have the potential to alter immune functioning over the lifespan (MacGillivray and Kollmann, 2014; Palmer, 2011) and to affect risks of mortality from infectious disease (Moore et al., 1999). This raises the possibility for bioarchaeologists to look at associations between early life stress and vulnerability to infectious disease in adulthood, i.e., not just limit themselves to non-communicable diseases that have gained predominance only recently in some contexts. Promisingly, a recent study by Cheng and

colleagues (2020) found that prenatal and early life exposure to nutritional stress during the Great Chinese Famine increased the risk of tuberculosis in adulthood across two generations, more clearly paving the way for bioarchaeologists to examine within-individual and intergenerational effects of diet and specific, skeletally diagnosable, diseases in the past

To better leverage skeletal stress markers to examine DOHaD in the past, more work needs to be done examining tissue formation processes, the timing of insults, and the mechanisms linking physiological insults and stress indicators. Emerging work on osteoimmunology (Crespo, 2020; Crespo et al., 2017), for example, provides a promising avenue for improved, more nuanced, conceptualizations of stressors, physiological and immunological responses, and skeletal markers that can fill in the existing lacunae between conditions of growth and what we can ultimately see in the skeletal record. Furthermore, adaptive plasticity and constraints, as described in section 9.2, need to be acknowledged and dealt with more carefully in studies that aim to address DOHaD, and understanding the expression of these trade-offs requires careful attention to cultural and ecological contexts (Temple, 2019b). As is true for other areas of interest in the field, we encourage standardized data collection to facilitate DOHaD research, specifically thoughtful consideration and implementation of those variables that might best capture critical periods of development and reflect stressors of both bioarchaeological interest and that have parallels with those studied in human biology (the latter in order to bolster arguments about mechanisms within bioarchaeological contexts and to put us in better conversation with those outside the field). Standardization would ideally facilitate metanalyses, which might overcome some of the limitations of small and incomplete datasets. As mentioned in the context of the Osteological Paradox, participants suggested targeted training or published guidelines/models for those interested in addressing DOHaD would be beneficial, e.g., descriptions of what types of data are needed and what types of analyses are ideally suited to address DOHaD.

10.3 Measuring Health

Discussions of health at the Workshop raised a critical question about whether it is possible for all bioarchaeologists to agree on terminology regarding "health" and what is it that we want to measure *vs.* what we can measure using skeletal data. As noted by Gage and DeWitte (2009), among others, it is difficult to define health for living people, for whom a variety of biological, genetic, social, and mental variables can be assessed, and there has been debate in bioarchaeology about how to define and measure "health" in the past (Temple and Goodman, 2014). There was discussion at the Workshop of using terms such as "skeletal health", "stress", "health/disease", "disruptions of homeostasis" rather than "health", or applying demographic measures (i.e., mortality or survival) as proxies for health. But given the lack of consensus in defining "health" even among members of the small breakout session at the Workshop, rather than imposing one particular view, we suggest instead that all bioarchaeologists interested in this topic be explicit about what terms they are using and how they are defining those terms in their studies.

10.4 Conclusions and Recommendation.

Given obvious interest in the Osteological Paradox and DOHaD, having clear examples for relevant data collection, research design, and analysis might encourage more bioarchaeologists to actively and fruitfully engage with both concepts. There may not be a one-size-fits-all approach for either, but scholars would benefit from the availability of more models

of approaches, explicitly framed as engaging with the Osteological Paradox and/or DOHaD, that they can apply to or build from for their own research. Ultimately, successful engagement with the Osteological Paradox provides us with the means to better understand intra- and interpopulation variation in well-being, health, and disease in the past. In turn, this is informative about larger issues of anthropological concern, such as resilience, the effects of social hierarchies, and how access to resources or exposure to disease varies by biosocial factors. The natural experiments afforded by bioarchaeological data mean that we might generate or contribute to models for use in modern clinical settings, such as providing resolution on the optimal timing of and outcomes of early life interventions. Lastly, given our interests in and capabilities to engage in the study of human adaptation and plasticity (Section 9), combined with a widespread interest in health in the field, there is also a huge potential for bioarchaeology to contribute (through sophisticated attention to the Osteological Paradox and DOHaD) to topics relevant to evolutionary medicine, such as coevolution between humans and pathogens, the interaction of disease with developmental plasticity and life history tradeoffs, and the effects of cultural context on disease experiences and outcomes (see e.g., Plomp et al., 2022; Trevathan et al., 2008).

11. RESEARCH DESIGN and QUANTITATIVE METHODS

11.1 Problem-Oriented Research Designs

As detailed in Section 1, the initial motivation for organizing the Bioarchaeology Workshop was to examine the reasons for a relatively low funding rates for bioarchaeological projects within the Biological Anthropology Panel of the National Science Foundation and other homologous organizations worldwide[16]. One potential contributing factor, for US-based scholars, is that bioarchaeology proposals are often co-reviewed by the Biological Anthropology and Archaeology programs of the NSF, which have different priorities that may be difficult to balance in a single proposal. Responses to the preliminary questionnaire and discussions at the Workshop highlighted concerns about the lack of problem-oriented research design apparent in bioarchaeology grant proposals and manuscripts submitted for peer-review. Participants noted that grant proposals that are ranked as non-competitive are predominated by an exclusive focus on subjects or culture areas at the expense of describing how the projects will address specific questions of broader relevance and what hypotheses will be tested. This includes, for example, proposed studies of un(der)studied skeletons from specific regions without clearly explaining the broader significance of the research. Similarly, many non-competitive proposals describe opportunistic research on skeletal remains seemingly for the singular reason that they are available for study, which reviewers do not find to be sufficiently compelling and worthy of grant support. Several Workshop participants summarized their impressions of such proposals as invoking reviewer reactions of "so what?". In some cases, these perceived shortcomings are the result of a prospective Principal Investigator failing to prioritize research questions according to reviewers' expectations. This can be addressed by scholars reading successful grant applications to particular agencies to learn how to better frame proposals in ways that align with agency- and subfield-specific expectations. Several participants noted the potential utility of an open-access centralized archive of submitted proposals (perhaps hosted by funding agencies or professional

[16] For a recent analysis of relatively low rates of applications to NSF, Wenner-Gren, and the National Geographic Society by women in archaeology in general, see Goldstein et. al. (2018).

organizations), and many would be willing to share their own (successful and unsuccessful) proposals to serve as models. However, it was also acknowledged that problems with research design are, in some cases, deeper than a relatively superficial issue with framing and description in the text of grant proposal. Some investigators are failing to identify clear, relevant, and compelling questions at the initial stages of research design or the theoretical frameworks they are applying (for a recent analysis of use of theory in the field, see Cheverko et al., 2020). They are also often not describing specific, clear hypotheses that they will test, as is necessary in work that is grounded in the scientific method. Addressing this deeper issue over the long term will require deliberate instruction in creating problem-oriented research designs and hypothesis testing, beginning with undergraduate researchers and continuing through graduate education (as detailed below).

Discussions of research design also emphasized the need to make clear, from the beginning of a research project, the linkages between the data that will be generated by the project and the research questions that they are expected to address. Further, investigators should produce clear, testable hypotheses and select analytical approaches appropriate to those hypotheses and relevant data. This contrasts with an unfortunate, all-too-common, tactic, criticized at the Workshop, of pursuing data collection and analysis without a stated research question, followed by an explanatory scenario seemingly generated without rigorous consideration of alternatives. Lastly, as is explicitly required by NSF, scholars should focus more clearly on the broader impacts of and the generalizable knowledge that can be produced by their research, and highlight mechanisms to implement those broader impact. In addition to being an essential way to articulate how bioarchaeological research is relevant to living people, explicit, deliverable broader impacts can distinguish a proposal.

11.2 Assumptions and Levels of Analysis

Levels of analysis may vary from a focus on the individual, as noted below, to community-based, regional, continental, or global studies. An example of the latter would be the issue of the impact of the "Neolithic Revolution," discussed in the Introduction (Section 1). Most investigations center on one of the intermediate levels, discussing matters ranging from migration histories (frequently continental, see Section 6) to the development and maintenance of identities such as masculinity (regional, see Section 7). In each case, the questions chosen for interrogation should be anchored by a set of assumptions, most commonly focused on the degree to which the study sample may be considered representative of the living individuals or groups who are the subject of inquiry. These assumptions are important as a device to assure both the researcher and any prospective reviewer that the study is rigorous. Are there other samples or individuals who should be included in the study? Are the assumptions about context met (e.g., how do we know that the group subsisted on or otherwise came into contact with infected zoonotic species, and why is this important)? A careful and explicit statement of assumptions and how they are justified is an important base for any ensuing study.

11.3 Interdisciplinarity and Collaboration

A common theme throughout the Workshop was the inherent interdisciplinarity of bioarchaeology, and one of the sessions explored ways to improve interdisciplinary approaches so that they are truly substantive and mutually beneficial to bioarchaeologists and scholars in other fields, such as public health, archaeology, medical anthropology, history, pathophysiology, and clinical medicine. Now that bioarchaeology is a well-established field, there has, in general,

been a "siloing" effect such that we primarily write for and collaborate with each other (as evidence by, for example, the common use of "The Bioarchaeology of …" in the titles of our publications, rendering them less likely to attract attention outside the field). Further, participants reported that most of the interdisciplinary projects they have participated in were initiated by bioarchaeologists rather than scholars outside the field. Disrupting this trend requires that we write essays that people in other fields want to read and that we be proactive about enabling others to see the value of our research.

Interdisciplinary elements need to be built into projects from the very start of research design, and collaboration should include relevant individuals from these initial steps and not as an afterthought. There have been remarkable advances in the tools and technology that can be used at the both the data collection and analytical stages to address a diversity of bioarchaeological topics, including but not limited to dietary reconstruction (e.g., stable isotope analysis), mobility patterns (via the application of engineering principles to bone), and identification of infectious pathogens (via aDNA analyses and paleoparasitology). While some bioarchaeologists certainly can obtain training in these and other advanced techniques, leveraging their advantages (particularly in combination) often requires collaboration with experts from other fields. This process includes careful consideration of both the benefits that can be obtained from interdisciplinary collaborations and the complexities that might arise because of variation in terminology across fields and different disciplinary expectations about co-authorship, data-sharing, analytical approaches, appropriate publication venues, and relevant background literature, among other things (see, e.g., Snoddy et al., 2020a, b). Another potential issue is in obtaining funding for interdisciplinary projects, as program officers and reviewers familiar with one field might not see the value in approaches and questions from another. Despite these potential hurdles, interdisciplinary research has the potential to improve our reconstructions of life in the past (see for example Sections 3 and 9), and to yield information of significant benefit to living people. For example, Larsen et al. (2019) summarize findings from their collaboration involving bioarchaeologists and archaeologists, focusing on questions of broad anthropological interest regarding health, migration, and mobility (informed primarily by biomechanics and stable isotope analysis) in Neolithic Çatalhöyük. Other recent successful examples of interdisciplinary work involving bioarchaeologists includes that of Han et al. (2017), Wells et al. (2016), Pomeroy et al. (2019), Seetah et al. (2020), and Smith-Oka et al, (2020).

Interdisciplinary, collaborative work can benefit from widespread, consistent use of standardized bioarchaeological data collection methods (see e.g., Buikstra and Ubelaker, 1994; Steckel et al., 2018) and the creation and maintenance of large datasets. There is an emerging conversation in biological anthropology, in general, regarding best practices for data storage and sharing that will help guide future project planning (see, e.g., Boyer et al., 2020).

11.4 Small Datasets

Bioarchaeologists are often faced with relatively small sample sizes, which preclude (or, in some examples, are mistakenly perceived to preclude) the use of analytical approaches more commonly used in other fields, such as those in epidemiology and formal demography. We acknowledge that there are cases in which sample sizes truly are too small to be compatible with rigorous analytical approaches, and it is not our goal to undermine the potential value of these data. Further, there are cases in which it is appropriate to eschew statistical analyses altogether (e.g., an osteobiography of one individual or a case study of a rare disease can have significant value in the absence of rigorous statistical analyses, see examples in the 2019 special issue of

Bioarchaeology International on osteobiographies and the 2021 special issue of *International Journal of Paleopathology* on rare diseases). However, in an effort to promote bioarchaeological work that is aligned with the goals of the other subfields within biological anthropology, i.e., to move beyond cataloging and description and to address issues of broader anthropological and evolutionary significance, we also want to promote the careful consideration of all feasible statistical analyses relevant to the questions being asked by bioarchaeological studies. Identification of appropriate statistical methods requires first considering all of the possible relationships that may exist among the variables under study – with respect to the broader cultural, demographic, environmental, biological, or evolutionary phenomena of interest. Then, the researcher should make explicit predictions from a plausible scenario (or, where appropriate, several alternative scenarios) regarding those relationships that are firmly grounded in preexisting information about the relevant context. For a recent illustrative example of an effective deployment of this strategy, see Rathmann et al.'s (2019) study of ancient Greek colonization of southern Italy, in which they used dental metric and nonmetric trait data to test several competing scenarios.

It is not feasible to provide in this paper a description of all possible analytical approaches relevant to bioarchaeological research, both because of space constraints and because there is no single method or set of methods that are universally applicable. In the interests of furthering rigorous bioarchaeological research, we will briefly note that, despite apparent assumptions to the contrary, there are suitable methods for the statistical treatment of ordinal/categorical variables and for simultaneously examining multiple types of variables (e.g., categorical and continuous). Examples of these applications can be found in work by Temple (2014), Yaussy (2019), Godde et al. (2020), and Obertová et al. (2020) among others. Informed consideration of feasible and suitable options relies on effective training in the application of quantitative methods, as detailed further below, or collaboration with colleagues with relevant expertise.

One strategy that is commonly used in bioarchaeology for dealing with the limitations of small samples sizes is to pool data within a site (e.g., by age, sex, or other variables) or pool samples across sites spatially or temporally in order to produce a working dataset sufficiently large to generate acceptable levels of statistical power, fulfill the criteria of specific statistical approaches, and yield interpretable results. While pooling samples is justified when the assumptions made for the generation of questions/hypotheses are not violated, the issue of assumptions is very important (see above). The strategy of pooling data thus introduces the problem of potentially (and to an unknowable degree) masking heterogeneity that might exist within the meta-sample. Putting aside the fact that heterogeneity itself is often of great interest to bioarchaeologists, this inevitably raises questions about whether the findings reflect experiences of just some subset(s) of the population and how generalizable they are to other contexts. For example, in an effort to discern the potential effects of the mid-14th century Black Death on general health in London, DeWitte (2014b) compared a sample of people who died prior to the epidemic (1000-1250 CE) to a sample of people who died afterward (1350-1538), and found evidence of increased survivorship (and thus improved health) after the epidemic. In subsequent work, DeWitte (2015b, 2018) found temporal variation within the larger pre-Black Death sample (1000-1200 vs. 1200-1250) indicative of a decline in health before the Black Death that was not discerned when those data were pooled. This is important for understanding the context of the emergence of the Second Pandemic of Plague and specifically the potential effects of climate change, subsistence crises, social inequality, and urbanization (DeWitte, 2020). Milner (2015,

2019) and Buikstra (1992) each make a similar point about masking important heterogeneity when assessing health, violence, and other variables when pooling pre-contact samples in North America.

Another tactic for dealing with small sample sizes (and which is often used in combination with data pooling) is to use methods that are expressly compatible with small sample sizes (such as pairwise Chi-square tests or Fisher's exact tests) and for which there is a preponderance of examples in the bioarchaeological literature. Such methods, though they can and do produce interesting results, do not, in isolation, allow for evaluations of higher order interactions nor enable one to effectively control for confounding variables, thus making it difficult if not impossible to draw clear inferences from the results. For example, a pairwise comparison of frequencies of skeletal pathologies between two groups of interest may yield findings suggesting a difference between those groups, but cannot by itself indicate what effect, if any, there is of variation between those groups with respect to age-at-death distributions, sex ratios, social status, temporal period, or other factors. The inability to analyze the associations of multiple variables efficiently and simultaneously is a concern given evidence from numerous studies that stress markers and other data of interest to bioarchaeologists vary according to variables such as age, sex, and social status (see, for example, DeWitte, 2012; Garland, 2020; Grauer, 1993; Nakayama, 2016; Pilloud and Schwitalla, 2020; Yaussy, 2019).

11.5 Missing data

A further issue that is not limited to small sample sizes, but that might disproportionately skew findings therefrom, is missing data. At the population level, data are missing from skeletal samples because of various selection processes such as selective mortality, preservation bias, systematic variation in burial practices or locations, and incomplete excavation of burial grounds (Milner et al., 2008). Data are also often missing from skeletal samples at the individual level for a variety of reasons, including incomplete excavation or truncation of burials, antemortem loss of elements (e.g., teeth), and poor preservation, age-related wear of teeth, or the presence of pathological conditions that destroy or obscure relevant skeletal elements or surfaces. Following Rubin (1976, p. 19) and colleagues' (Little and Rubin, 2019) formalization, Stojanowski and Johnson (2015) provide an overview of the ways in which data (in their case, of dental traits) can be missing and a case study of the implications of "missingness". Data can be categorized as missing completely at random (MCAR), missing at random (MAR), or missing not at random (MNAR), and all mechanisms of missingness can potentially affect a single dataset. Data that are MCAR are missing for reasons that are unrelated to the value of the variable of interest or to any other variables included in analysis, and there is no pattern to the values of the missing data; data that are MCAR produce no systematic differences between individuals in the samples with and without missing data (Mack et al., 2018), and observed data can be viewed as a random subsample of the hypothetically complete data (Baraldi and Enders, 2010). Data that are MAR are missing for reasons that *are* related to some other variable in the dataset but not related to the value of the variable of interest itself; as with data that are MCAR, there is no pattern to the values of the missing data. Data are MNAR if they are missing for reasons that are related to the variable of interest's values, and the values of missing data are not random; for example, incisor shoveling data are MNAR if the probability that they are missing is related to the severity of shoveling (Stojanowski and Johnson, 2015).

Unfortunately, it is possible to test empirically only for the MCAR mechanism, as the MAR and MNAR mechanisms depend on the unobserved data (Baraldi and Enders, 2010).

According to Rubin (1976), missing data are a common problem, and often analyses proceed under the (implicit or explicit) assumption that the processes that produce missing data can be ignored. However, while MCAR and MAR are considered ignorable missingness (e.g. they both yield unbiased parameter estimates), MNAR is considered non-ignorable missingness (Graham, 2009). Stojanowski and Johnson (2015) highlight the potential for data that are MNAR to introduce considerable bias to bioarchaeological analyses. They compare data collected by the first author to those previously collected by Powell (1995) relevant to debates about patterns of dental variation in early populations in the Americas, and specifically whether inconsistencies across studies reflect true patterns of dental variation (and thus population history) or improper scoring of worn teeth (i.e., scoring worn teeth as lacking a trait rather than as missing data, or what is referred to as trait downgrading). Their analyses suggest that differences in their findings and those of Powell may be an artifact of missing data, though the mechanism (MCAR, MNAR, or MAR) appeared to vary by dental trait, and, importantly, that missing data may influence inferences about population history in the Americas. Stojanowski and Johnson (2015) urge bioarchaeologists to consider the potential for missing data at the research design stage and to select sampling strategies that account for anticipated missingness. Wissler (2021) recently assessed methods for data imputation – as a way to deal with missing data – that are feasible and useful for bioarchaeological research.

11.6 Bayesian Approaches

Several participants in the Workshop highlighted the potential value of Bayesian approaches to bioarchaeological research. A comprehensive overview of Bayes' theorem, with examples of its applicability to biological anthropology, is provided by Konigsberg and Frankenberg (2013). Though they argue that biological anthropologists think in probabilistic terms and that our perspectives and research rely on prior knowledge (i.e., aspects that are inherent to Bayesian approaches), we often use statistical approaches that are unrelated to our research questions. Konigsberg and Frankenberg (2013: 153) promote consideration of Bayesian approaches (where appropriate) because they offer such advantages as "creating estimates and uncertainties about those estimates without asymptotic approximation" and of explicitly incorporating prior information with data "to generate problem-specific distributions in a systematic and logical way." Bayesian approaches produce "interpretable answers in terms of a probability distribution", which makes them potentially more intuitively useful than the confidence intervals produced by frequentist approaches (which are often misinterpreted, see Konigsberg and Frankenberg, 2013: 156). Importantly for bioarchaeological data, Bayesian approaches accommodate missing data and complex parametric models, and allow for comparison between models (see more about models below). Given that Bayesian approaches require making explicit the subjective information within or associated with the study sample (inherent to but often unacknowledged by many frequentist approaches), they also allow for better evaluations of the inferences scholars make from their results and can potentially enhance the reproducibility of findings (Konigsberg and Frankenberg, 2013: 175).

There are numerous examples of Bayesian methods and inference in bioarchaeological research, including for the purposes of estimation of individual skeletal ages and paleodemographic analyses (Coqueugniot et al., 2010; DiGangi et al., 2009; Godde et al., 2020; Godde and Hens, 2012, 2021; Gowland and Chamberlain, 2002; Konigsberg and Frankenberg, 1992; Łukasik et al., 2021; Müller et al., 2002; Nagaoka and Hirata, 2007; Sasaki and Kondo, 2016; Séguy et al., 2013); estimation of sex (Konigsberg and Hens, 1998), ancestry (Rathmann et

al., 2019), or stature (Konigsberg et al., 1998); paleopathological diagnosis (Boldsen, 2007; Byers and Roberts, 2003); evaluation of antemortem tooth loss (Gilmore, 2013); and dietary reconstruction (Arcini et al., 2014; Chinique de Armas et al., 2017; Stantis et al., 2020). Although many scholars may recognize the value of the analytical rigor that Bayesian approaches represent and their advantages over frequentist approaches and classical hypothesis testing, some Workshop participants suggested that a greater number of bioarchaeologists (particularly in US contexts, as Bayesian approaches are used more commonly elsewhere) may be more strongly compelled to adopt them if more bioarchaeological studies were published that explicitly demonstrate their practical utility with respect to the questions we want to address (e.g., similar to Konigsberg and Frankenberg 2013). That is, compared to those statistical approaches used most often in bioarchaeology, what difference does a Bayesian approach actually make with respect to the inferences we draw from bioarchaeological data?

Several bioarcheologists interested in paleodemography or age-structured analyses of pathological or other data have leveraged the advantages of hazards analysis (Godde et al., 2020; Godde and Hens, 2012, 2021; Hughes-Morey, 2016; Konigsberg and Frankenberg, 1994; McCool et al., n.d.; Redfern et al., 2019; Redfern and Dewitte, 2011; Watts, 2015; Wood et al., 2002). Hazard models specify the time until a certain event, such as death, occurs. Hazards analysis is a potentially powerful way to extract information from relatively small and biased samples of human skeletal remains, and has been promoted, in particular, as an alternative approach to paleodemographic life table estimation (Konigsberg and Frankenberg, 2013; Wood et al., 2002). Hazards analysis in bioarchaeology often involves fitting a fully parametric mortality function, survivorship function, or age-at-death distribution (all of which are related) to skeletal age estimates and other data representing covariates of interest (e.g., to examine differences in hazards by sex, social status, or time period). Gage (1989) and Wood et al. (2002) have detailed several relevant parametric models, including their biological rationale, for bioarcheological applications, including the Gompertz, Gompertz-Makeham, and Siler models. Though parametric models can be "data-hungry", models with a small number of parameters can be applied to small samples. For example, maximum likelihood estimation can perform well (i.e., recover known parameter values from a simulated dataset) with samples of less than n = 100 for models with relatively few parameters, such as the two-parameter Gompertz model (El-Sherpieny et al., 2013; Usher, 2000). Importantly, hazards models provide the benefit of accommodating missing data and smoothing random variation in mortality data that can be an artifact of small samples without imposing any particular age pattern on those data. The flexibility of these models, which allows them to be applied even to conventional age estimates with broad terminal age-intervals, makes them appealing to some scholars while the field grapples with the issues of accuracy and precision of skeletal age estimation. In addition to these fully parametric models, bioarchaeologists have also applied the semi-parametric Cox proportional hazards model, which allows for the estimation of the risk of death and potential variation in that risk across variables of interest (Betsinger and DeWitte, 2017; Hughes-Morey, 2016; Temple, 2014; Walter and DeWitte, 2016; Watts, 2015). Because hazard functions do not require the specification of a baseline hazard of mortality, parameters are not estimated, which makes it suitable to relatively small sample sizes. Patterns of survivorship can also be assessed non-parametrically using approaches such as Kaplan-Meier survival analysis (Boldsen, 2005; Gamble et al., 2017; Ham et al., 2021; Wilson, 2014).

Many workshop participants emphasized a need for improved training in quantitative methods for bioarchaeologists (see more details in Section 12). Until such training is widely

available and routinely a required component of graduate programs (and given that there are programs in which effective and required quantitative methods training may continue to be unfeasible), a potentially useful mechanism would be for qualified bioarchaeologists to organize regular quantitative methods workshops at annual conferences (e.g., the AABAs, PPAs, and SAAs), or leverage emerging trends for publicly available virtual seminars, highlighting appropriate statistical approaches suited to bioarchaeological data.

11.7 R Programming Language

Broader adoption of rigorous, informative, and suitable quantitative methods may also be enhanced by the increased use of R by biological anthropologists and archaeologists. R is a programming language and environment that is valued for its flexibility, transparency (e.g., details of R algorithms are publicly available), availability of a large number of methods, and the level of control it gives to the user (Marwick, 2018; Mascaró et al., 2014). In contrast to commercial software such as SPSS and SAS, R-users are not limited to built-in functions or reliant on sluggish rates of additions of new methods (which can be particularly problematic for relatively narrow markets), but rather can use code produced by others or create their own (Carlson, 2017; Marwick, 2018). R code can be shared easily, including via searchable online repositories – Comprehensive R Archive Network (CRAN), Bioconductor, and GitHub – and code can be published with (or as supplementary material to) articles reporting findings produced using the code. There is a large community of R users, who are constantly producing new packages for R (Li, 2018), and the online R community is notably friendly to novices (Marwick, 2018). According to Lynch and Stephen (2018), "over half of currently available computer analytic tools in forensic anthropology use R," and according to Marwick (2018: p. 1), R is the "most widely used scientific programming language in archaeology". Many R users inside and outside the field generously share their code online, providing a potential source of guidance for bioarchaeologists adopting R for their own purposes. R users can also share the scripts that are produced during data analysis, which report each step in the analysis, further increasing transparency. This not only makes it ideally suited for furthering the reproducibility of findings in the field, but may also serve to encourage bioarchaeologists to adopt R – i.e., sharing R code that has been used to produce peer-reviewed findings reduces the coding burden and uncertainty about best practices for those bioarchaeologists who are novices to R. Another major advantage of R is that it is an open-source software program and therefore accessible to all scholars regardless of institutional affiliation or financial circumstances. R has a reputation for having a steep learning curve (Li, 2018); however, the clear advantages of R and the friendly community of users can undermine existing hesitation to adopt it.

11.8 Summary

It is clear, as highlighted throughout this paper, the ability and potential of bioarchaeology to produce profound understandings about life in the past. However, fully achieving that potential requires problem-oriented research design (and in many cases, hypothesis testing), use of appropriate and maximally informative statistical methods (and relevant software), substantive and well-planned interdisciplinary work, collaboration with colleagues with complementary skillsets (e.g., for leveraging advantages of technological advances), and recognition of and accounting for missing data. We detail below how, for future generations of scholars, these surmountable hurdles can be addressed via targeted training in graduate programs.

12. GRADUATE TRAINING

12.1 PhD Production and Job Placement

As detailed in the Introduction, because of the initial motivations for organizing the Workshop, most of the participants work at institutions in the United States. As a result, the following is primarily focused on graduate training in the US. From 1985 to 2014, ~13,000 PhDs in anthropology were awarded in the US, and, as of 2014-2015, approximately 21% of those individuals were in tenure-track positions in anthropology departments (Speakman et al., 2018). The alarming current trend of increasing proportions of contingent faculty in often exploitative and precarious positions does not appear to be on the wane in the near future. Given these patterns, we should be transparent with students about the relative dearth of permanent, full-time employment opportunities in academia in the US. Further, departments should be proactive about helping students seek out and apply for postdoctoral positions and fellowship opportunities. Several Workshop participants have seen increasing numbers of their own PhD students secure postdoctoral positions, as has been common in the physical and biological sciences. Though many postdoctoral positions are obtained through informal channels, there are routinely opportunities to apply for postdoctoral fellowships from NSF, NIH, the European Commission (e.g. the Marie Skłodowska-Curie fellowship), and other agencies (e.g,the British Academy, UK). Lastly, it is vital that we support the knowledge and skills training of biological anthropology/bioarchaeology PhD students who can then transfer those attainments to careers outside of academia (such as in cultural resource management, as NAGPRA coordinators, data analysts in industry settings, education specialists at museums, employment with the Defense POW/MIA Accounting Agency). Not only does this further expand opportunities for gainful employment for our students, it also provides avenues for spreading the word more widely about our value as bioarchaeologists.

Given evidence that production of graduates with PhDs in anthropology annually outpaces the availability of academic jobs (Speakman et al., 2018), institutions and individual faculty need to address explicitly the ethical issues associated with admittance practices to graduate programs that provide training related to bioarchaeology, beginning at the undergraduate level. Though we can provide a quality education and help students cultivate transferrable skills, many Workshop participants see it as our role to make clearer the realities of job prospects inside and outside the field. Students often rely on the advice and recommendations of their undergraduate faculty advisors when deciding whether to pursue graduate study. Ideally, opportunities to engage in research should begin at the undergraduate level with a thesis or a course that involves independent research. Students can use these experiences as one mechanism for evaluating whether graduate school, with its major focus on cultivating independent research skills, is a good fit. This kind of experience-based self-reflection can relieve the burden of "gatekeeping" by faculty and help shift that decision-making authority into the hands of students. Prospective graduate students might also reflect upon which type of graduate program is the best fit for them (e.g., M.A. or PhD, applied or pure research focus). Some students will self-select out while others who might otherwise not have considered graduate school as a viable or desirable option will decide to apply, resulting in applicants who will be more fully prepared to undertake graduate studies. Additionally, with respect to US graduate programs (the structures and financial restrictions of which most participants were familiar), we strongly recommended that programs fully fund their students (i.e., provide tuition

abatements for full-time enrollment and stipends) for the typical or ideal duration of the relevant graduate program (e.g., two years for MA programs and four to five years for PhD programs). This is with the exception of students who have secured other sources of funding or for whom the financial cost of graduate studies has a strong likelihood of producing benefits in the near future with respect to securing or advancing employment opportunities (e.g., students interested in cultural resource management). While we acknowledge that the availability of graduate funding packages is not uniformly known at the time of admission and that university administrations or granting agencies are ultimately the arbiters of graduate funding packages, we would like to see a transformation of these practices and push institutions to establish funding packages at the time of admission as a standard. We also recognize that funding decisions are a gatekeeping mechanism that can be biased against BIPOC and ethnic minority students, and addressing this structural issue will depend upon success in efforts to increase inclusion and diversity within academia. Recommendations for non-US contexts, with different traditions of funding, may well differ.

Elsewhere, we have discussed the need for departments and faculty to address systemic issues plaguing academia (see Section 2), particularly regarding equity and racial justice; we need to ensure that bioarchaeology graduate programs are likewise proactive in addressing these issues. Just as individuals from marginalized groups working as academic staff, faculty, and administrators face additional barriers in their careers (Muhs et al., 2012), graduate students from underrepresented groups also experience substantial obstacles to their professional development. Several steps may be taken to ensure that graduate programs and admissions processes are more inclusive, and to improve trends in recruitment and retention of, and support for, students from racially marginalized groups, students with disabilities, and students from low socioeconomic backgrounds. First, departments can improve equity in admissions, starting by removing GRE score requirements from applications. Recent reporting and research demonstrates that the GRE suffers from many of the same limitations as other forms of standardized testing, including cultural and socioeconomic bias (Miller and Stassun, 2014; Clayton, 2016; Kent and McCarthy, 2016), and it has low predictive value with respect to graduate student success (Petersen et al., 2018). Programs may also consider contextualized admissions decisions, i.e., taking into account individual backgrounds and obstacles. Additionally, Heath-Stout and Hannigan (2020) described how fieldwork experiences are often cost-prohibitive for many students and limit participation (and consequently, career advancement) of minoritized and non-wealthy students. Until we normalize free and low-cost field schools, program admissions need to reconsider the weight given to prior fieldwork experience when evaluating applications. After admittance, requirements or informal expectations regarding fieldwork, especially field excavation, in graduate study are often designed around the presumption of the participation of able-bodied individuals and are therefore not inclusive. Further, we need to consider the issues of harassment and assault based on perceived gender or sexual orientation and against archaeologists of color and those with disabilities in field settings and how these limit fieldwork opportunities (Clancy et al., 2014; Nelson et al. 2017; Voss, 2021). Considering the preponderance of previously-excavated skeletal collections in museums and other institutions such as universities, and previously-collected data available for study and the laboratory analyses that are commonly used in bioarchaeological research, local, non-residential options for experiential, on-the-ground training are increasingly available to graduate students. Thus, while we acknowledge that in some cases important contextual information may be missing from existing datasets and that a lack of standardization of data collection methods may limit metanalyses, we think that

expectations regarding students' training in field methods should ultimately be tailored to their program of study and appropriate to their career goals. This increased flexibility benefits students of all ability statuses, as well as non-traditional students and students who are caregivers (Healey et al., 2002).

Finally, the climate of graduate programs should become more inclusive and supportive of all graduate students. Anthropology graduate students of color have reported receiving fewer opportunities for career advancement than their white peers (Brodkin et al., 2011). Addressing this problem requires systemic change, wherein departments develop a reflexive attitude toward their own racial discourse, hire more faculty of color, diversify theoretical perspectives and curricula, develop or make partnerships with mentorship programs designed specifically to support minoritized groups, and hold white faculty accountable for increasing racial justice (Brodkin et al., 2011). Inclusive universities should also support students' mental health, given that mental health concerns are increasingly common among graduate students (Evans et al., 2018), and ideally ensure diverse student councilors that specialize in racial trauma and mental health stress specifically faced by minoritized groups. Although access to health services largely depends on resources provided at the institutional level and we do not advocate that faculty take on additional burdens for which they are not trained, we can play a supportive role both as faculty advocates (to administrators) and faculty mentors (to students).

12.2 Preparing for Career Diversity through Training for Careers in Academia

Institutions and faculty must recognize that most PhD students will ultimately have careers outside of academia, and training and advising should reflect this. This is not a recommendation for diminished scholarly training; instead, we emphasize the need for faculty and students to identify how academic skills and knowledge are translatable to a variety of settings. This does not require a major re-working of (most) graduate curricula, but an explicit recognition that much of the knowledge and skills that students acquire in a bioarchaeology PhD program are transferable to a variety of careers. For example, skilled research design and grant writing is not only the core of academic research, but it is also broadly applicable to a variety of careers. It is a form of persuasive writing that requires the ability to understand significant amounts of data and text, synthesize them meaningfully, identify the missing components and important questions that remain unanswered, and convince others that a particular research design and skill set is best suited to address those relevant questions.

Graduate programs should provide sufficient support, guidance, and flexibility to enhance students' development as independent learners. However, it is impossible for institutions and faculty to plan for (or find the time to teach) all of the skills and knowledge needed for particular tasks or careers. Programs can encourage students to identify and develop new skills and collaborations particular to their interests and plan of study, which will serve students in a variety of academic, professional, and personal situations.

Bioarchaeology graduate programs should also leverage the services provided by university career centers. While these centers often lack specific content knowledge or are primarily structured to serve the needs of undergraduate students, of specific subjects, they can give broadly applicable advice on issues such as: transforming CVs to resumes, articulating how research in foreign countries and deep knowledge of various cultural groups is translatable into cultural competencies, and viewing grant writing as a skill in persuasive writing. Programs should also coordinate with the Graduate School/Graduate College to find internships or

professionalization workshops/seminars for graduate students and encourage students to take charge of their education and articulate how their skills are translatable to a variety of careers.

12.3 Graduate Training

Curricula for graduate training need to parallel academic professional work (e.g., writing papers that resemble published articles; reading/reviewing grant proposals; intensive reading to develop deep knowledge), and this training needs to start early and persist throughout the entirety of the program. Not only will this improve bioarchaeological research projects, but these skills are translatable to non-academic jobs. To develop recommended curriculum requirements for programs that train bioarchaeologists, we first assessed existing curricula. We collected data on graduate program curricula from graduate degree-conferring institutions with bioarchaeologists on staff, identified using the online American Anthropological Association (AAA) AnthroGuide. Additionally, graduate degree-conferring institutions not in the AnthroGuide but represented in the 2020 Bioarchaeology Workshop were also included. This resulted in a total sample of n = 84, predominately of US institutions but also including some from the UK (n = 3), Canada (n = 6), Portugal (n = 2), and Mexico (n = 1). Data were collected on degree types, tracks, and course requirements from the webpages and graduate handbooks for each institution sampled (**Table 1**). Seven key categories of curriculum requirements were identified: Professionalism/Ethics, Research Design/Proposal Writing, Theory, Breadth, General Methods, Quantitative Methods, and Proficiency in a Research Tool or Foreign Language (described in **Table 2**).

Importantly, several graduate programs had requirements that varied by degree concentration and/or included requirements that could be fulfilled by taking courses or pursuing training in multiple curriculum categories. Each curriculum category was recorded as Required, Optional to Fulfill Requirement, or Required Only for Certain Degree Tracks, as shown in **Figure 2**. **Figure 3** illustrates those curriculum categories that are required for all degree tracks by degree type (Terminal Master's, PhD Only, Master's/PhD). These figures and data will be discussed in the following sections, which will describe recommendations for improving curricula in bioarchaeology training programs.

[Insert Figures 2 and 3 here]

12.3.1 Professionalism/Ethics

Professionalism and ethics are inextricably intertwined and should be integrated into graduate training, ideally in a standalone course. Currently, only about 26% of the bioarchaeology graduate programs evaluated (n = 22) appear to require a course in professionalism and ethics. While some of this training occurs through apprenticeship (e.g., co-teaching; collaborating on field projects and co-leading community outreach projects; lunches with advisers and their colleagues at conferences, etc.), these processes need to be formalized by mentors within a professional framework, more explicitly acknowledged, and more equitably made available to graduate students. If the curricula do not allow for stand-alone courses dedicated to these topics, ethics should be meaningfully addressed in all other courses/modules; an additional option would be to develop workshops with the explicit goal of discussing ethics.

We need to teach our students how to be ethically responsible biological anthropologists who embrace the concept of do no harm, in the contexts of both their home institutions and their

field research settings. Social identity does not end at death, and our students need to be aware of this and how social identities of the deceased still resonate in descendant communities (in all the varied locations we do our work around the globe) and the general public. We also need to educate our students on how to engage with descendant communities and form collaborative relationships with them, from the initial steps of research design (rather than engaging them as *post facto* consultants), if they are receptive to it. Key issues to address include bioarchaeological ethics (Zimmerman et al., 2003; Scarre and Scarre, 2006; Vitelli and Colwell, 2006; Mays et al., 2013; Lambert and Walker, 2019; Squires et al., 2020); collaborating with descendant communities and other stakeholder groups (Boutin et al., 2017; Mihesuah, 2000); deep knowledge of NAGPRA and repatriation in general (Rose et al., 1996; Mihesuah, 2000; TallBear, 2003; McEvoy and Conway, 2004; Bruning, 2006; Threedy, 2007; Beisaw, 2010; Welch, 2010; Schillaci and Bustard, 2010; Blau, 2011; Kakaliouras, 2012; Chari and Lavallee, 2013; Meloche et al., 2020); collaborating with colleagues (professors, students, and other professionals), including co-development of projects, co-directing projects, co-publishing, and data sharing (Ledford, 2008); networking; plagiarism (what constitutes plagiarism and what to do if someone plagiarizes you); discussion of Title IX (civil rights law in the US that prohibits sex-based discrimination in federally funded schools or education programs) (Clancy et al., 2014; Nelson et al., 2017; Colaninno et al., 2020); Institutional Review Board (IRB) and ethics approvals from universities, communities, and tribes; explicit discussion of power differentials; diversity, equity, and inclusion (and lack thereof) in bioarchaeology; proactive work toward decolonization; and fieldwork safety and inclusivity.

12.3.2 Research Design

Graduate students in bioarchaeology should take a course in research design/grant proposal writing. Currently, less than half (n = 34) of the bioarchaeology graduate programs evaluated require such a course. Core components of this course should include reading about grant proposal writing, reviewing successful and unsuccessful grant proposals, and writing multiple drafts of grants with peer-review by other students. This course should encourage students to think about what is novel in their research; how does it push existing boundaries? What are the past, current, and future trends in bioarchaeological research and publishing (Buikstra, 1991; Stojanowski and Buikstra, 2005; Buikstra and Roberts, 2012)? What compelling problems can their research address and how do they formulate testable hypotheses to address those problems? Students should learn to start any project by first identifying a problem to address and then selecting appropriate analytical and methodological approaches (rather than starting from an interest in tools and methods and looking for a context to apply them). Students should also learn to identify the broader impacts of their research and how to make those impacts an integral component of their projects rather than viewing them as an appended task included simply to satisfy granting agencies' requirements. Given the need to improve interdisciplinary approaches and the many technological advances relevant to bioarchaeological data collection and analysis (Section 11.2), students should begin the process of recognizing opportunities for interdisciplinary training and pursuing collaboration with scholars in other fields early in order to enhance their potential for engaging in substantive interdisciplinary work over the long term. This process will require, with support of mentors, students developing realistic expectations and confidence regarding what they are capable of accomplishing on their own vs. areas that are best served through interdisciplinary collaboration.

As we issue the call more broadly for bioarchaeologists to speak out about how their research speaks to contemporary issues, we should likewise teach students to incorporate outreach into their research design. A research design course may assist students in identifying outlets for disseminating their work to a larger and more diverse audience (e.g., journalistic articles like those published in *The Conversation* and *Sapiens*, blog posts, and podcasts). Additionally, students should learn about resources and opportunities to help them more deeply engage with various publics (e.g., PAGE Fellowships for public scholarship; Wenner Gren Engaged Anthropology Grant, etc.). This work contributes to career progression and increasingly counts in considerations for academic promotion.

12.3.3 Theory

Figures 2 and 3 show that overwhelmingly, bioarchaeology graduate programs (regardless of degree type) require that students take at least one course in theory and most require that students take courses outside of their subdiscipline/concentration (breadth). These requirements are seldom optional and almost always required for all degree tracks. This is an excellent start, but we should ensure that theory is fully integrated into curricula beyond courses explicitly dedicated to it. Embedding social and evolutionary theory in thematic/topical and methods/applied courses, is a very effective way to demystify theory, demonstrating how various theories can be applied to interpretations of data. Embedding theory in methods courses disabuses students of the notion that any given method leads to one "correct," unambiguous answer.

Theory courses are an opportunity for students to develop and refine skills in critical thinking, reading, and writing. Rather than focusing too narrowly on methods/techniques, students trained in social and evolutionary theory learn to conduct problem-oriented research in service of answering "big picture" research questions. A strong foundation in theory enhances participation in experiential learning (e.g., internships, service learning, public outreach) by illustrating application of theory to practice (praxis). This is especially effective at a local/regional scale, which promotes disciplinary relevance to the public, and can help students apply data from the past to the solution of current social challenges.

All standalone or theory-oriented courses should also include discussions of ethics as well as ethical considerations for current practices, regardless of whether standalone ethics courses are offered and/or required. These courses should be part of a more broadly decolonized curriculum, which enhances critical thinking skills, interrogates the production of knowledge, and promotes a more inclusive academy.

12.3.4 Methods

While ~73% (n = 61) of the bioarchaeology graduate programs evaluated require coursework in anthropological/archaeological methods, only 24% (n = 20) of graduate programs require coursework or training in quantitative methods, specifically (see Figure 2). Additionally, 11% (n = 9) require proficiency in a foreign language or research tool, and in some cases, statistics proficiency is listed as an option to satisfy the research tool proficiency requirement, while others emphasize GIS or advanced field excavation methods.

It is clear from these requirements that general methods training is a cornerstone in bioarchaeology graduate training, while quantitative methods receive less emphasis. To make specific recommendations about the nature of that training, we collected data from published information on grantees from the National Science Foundation (NSF), the Wenner-Gren

Foundation, and the Social Sciences and Humanities Research Council (SSHRC) between 2010 and 2020 and analyzed the methods described in the abstracts and/or keywords for funded doctoral and postdoctoral bioarchaeological research (n = 232 projects). Over this period, NSF funded 53% of these bioarchaeology research projects, followed by Wenner-Gren with 27%, and SSHRC with 20%. Bioarchaeological projects were coded based on the methods described in the abstracts and/or keywords. Only methods that were explicitly stated or could be reasonably inferred were included. Fourteen major method categories emerged from this content analysis, described in detail in **Table 3** below. All projects had at least one methodological code. Most had more than one, and several methods commonly appeared together (as noted in the table).

Overwhelmingly, these bioarchaeology research projects relied on osteological data, paleopathological analyses, and isotopic data. However, these data show that mortuary analysis, molecular analysis, osteological and dental morphometrics, and biodistance analyses are also common. Due to their centrality in current bioarchaeological research, it is vital that students in bioarchaeology are trained in these methods. Of course, the extent of this training is largely institution-dependent, particularly regarding laboratory methods like biogeochemical and molecular analyses, but at a minimum students should be familiar with interpreting and evaluating data produced from these methods.

We want to emphasize again the importance of training in quantitative methods. Although statistical model development/testing is less common in bioarchaeological research (see **Figure 4**), it is undeniable that identifying appropriate quantitative methods for a given research question and interpreting them is vital in addressing current limitations and challenges in bioarchaeology. As previously noted, approximately one quarter of the graduate programs evaluated explicitly require at least one quantitative methods course. That said, fluency in quantitative methods comes from exposure to different statistical methods and practice using them. Bioarchaeology graduate courses should routinely discuss quantitative methods and encourage students to use datasets for course-based research projects when relevant. Additionally, ecology, biology, epidemiology, and biostatistics departments often offer courses in bioarchaeologically-relevant statistical methods like Bayesian statistics (as opposed to psychology or statistics departments, which tend to rely on regression).

[Insert Figure 4 here]

12.4 Best Practices for Graduate Training

Overall, most of the graduate programs evaluated for our study currently train bioarchaeology students in theory and methods and require some degree of breadth in student coursework. Training in quantitative methods, research design, and professional ethics are much more variably required. Importantly, these data are a limited perspective on graduate training; they only reflect formal degree requirements and cannot, by themselves, characterize students' training from any of these institutions. It is important to remember that fewer requirements typically allow for more flexibility, and students may ultimately be trained in many of the above categories (and potentially, more) even though they are not explicitly required by the degree program. Nonetheless, we can use these requirements as a general heuristic of what graduate programs consider core values.

Given the constraints of time, funding, and faculty composition of most graduate programs, graduate training cannot be comprehensive, but it must be foundational. The ideal

education for a broadly trained bioarchaeologist includes both archaeology and biological anthropology. Students should emerge from graduate school with the core skills and knowledge necessary to be competent bioarchaeology professionals, including understanding basic skeletal and dental biology, and generally how the social and biological conditions people experience influence growth and development and are otherwise embodied in the skeleton. Here and elsewhere in this article we have emphasized that 21st century bioarchaeology will require strong professional ethics to be practiced, public outreach to be key to disseminating research outcomes, and interdisciplinary collaborations to be promoted; further, to address the big picture questions and challenges facing our field, we need to continue drawing on social and evolutionary theory and improved quantitative methods. Graduate students developing their plans of study and faculty improving curricula and revising program requirements should bear in mind these points and endeavor to incorporate these, formally or informally, into graduate training.

We suggest a possible framework (i.e., curriculum, loosely defined) for graduate training in bioarchaeology that follows the knowledge needed for writing each section of a standard, peer-reviewed research article (see **Table 4**). This model would provide a clear justification and explanation for why students are being trained in particular areas. For example, writing the introduction to an article often requires that the work speaks to a larger theme or theoretical issue in the social or natural sciences; courses in anthropological or evolutionary theory provide the knowledge foundation that will form the basis of the introduction. Similarly, the methods section requires knowledge and skills that demonstrate how the bioarchaeological research will be conducted and why those particular methods are suitable (Buikstra and Ubelaker, 1994; Aufderheide and Rodríguez-Martin, 2003; Buikstra and Beck, 2006; Buikstra, 2019c); methods courses provide that training and context. Although Table 4 summarizes the article sections and associated substantive topics and coursework, we highlight that a key goal of graduate education is that our students become independent learners and researchers, engaging in honest self-reflection about existing lacunae in their knowledge bases and skill sets and proactively seeking to learn what is necessary. Faculty cannot foresee every possible methodological advancement, theoretical trend, or software development, but faculty and graduate students can collaborate to ensure that students acquire the knowledge and abilities to continue advancing after they have earned a graduate degree.

13. CONCLUSIONS

Over the past half-century, bioarchaeology has made important contributions to understanding life in the past, including clarifying the individual- and population-level experiences and effects of infectious diseases, variation in health across biosocial variables, patterns and consequences of migration, and trends in interpersonal violence. In multi-scalar fashion, our field has illuminated the histories of individuals, regions, and continents. We have also explored general phenomena of significance to our global past, present, and future. As illustrated in this article, bioarchaeology is also poised to make further, potentially transformative, contributions. In this article, we have offered comments designed to strengthen all such initiatives, including remarks about research design, training programs, topics of special significance, and ethical considerations that should guide our profession during the coming decades of the 21st century. A further immediate need, which will require substantial proactive efforts, is decolonizing and transforming the field to one that is more inclusive, representative, and sensitive to the desires of descendant populations.

Multiple approaches to bioarchaeological research are clearly to be encouraged, though we strongly encourage rigorous approaches that address significant questions about human life in the past and that, where possible, are applicable and relevant to living people. One overall challenge for our field is how to contextualize our data when focusing upon issues of broad significance, such as resilient responses to climate change, the context of the emergence of infectious diseases, and participation in various forms of violence. Do we begin with exquisitely detailed regional studies from which we extract common themes or do we start with "big data", multi-regional approaches? In both cases, we must address issues of data comparability and strive for striking a balance between contextual richness and general trends. Our field's most broadly publicly recognized achievement, the impactful conclusions developed from the initiative to examine health at the origins of agriculture (Cohen and Armelagos, 1984; (Cohen 1989, Cohen and Crane-Kramer 2007), involved comparisons across regionally contextualized datasets. The wide dissemination of these findings urges us to consider whether this is the best way to proceed further with other major questions, such as the impact of climate change.

In bioarchaeology, we have denaturalized the natural disaster by recognizing that moments of crisis and chaos can be products of human behavior and are also windows for socio-cultural change and biological adaptation. When reframed in this way, we remove the tendency to think of change as bad and to inadvertently reify pre-existing structures as somehow "good" or "natural" for that time and place. For example, bioarchaeological perspectives on violence and social institutions converge on a few simple ideas: inter-personal violence is in no way a "natural outcome" of climate and environmental change; violence is not necessarily abated by strong social institutions, particular forms of government, or tighter social control, phenomena that can also represent forms of violence; and there is no single meaning of nor a single trajectory for violent behavior in human history. Are there yet unasked questions that merit attention? Perhaps the response of peoples during the immediacy of change, the "transformational periods." We may hypothesize that change /transformation is not necessarily deleterious, but if we drill down into major transformations, such as those in food production, industrialization, and urbanization, should we consider the process of change itself or the final result that was the negative or positive health and wellbeing outcome? Perhaps managing change is one of the greatest human behavioral problems in the 21st century?

In the course of exploring the issues raised here, including those of resilience modeling and social transformations, we find that social identities, including intersectional identities that reflect and maintain structures of violence are crucial attributes that require our attention, first to the accuracy of our biological observations and then to the contextual details that facilitate a discourse attuned to social identities of gender, age, and kinship. Further developments in the field also hinge on improving our willingness and ability to work effectively with multiple lines of evidence and to embrace and proactively pursue interdisciplinarity (within and beyond anthropology). Such breadth should be featured in our research and especially in our training programs. We also recognize that some bioarchaeological work is limited by a failure to use relevant statistical analyses, and addressing this will require improved training in quantitative methods. Similarly, achieving a rate of funding of bioarchaeological research that matches the potential our field represents and the massive interest in it by students and scholars necessitates improved training in research design.

Several colleagues have already produced impressive articles, books, and edited volumes on topics such as climate change, migration, violence, and social inequality (see e.g., Blakey and Rankin-Hill, 2009; de la Cova 2012; 2021; Gregoricka, 2021; Harrod and Martin, 2014;

Nystrom, 2014; Robbins Schug, 2020). These achievements in reconstructing the lives of past peoples are to be celebrated and, as appropriate, their conclusions should be directed toward resolving contemporary issues (Buikstra, 2019). Nonetheless, we recognize that while important bioarchaeological research is and should be used to illuminate our past in ways that engage varied audiences, our ability to tell the stories of past individuals carries with it a responsibility to living descendants. These results should thus proactively also be made available to living descendants and nonspecialist audiences, in accessible language. As we generate and disseminate research conclusions with contemporary significance, how do we most effectively communicate our results beyond our profession? How best do we get past the scholar's recourse to "it depends" followed by polysyllabic swamps and descent into details, however interesting we find them? Challenges abound!

The need to decolonize the field and make it more inclusive in general, and the substantial proactive effort this will require, permeated many discussions at the Workshop, as is occurring within the field of biological anthropology more generally. As has been noted by Fuentes (2021) for biological anthropology, our intimate understanding of and focus on the outcomes of stress and marginalization makes inaction towards resolving a lack of diversity and inclusion in bioarchaeology inexcusable. For example, there is a major potential for bioarchaeological studies of adaptation during early life to push current knowledge further by documenting survival of early life stress and consequences at later stages of the life course in relation to systemic racism and other structures of inequality and power imbalances. However, a substantial lack of diversity in bioarchaeology suggests that such studies will result in subjectification until marginalized voices are included in the exploration of these and other questions. The framing of questions towards plasticity, constraint, resilience, and context in bioarchaeology requires inclusion of marginalized voices in research design as well as training a diverse generation of scholars for future research. Similarly, discussions of the ethical use of skeletal remains – particularly those of Indigenous peoples, enslaved individuals, or socially marginalized people – for pedagogical or research purposes will fall far short of their potential to promote social justice if they fail to include a diversity of perspectives and privilege the desires of descendant populations.

It is such transformation we seek, of ourselves and of our discipline, to prepare future generations to meet the challenges of a rapidly change world. The field of bioarchaeology must change, decolonize and embrace diversity in a manner previously unknown. As responsible educators and researchers, we should use our knowledge and our pedagogic skills to bring our knowledge of deep time to contemporary and future challenges that face humankind, not the least of these being epidemic disease, violence, inequality, and other trials that tax our resilience as individuals and in collectivities. This implies changing reward structures in universities to include communicating with non-specialist audiences, and it requires our training students in ethics, in transdisciplinary thinking, in the collaborations that are necessary to provide the nuanced interpretations that inform on general issues. These are significant challenges, ones that we must face to help frame our world and our global futures.

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Table 1. Institutions Sampled by Country and Degree Type.

	USA	UK	CAN	PT	MX	Total
Terminal Master's	26	0	2	0	0	28
PhD only	15	0	0	1	1	17
Master's/PhD	31	3	4	1	0	38
Total	72	3	6	2	1	84

Table 2. Categories of Curriculum Requirements.

Category	Description
Professionalism/Ethics	Course(s) in professionalism/professional development, introduction to graduate studies, ethics in anthropology
Research Design/Proposal Writing	Course(s) in research design, research strategies, proposal writing, writing for anthropology/archaeology
Theory	Course(s) in anthropological theory, history and theory of anthropology, and theory and methods courses of each subdiscipline
Breadth	Course(s) outside of subdiscipline/department; alternatively, multiple "general anthropological theory" courses
General Methods	Laboratory/analytical training, general methods training in method/theory courses, field method training, quantitative method training, internship/practicum requirements
Quantitative Methods	Quantitative methods requirement, typically either a course in quantitative methods in anthropology or other statistics course(s)
Proficiency in Research Tool OR Foreign Language	Proficiency in either a research tool (e.g., GIS, statistics, an advanced field method, etc.) OR a foreign language

Table 3. Method Categories.

Category	Description
Bioarchaeology (Unspecified)	Studies that applies a range of methods to archaeological human remains, described as “bioarchaeological” in nature but not specified beyond that.
Biodistance	Studies of relatedness between and within populations, typically assessed through skeletal metric and non-metric traits, and geometric morphometrics (see Osteo/Dental Morphology category). Often used in conjunction with DNA and/or Isotope analysis.
Biomechanics	Studies of movement-related skeletal variation. Includes studies of skeletal morphology/geometric morphometrics/robusticity (see Osteo/Dental Morphology category), studies of internal trabecular and cortical structure (see CT/Radiography category), and other studies of activity-related change (specific methods unspecified).
CT/Radiography	Studies that use CT, microCT, and/or other radiographic methods. Typically used in service of either biomechanical analysis (see Biomechanics) or paleopathological analyses (see Paleopathology).
DNA	Studies that use DNA analysis. These vary widely to include studies of population genetics, migration (see Isotopes), and pathogens (see Paleopathology).
Isotopes	Studies that use stable and/or radiogenic isotope analysis (e.g., for diet and mobility). Commonly used alongside Osteology, Paleopathology, and Mortuary Analysis methods (see respective categories).
Microscopy/Histology	Studies that rely on microscopic evaluations of skeletal/dental morphology. Typically used in Paleopathology.
Mortuary Analysis	Studies that include analyses of archaeological data such as burial practices (treatment of the body, body positioning), grave furniture, etc.
Osteo/Dental Morphology	Studies that include analyses of skeletal/dental morphology, morphometrics, geometric morphometrics, robusticity. These methods were often used in the service of biomechanical analysis or biodistance analysis.
Osteology	Studies that explicitly rely on osteological examination beyond any other methods listed in this table. These are studies of bones for creating biological profiles of skeletons (or components of the biological profile) or studies that otherwise rely on unspecified “osteological data.” For example, studies of paleopathology and/or paleodemography are almost always also included here, as they begin with analyzing bones and teeth.
Paleodemography	Studies that evaluate human population dynamics using skeletal samples. Commonly used with Osteology and Paleopathology methods.
Paleopathology	Studies that evaluate skeletal and dental health and/or the emergence of pathogens in the past. These studies almost always also use Osteological methods.

Spatial Analysis	Studies that evaluate geographic distribution patterns using GIS.
Statistics	Studies that are significantly based in statistics. Data aggregation, model development, or model testing is an explicit aim.

Table 4. Outline of a 'typical' bioarchaeology research article, suggesting how those sections connect to substantive ideas, graduate coursework, and broad training applicable to a variety of careers.

Outline of a research article	**Substance**	**Related Courses**	**Application in diverse careers**
Introduction & Theoretical Framework	Big ideas in anthropology/ social sciences	Courses in social theory and biological/evolutionary theory	Ability to process and integrate diverse sources of knowledge. Critical thinking.
Background: Culture & History	Deep content knowledge	Courses in the population, geography, history, and language of communities being studied	Deep content knowledge and ability to generate deep knowledge in new fields (learning how to learn)
Methods	Lab and related skills and deep knowledge of the appropriateness of certain methods	Methods courses: osteology and lab specializations (isotope, pathology, DNA, histology, GIS, etc.). These courses should include both the applied (skills) components and the theoretical/historical background on the methods.	Lab and related skills applicable in industry and the wider world of work; ethical considerations
Research Questions/ Hypotheses	Research Design	Research Design and grant writing course	Grant writing/ persuasive writing; clear thinking and organizing ideas; awareness of previous relevant work

Results	Generating and organizing new data/knowledge	Course in statistical methods and data presentation & data visualization	Analytical (statistical) skills and communicating data (e.g., data description and visualization) are widely applicable.
Discussion & Conclusion	Bridging big ideas with deep content knowledge and new data; use of relevant published literature; noting limitations of data/study	Content specific courses; Independent Studies	Synthesizing large and diverse sets of information, often from several different disciplines; Learning how to learn
Acknowledgements	Professionalization; Collaboration, Ethics	Course on Professionalization, Academic & Community Collaborations, and Ethics	Professionalization; Ethics, Networking
Literature Cited	Deep scholarship	All classes + self-directed readings	Deep knowledge; Learning how to learn
		Total number of courses	

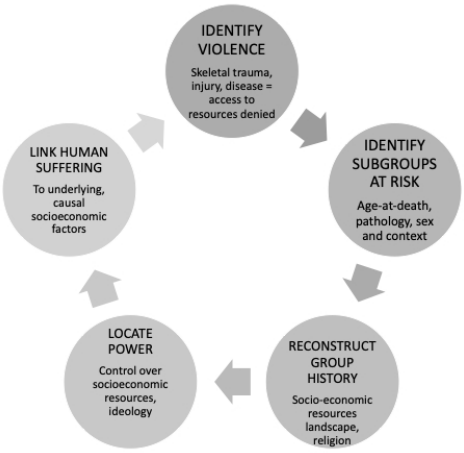

Figure 1: Chart illustrating possible pathways for linking bioarchaeological remains and contexts to structural violence (after Martin and Harrod, 2015: 134).

338x190mm (72 x 72 DPI)

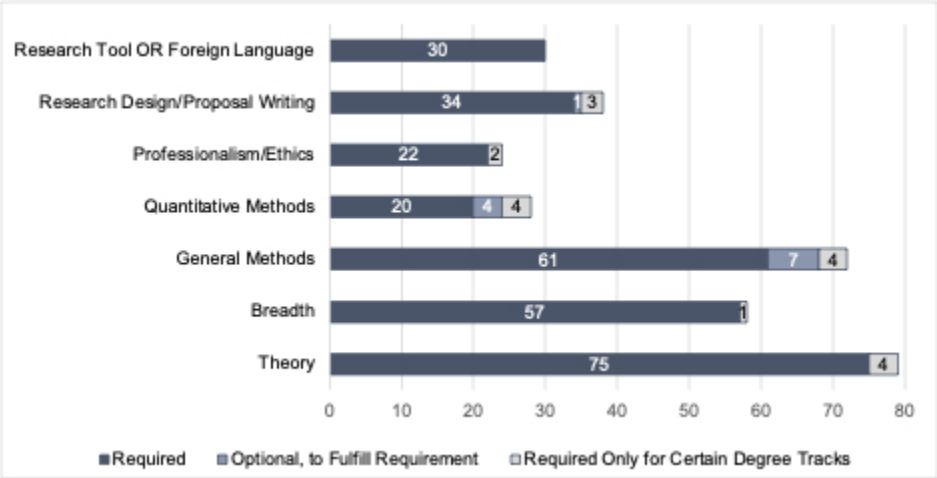

Figure 2. Curriculum Categories by Type of Requirement.

165x84mm (72 x 72 DPI)

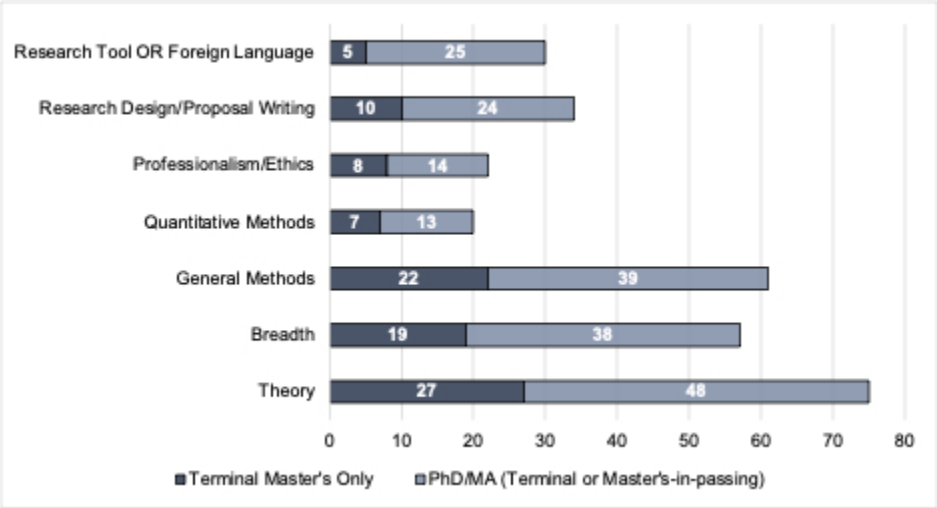

Figure 3. Program Requirements by Degree Type.

165x89mm (72 x 72 DPI)

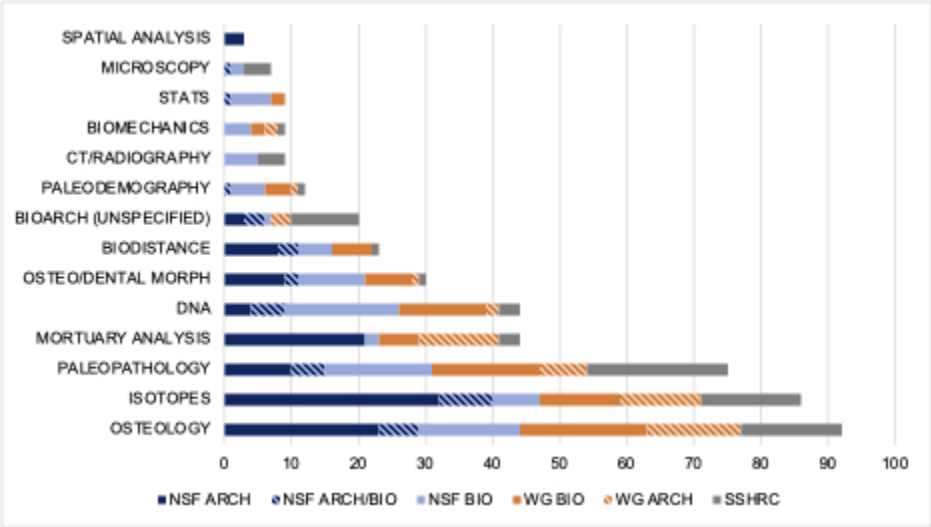

Figure 4. Methods in Bioarchaeology Research Funded by NSF, Wenner-Gren, and SSHRC, 2010-2020. Methods used in Osteology, Isotopes, and Paleopathology are by far the most common, followed by DNA and Mortuary Analysis, Osteo/Dental Morphology, then Biodistance. The remaining methods each appear in less than 10% of funded projects.

164x93mm (72 x 72 DPI)