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Moving Forward: A Bioarchaeology of Mobility and Migration

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Abstract

Growing interest in bioarchaeology and its ability to address complex questions tied to social and biological identities in the past has led to the development of nuanced methods for evaluating mobility and migration using human skeletal remains. Improving our ability to identify both short- and long-term migration through observations of body modification, analyses of biological distance, and applications of biogeochemical and aDNA techniques has enabled us to move beyond the simple dichotomous classification of past individuals as either local or nonlocal. These approaches have elucidated the complexity of migration processes while also revealing the heterogeneous ways in which individual agents and social groups incorporate, instigate, experience, and adapt to movement. These data have likewise demonstrated the potential of bioarchaeology to reveal broader patterns of social organization, social and ethnic identities, fictive kinship, postmarital residence, gender roles and relations, detailed life courses, responses to climate stress, and pathways of disease transmission. As bioarchaeology continues to contribute to mobility and migration studies, human skeletal data should be further contextualized by the archaeological record and linked to anthropological, archaeological, and bioarchaeological theoretical frameworks as part of more holistic attempts to explain the diversity and dynamics of human movement, interaction, and identity construction among communities in the past.

Keywords Theory · Identity · Isotope analyses · Ancient DNA · Body modification · Biodistance analyses

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Introduction

In the past, anthropologists tended to view mobility as a deviation from sedentary activities and not as a normative act in its own right (Bakewell 2008; Malkki 1992, 1995). Nevertheless, recognition that all societies possess at least some faction of mobile individuals is growing (Wendrich and Barnard 2008). This awareness has occurred alongside an enhanced appreciation for the importance of investigating human movement not as an event of limited scope and impact but as a multifaceted process guided by a convoluted array of societal structures, agential motivations influenced by culturally specific economic, political, and ideological circumstances, and human responses to external forces such as climate change. As mobility and migration occur within communities whose social organization inevitably changes over time, it follows that these processes too will change, necessitating models of human movement that incorporate fluidity and acknowledge the diversity of human interaction.

Through the act of movement itself, migrants become differentiated from both their population of origin as well as those communities they encounter in their new setting (Zakrzewski 2011). Bioarchaeologists subsequently attempt to identify biological changes associated with mobility and migration but, importantly, seek to contextualize skeletal materials more broadly within the "social construction of the human experience" (Knudson and Stojanowski 2008, p. 398). In this way, the identities of those who both impact and are influenced by the places through which they move as well as the peoples they encounter are not restricted merely to geographic origin or biological distance; instead, they may be conceptualized within markers imbued with social meaning and further shaped by self-perception, including age, sex, gender, status, and ethnicity (Brettell 2008; Díaz-Andreu et al. 2005; Insoll 2007; Knudson and Stojanowski 2008). Such bioarchaeological retrospection requires the implementation of social theory to generate effective explanatory frameworks that contribute to more meaningful interpretations of skeletal data (Martin et al. 2013a).

Using these approaches, and alongside fundamental questions related to how mobility intersects with sex, gender, age, status, ethnicity, religion, and other social categorizations. I first define the nuanced lexicon associated with the anthropology of human movement, discuss the history of anthropological and archaeological approaches to migration theory, and outline bioarchaeological applications to a social theory of migration using identity and gender frameworks. I then review methodological developments in the bioarchaeology of migration, including body modification, ancient DNA, biological distance, and radiogenic and stable isotopes. Within these contexts, I explore how bioarchaeologists can contribute to studies of mobility and migration among past individuals and populations. When coupled with social theory, a more meaningful and applied bioarchaeology emerges that has the potential to reveal the motivations for, logistics behind, and impact of mobility practices, and more holistically, processes of social and biological identity construction.

Defining Mobility and Migration

Mobility and migration are notoriously difficult to define, particularly given the complex task of classifying a continuum of mobile behaviors interpreted through the lens of a limited and biased archaeological record. Moreover, attempts to standardize definitions surrounding human movement have been met with increasing resistance and criticism, particularly as static, boundary-driven assessments largely ignore the dynamic nature of human social organization and the numerous modes of production that typically contribute to the structure of a single community (Anthony 1997; Cabana and Clark 2011; Tsuda et al. 2015; Wendrich and Barnard 2008). Simplified, bimodal terminologies (e.g., mobile vs. sedentary, hunter-gatherer vs. pastoralist, hunter-gatherer vs. farmer) have subsequently facilitated black-and-white models of movement that focus too exclusively on singular motivations for mobility (namely, subsistence) without taking into account the multifaceted incentives and influences beyond such practices, ranging from the ideological, religious, economic, and climatic to fleeing persecution, structural violence, or interpersonal conflict (Tsuda et al. 2015; Wendrich and Barnard 2008).

In lieu of modeling mobility solely along subsistence-based extremes, which necessarily focus on differences while ignoring cross-cultural similarities between groups, a growing number of archaeologists have recognized the utility of generating context-based typologies specific to the populations under investigation (Cabana and Clark 2011; van Dommelen 2014; Wendrich and Barnard 2008). While diversity in motivations surrounding patterns of mobility must certainly be recognized, additional factors structuring human movement—including *scale* (time and/or distance travelled, group size) and *participant identity* (the segment of the population engaged in mobility, framed by membership in sex, gender, age, status, or other socially structured categories)—should also be considered (Cabana and Clark 2011; Campbell and Crawford 2012; Frieman et al. 2019; Wendrich and Barnard 2008). Nevertheless, this work is complicated by the challenge of generating terminology that adequately encapsulates the variability and fluidity of mobile behaviors while at the same time recognizing that the development of any such vocabulary inevitably reduces this complexity into rigid categories that may oversimplify the very cultures we seek to better understand. How, then, do we move forward?

Minimalist definitions have recently been explored as a means of instigating interdisciplinary and inclusive conversations surrounding mobility and migration. Wendrich and Barnard (2008, p. 5) broadly define mobility as the "capacity and need for movement from place to place." This characterization is purposefully vague in its emphasis on movement but little else; the authors carefully avoid mention of any motivations driving mobile behaviors. This sentiment is echoed by Cabana and Clark (2011, p. 5), who contend that migration must minimally involve "an individual moving from origin to destination," without conjecture related to motivating factors that may have initiated migration or post-migration outcomes. Such definitions provide a useful common ground from which

increasingly detailed descriptors can be established to better facilitate the examination of mobility among past communities and to improve the means by which archaeologists capture the enormous range of mobile behaviors incorporated into the social organization of these groups. As we look to expand and refine minimalistic definitions, scale and participant identity provide a useful starting point.

Scale

A basic distinction in evaluating human movement is scale, or time and distance travelled. Many archaeologists differentiate between past practices of mobility and migration based on scope of movement. First, *mobility* involves individual or group movement across shorter distances that typically takes place within one's own cultural and/or political boundaries (Tsuda et al. 2015). Such localized movements are subsequently transient in nature, a temporary and often cyclical pattern of travel (Cabana and Clark 2011) interspersed with stationary periods of variable length for activities ranging from sleep to the production of goods (Wendrich and Barnard 2008). Most patterns of mobility among past communities likely involved short-term movements across shorter distances, in part because these were conducted within well-known interaction spheres and environmental zones (Anthony 1990; Hagerstrand 1967; Lewis 1982; see also Ravenstein 1889). Frequently, mobility is seasonal, part of broader subsistence strategies aimed at accessing resources in different habitats throughout the year. In other cases, information fields (Hagerstrand 1967), which incorporate depth of understanding of place coupled with connections to extended kin relations or other known social groups inhabiting nearby areas, enhance logistical and social support beyond cyclical mobility; thus, even one-way movements associated with residential relocation for economic opportunity or marriage occur across relatively short distances and/or within cultural boundaries (Brummell 1979; Connell et al. 1976).

Migration, on the other hand, is typically defined as a one-way, long-term or permanent relocation of one or more persons following travel across real or perceived political, environmental, or cultural borders (Cabana and Clark 2011; Tsuda et al. 2015). Framing migration as a relocation, however, should not imply that movement occurs as a singular or isolated event in time and space. Instead, migration is better conceptualized as a dynamic, long-term process, one that can span generations (Baker and Tsuda 2015; Bernardini 2011). While traversing such boundaries often requires long-distance travel, substantial socioeconomic or environmental borders may exist nearby; as such, migrations are not always long-distance acts but are inevitably long term in scope. Nonetheless, some anthropologists have begun to question whether our modern conceptions of boundaries adequately reflect those encountered in the past. Bernardini (2011), for instance, argues that prehistoric social landscapes were likely more fluid, political boundaries less defined, and ethnic identities more inclusive. Subsequently, instead of assuming that significant socioeconomic or ideological boundaries must be traversed for migration to take place, archaeologists should acknowledge the possibility of migrations taking place across "politically

and economically continuous" landscapes rather than discrete borders (Bernardini 2011, p. 31).

Scale can also refer to the number of individuals engaging in mobile behaviors, and group size represents an important consideration in examining the social structure of mobility or migration practices. Individuals in small mobile groups tend to operate with relative autonomy, albeit with some rudimentary structure tied to shared motivations (Cabana and Clark 2011; Cameron 2013). For instance, a subgroup may be tasked with travel in order to trade local goods for nonlocal products before returning to a base settlement and thus possess a collective goal that motivates their actions. Large mobile groups, on the other hand, must be organized and governed more formally (Cabana and Clark 2011). Due to the complicated logistics of structuring a large mobile group for any length of time, they are unlikely to undertake temporary journeys traditionally associated with mobility and are more likely to engage in long-distance and/or long-term migration.

Participant Identity

The identities of those engaged in mobile behaviors are another key factor that structured these processes in the past. Identity refers to attributes (as well as personal perceptions of such attributes) including age, sex, gender, social standing, and ethnicity, all of which inform an ever-shifting sense of self as individuals navigate different social spheres (Díaz-Andreu et al. 2005; Knudson and Stojanowski 2009). Individual identities are embedded within broader societal structures, or *habitus*, which are unconsciously internalized and continuously reproduced by participants belonging to that community (Bourdieu 1977, 1990). Correspondingly, the motivations underlying mobility or migration, the agential decisions that take place during movement, and post-relocation behaviors and actions together form a complex interplay between individual identity and social structure, making them fundamentally social processes (Cabana and Clark 2011). Alternatively, others have observed that the ways in which archaeologists conceptualize identity construction among past peoples rely too heavily on Western and/or capitalist constructs that extol individuality (e.g., Boutin 2016; Fowler 2004; Moutafi and Voutsaki 2016) and that instead, collective or relationally formed identity construction may better explain the motivations and subsequent decisions made by social actors (Baustian et al. 2014; Clark and Wilkie 2006; Fowler 2016; Gregoricka 2020a; Hertz 1960; Shanks and Tilley 1982; Sørensen 2013). Bioarchaeologists working to interpret human movement among ancient groups should subsequently recognize social or community identities that may have superseded those of the individual.

Mobile portions of society consist of a variety of identity-based subgroups typically tied to subsistence-based motivations. Logistical mobility refers to the segment(s) of a community that utilize mobile behaviors to seek out food resources that support all group members (Binford 1980; Kelly 1992). Those responsible for obtaining subsistence through mobile foraging or hunting vary cross-culturally and might include the young and/or old, women and/or men, and skill- or kin-based groupings. Logistical mobility differs from transhumance, which refers

more specifically to a societal subgroup responsible for guiding the seasonal grazing of herd animals (Jones 2005). Alternatively, movement may involve the entire community, as with residential mobility (Binford 1980; Kelly 1992); from an evolutionary perspective, such mobility may be linked to kin-structured migration or the enhanced tendency for biological (or fictive) kin to engage in mobile behaviors cooperatively as a means of enhancing success and reproductive fitness for the group as a whole (Fix 2004, 2012).

Theoretical Approaches to Migration

To more effectively and systematically understand migration, anthropological theory rooted in socioeconomics and gender can provide a useful tool and starting point for conceptualizing relationships between migrants and the peoples and landscapes with which they interacted, as well as underlying motivations for mobile behaviors. Here, I explore the evolution of cultural anthropological and archaeological thinking regarding mobility and migration and end with recommendations for how bioarchaeologists might utilize theory to better frame interpretations of past human mobility.

Cultural Anthropological Approaches

Anthropology underwent a long period of relative disinterest in migration studies until the 1950s and 1960s, when rapid globalization and subsequent transnational trade agreements instigated new and substantial waves of migrations that caught the attention of anthropological theorists (Horevitz 2009; Kearney 1986). Such migration was initially simplistically characterized as movement away from the traditional, rural countryside toward modernized, developed urban environments where labor was in high demand, later called *modernization theory* (Brettell 2008; Kearney 1986). The unilineal push-pull dynamic of such movement (Lee 1966) focused on the identity, motivations, and decisions made by individual migrants (Brettell 2008; Horevitz 2009; Kearney 1986). Nevertheless, by the late 1960s and early 1970s, increasing recognition that (expected) development did not necessarily follow urbanization forced theorists to rethink modernization, resulting in a neo-Marxist reframing known as *dependency theory* (Frank 1967; Kearney 1986). This model focused not on individual actors but on broad, macroeconomic relationships and resultant inequities between underdeveloped, labor-exporting and developed, labor-importing regions, thereby contextualizing migration within a decidedly historical-structural perspective (Kearney 1986).

However, the structural, macrolevel approaches of dependency theory were difficult for anthropologists to apply to the local communities in which they worked, particularly as migrants were depicted as passive pawns controlled by global, capitalist market forces rather than as social agents capable of decision making and instigating change in their own right (Brettell 2008). One offshoot of dependency theory that at least partially addressed such concerns was *world-systems theory*, which maintained that a modern, capitalist-based world system was a direct product of an economic

history stretching back to the late 15th century AD, as Europe began extending its reach beyond its borders (Wallerstein 1974). This European expansion triggered the formation of interdependent long-distance exchange networks, generating a world system that consisted of developed, capital-intensive "core" areas that hegemonically manipulate low-skill migrant laborers from "peripheral" regions as a means to obtain economic surplus (Wallerstein 1974). This extension of dependency theory was viewed favorably by some anthropologists as enabling a more local perspective that shifted focus to peripheral communities.

A second post-dependency model emerged in the 1980s and 1990s known as *articulation theory*, referring to the articulation between communities receiving immigrants and those sending them (Brettell 2008; Horevitz 2009; Kearney 1986). This model shifted perspective from a worldwide, unitary macroeconomic system to analysis at the community level, which focused on labor derived from household units and the resultant surplus produced by noncapitalist modes of production (Horevitz 2009; Kearney 1986). Peripheral communities were conceptualized as self-sustaining structures that continued to reproduce themselves despite, or perhaps even because of, external influence from imperial, capitalist centers (Horevitz 2009; Kearney 1986). Such a household-based approach appeased those anthropologists dissatisfied with macrolevel paradigms who were eager to link theory to anthropological fieldwork performed within communities at the household level (Horevitz 2009). Nevertheless, critics of articulation theory framed it as not only too narrow in focus but also as perpetuating a view of migrants as "passive pre-capitalists" whose movement away from their home communities was directed solely by external rather than local economic drivers (Horevitz 2009, p. 751).

These criticisms instigated new ways of thinking about articulation, leading to the development of an alternative model known as *transnationalism*. Anthropologists taking a transnationalist approach acknowledge that migration is not a unidirectional movement in which ties with one's home region are cut off and assimilation automatically takes place; instead, they contend that such mobility is inherently a social process in which migrants move back and forth between different sociocultural systems, maintaining social relationships with those in their place of origin (Brettell 2008, 2016; Glick Schiller 1995; Glick Schiller et al. 1992). This occurs as migrants increasingly have access to modern communications technology as well as to improved transportation methods as part of the broader impacts of globalization, resulting in the enhanced ability to "transgress geographic, political, and cultural borders" (Brettell 2008, p. 120). The construction of social identity among those migrants consequently involves a complex array of hybrid social influences ranging from local to international (Brettell 2016; Kearney 1995).

Transnationalism and migration have ties to *feminist theory* as well. Previously, the role of women in migration was generally not considered by scholars, was conceptualized as a secondary or passive role relative to the men they were following, or framed women as nonmigrants who remained in rural, underdeveloped areas while their more mobile male counterparts prompted modernity and change (Brettell 2008; Sheller 2008; Skeldon 1995). Although discussions of gender, gendered inequality, and migration studies began in earnest in the 1980s (e.g., Morokvásic 1984), feminist theorists eventually used transnationalist concepts as a means to bring the

integral role of female migrants into greater focus, highlighting pre- and post-migration experiences as well as the impact of their migration on gender relations, family structure, and authority and power (Brettell 2008; Pessar 2003; Pessar and Mahler 2003). Such a gendered lens is especially critical with increasing recognition that economic rationalizations for migration among males do not necessarily mirror the motivations for and subsequent experiences of females (e.g., Kana'iaupuni 2000). Feminist theorists similarly advocate for the incorporation of nationality, ethnicity, class, and sexuality as well as gender into theoretical discussions of migration, concurrently seeking to contextualize these intersecting aspects of identity both socially and historically (Nawyn 2010).

Aspects of transnationalism have nevertheless been challenged by some anthropologists who see little innovation in transnationalist ideas (Horevitz 2009; Kivisto 2001). While acknowledging that modern technology has enhanced communication across borders, they argue that the actions of migrants to preserve social relationships and connections with their place of origin are not a novel outcome of globalization but one that has characterized migration across much of human history (Horevitz 2009; Kivisto 2001). This criticism echoes arguments made by archaeologists that ancient borders should not be conceptualized as discrete boundaries but as more sociopolitically and ideologically fluid than today, which likely affected the ways in which ethnicity and other forms of social identity were constructed and negotiated (e.g., Bernardini 2011). Furthermore, as outlined by Horevitz (2009), it is unclear whether transnational behaviors between a migrant's homeland and destination would be sustained in the long term due to enhanced assimilation characteristic of subsequent generations (Esser 2004; Levitt et al. 2003).

Archaeological Approaches

Like cultural anthropologists, archaeologists generally avoided migration studies for decades (Anthony 1990; Burmeister 2000; Chapman and Hamerow 1997), contending that migration was of little interest because it could not be assessed through generalized, theoretical principles (e.g., see Renfrew 1982), and because it was so difficult to identify in the archaeological record (Anthony 1990). Migration was often relegated to an oversimplified, explanatory role when archaeologists were confronted with changes to material culture; such changes were perfunctorily attributed to either transcultural diffusion (i.e., movement of ideas and material culture, not people) or to population replacement with the arrival of an incoming, migratory group (Adams 1968; Adams et al. 1978; Anthony 1990; Rouse 1986; Storey and Jones 2011; Trigger 1980, 2003). Such ideas were firmly grounded within a *culture-historical* approach, corresponding with unsubtle racial undertones that some Indigenous cultures or ethnic groups were incapable of internally driven innovations and so must have adopted ideas from external sources (Trigger 2003, 2006; see, for example, Smith 1915, 1933).

With the advent of the New Archaeology in the 1960s and 1970s, *processual* approaches replaced efforts to organize past societies into distinct groups based on their material culture and instead emphasized scientific interpretation of

archaeological evidence over description (Binford 1962; Johnson 2004). Processual archaeologists were interested in answering big-picture questions of diachronic cultural change through the development of universal, cross-cultural models (Binford, 1962; Trigger 2003). Unlike culture-historical paradigms, ancient human populations were believed to possess the ability to adapt and change themselves, rather than change being driven by external forces including migration and population replacement (Binford 1968). However, as migration could not be universally applied to explain or predict change, processualists ignored or even abandoned migration studies for decades (Adams et al. 1978; Burmeister 2000; Chapman and Hamerow 1997).

Processualism was contested beginning in the 1980s by *post-processualists* who argued that processual attempts to construct broad, overarching theoretical frameworks were futile, as these interpretations are inherently subjective and biased by the worldview of the archaeologist (Hodder 1982, 2004; Miller and Tilley 1984; Trigger 2006). In particular, post-processualists bemoaned the loss of agency at the expense of reliance on universal paradigms sought by processualists and contended that archaeological data should be heavily contextualized to the specific individuals and groups under investigation (Barrett 2012; Hodder 2004). While these tenets could have opened the door for migration to return as a meaningful topic of study, migration was largely ignored by post-processualists as well (Burmeister 2016; van Dommelen 2014).

Migration continued to be overlooked by American and British archaeologists until Anthony (1990), who maintained that archaeologists recognize the importance of migration but have not approached it effectively, leading to avoidance of the topic. He asserted that while identifying migration archaeologically would require the development of methodological frameworks, archaeologists must focus on the structural conditions within which migration occurs and not on methods or the complex causes of migration (not everyone agreed with this assessment; see, e.g., Chapman and Dolukhanov 1992). The recognition that motivations for migration in prehistory likely extended beyond the economic and into the ideological made it all the more prudent to focus on structure over cause (Anthony 1990). Ten years later, Burmeister (2000) encouraged archaeologists to utilize theory as a means to better understand human migratory behaviors. Nevertheless, while archaeologists since that time have shown more interest in the topic, there is no "integrated theory" for migration (Cabana 2011, p. 25). Similarly, van Dommelen (2014, p. 479) argued that "archaeological understanding of migration as a 'multilayered process' is practically non-existent," and that more emphasis has been placed on simply identifying migration in the past rather than on its underlying motivations and consequences (see also Burmeister 2000).

Conversely, among archaeologists of continental Europe, ongoing culture-historical paradigms have served to preserve migration as an explanatory framework for change (Burmeister 2000, 2016). For many, this model has changed little since its inception and continues to fall into Kossinna (1911)-esque tropes that make oversimplified connections based on assumptions that material culture can be directly equated with biologically homogeneous populations represented as discrete cultural groups (Furholt 2018; Heyd 2017). Other European scholars have employed

more complex and holistic frameworks that, while still grounded in culture-history, interject elements of processualism and post-processualism to better socially and structurally contextualize spatial distributions of and diachronic changes to material culture (Anthony 2007; Furholt 2019a; Kristiansen 1989; Kristiansen et al. 2017). Recent advances in ancient DNA (aDNA) analyses have particularly revitalized migration studies, as these data can be linked to associated archaeological, biological, and linguistic evidence at scales ranging from the individual (e.g., Frei et al. 2015) to interactions between broader communities and populations (e.g., Allentoft et al. 2015; Haak et al. 2015; Kristiansen et al. 2017). Nevertheless, simplified interpretations of aDNA datasets risk falling back into outdated culture-historical frames of reference in which migrations are viewed as large-scale, single events composed of biologically closed populations driven by collective agency (Furholt 2018). Instead, care must be taken to recognize migration as a heterogeneous and complex social process best interpreted through engagement with anthropological theory (Anthony 1990; Burmeister 2000; Furholt 2018).

Migration Theory and Bioarchaeology

As Baker and Tsuda (2015) point out, it is rare for discourse to occur between scholars who investigate past and present mobility, largely because it is assumed that the impetus, process, and effects of migration today differ markedly from those in prehistory. Yet considerable potential exists for these ideas to instigate new and more holistic ways of thinking about mobile behaviors. As migration is inherently a dynamic social process (Anthony 1997), some aspects of anthropological and archaeological theoretical frameworks may be complementary and of value to bioarchaeologists, whose own work is predicated on human social behaviors being "written" into bone (e.g., Agarwal and Glencross 2011). For instance, Anthony (1990) contends that we must focus on the structural conditions impacting migration. In this sense, bioarchaeology is uniquely suited to tackling such an assessment; while archaeological evidence might be lacking, indicators of mobility and migration have been embodied in the skeletons of those individuals acting within the confines of societal structures. At the same time, Greenblatt (2010, p. 251) argues that "mobility studies should account…for the tension between individual agency and structural constraint." As bioarchaeology allows us to examine the individual and social circumstances surrounding biological changes incorporated into bone, skeletons act as a direct link to past peoples performing (or coerced into) migratory behaviors.

These concepts form the core of embodiment theory, in which the body is thought to biologically inscribe the environmental and social influences enacted upon it over the course of an individual's life. This perspective enables bioarchaeologists to more directly explore the lived experiences of individuals due to the plasticity of the skeleton and its ability to respond and adapt to its biosocial surroundings (Joyce 2005; Larsen 2018; Sofaer 2006). In this way, the bodies of migrants are irreversibly affected by movement, place, and space, and subsequently manifest home, journeyed, and destination environs (Campbell and Crawford 2012) in ways that may be accessible to bioarchaeologists. Embodiment is therefore essential for accessing

the identities of migrants who may have been socially marginalized or otherwise archaeologically obscured, including non-elite, female, nonadult, elderly, disabled, and queer bodies (Boutin and Porter 2019; Byrnes and Muller 2017; Geller 2017; Gravlee 2005; Joyce 2005; Lucy 2005; Sofaer 2006). By accessing such identities, bioarchaeologists can reach a more meaningful understanding of the motivations behind past mobility and migration (Tung 2012) that may vary among different segments of society.

Incorporating anthropological theory and bioarchaeology is mired with numerous challenges, as many economic anthropological paradigms have been constructed around capitalist-driven observations of modern migration behaviors and patterns (Horevitz 2009) and thus may not translate fully into precapitalist sociopolitical structures characteristic of past cultures (e.g., see Lamberg-Karlovsky 2009; Ratnagar 2001). Nevertheless, drawing at least partially from these frameworks may enable archaeologists to more effectively explore the manifold motivations for and consequences of migration. In particular, bioarchaeologists can incorporate transnational frameworks to better assess the identities of migrants using the human skeleton, elucidating not just the demographic aspects (sex, age) of those on the move, but also more complex social attributes (e.g., gender, ethnicity) that play into the impetus and outcomes of migratory behaviors (e.g., Frieman et al. 2019). Such markers of individual and social identity are critical pieces of information within transnationalist perspectives, which characterize the borders traversed by migrants as fluid but concurrently as powerful symbols that enforce status and value (Horevitz 2009; Kearney 2004).

Because a person's social value may decrease after crossing borders (Horevitz 2009), structural violence may similarly be visible in skeletal markers on migrant bodies. Structural violence refers to the normalized harm embedded within and sanctioned by socioeconomic and political structures inflicted upon both individuals and groups, with those most commonly affected belonging to the most vulnerable factions of society (Farmer 2004; Galtung 1969). While such harm may be directly observed as physical violence in the form of traumatic injury (de la Cova 2012, 2017), indirect harm may also be assessed, reflected as long-term, systemic stress across the skeleton (Klaus 2012; Nystrom 2014). This approach offers a particularly useful means to bioarchaeologically assess forced migrations, as coerced mobility may not simply involve physical injury but also endemic physiological or nutritional stress (e.g., Laffoon et al. 2018).

Observations of skeletal markers may similarly reveal changes tied to shifting chronological and social age alongside migration. Known as life course theory, this framework refers to the diachronic examination of experiences that together form the life of an individual, embedded within their particular sociohistorical contexts (Agarwal 2016; Agarwal and Glencross 2011). As human growth and development is continuously shaped by biological, social, and environmental pressures, the trajectory of the life course may correspondingly change as individual developmental plasticity enables variable adaptations dependent on endogenous and exogenous surroundings (Agarwal 2016; Halfon et al. 2014). Subsequently, age-specific patterns of nutrition, health, trauma, stress, or activity can reveal social meanings and behavioral differences behind chronological

age, made possible by the accumulation of shared, learned developmental experiences and constraints (Halfon et al. 2014; Sofaer 2011a, b). As human skeletal tissues form at different times throughout an individual's life, longitudinal data on mobility patterns and its relationship to age of tissue formation—particularly with the ability of biogeochemical signatures from teeth and bone to explicate past geographic residence through life—may concomitantly reveal important information about the ways in which past peoples adapted to environmental and social circumstances and allow bioarchaeologists to better reconstruct the lives of migrants.

The intersection of gender theory in both cultural anthropology and archaeology with transnationalism also provides fruitful ground for bioarchaeologists to meaningfully contribute to migration theory. Gender theorists in cultural anthropology have long recognized the complexities of gender identity formation and negotiation for female migrants, particularly as they must navigate between numerous gender roles across the varying social and spatial environments they inhabit, ranging from small scale (e.g., the individual body) to broader scales of being and interaction (e.g., family, state) (Mahler and Pessar 2001; Pessar 2003). In this way, both male and female migrants may maintain, question, or even reshape gendered hegemonic systems, a process of change that in some cases is instigated by mobility (Pessar and Mahler 2003). Archaeologists interested in gender roles are necessarily limited to material culture to extract the complexities of gender dynamics among past peoples that played out in social structures ranging from subsistence strategies to exchange systems. Nevertheless, as we introduce our own sets of assumptions about task-differentiated, gendered divisions of labor, we must work to avoid perpetuating stereotypes when we characterize the gender roles and structures of communities under archaeological investigation (Conkey and Spector 1984).

In contrast, bioarchaeologists work directly with those bodies that were shaped by gendered social structures, which offer a rich source of information spanning the life course when supplemented by archaeological findings (Geller 2009; Sofaer 2006). Tied to both structural violence and embodiment, "gender theory in bioarchaeology is not about adding discussions of sex or gender into the conversation, but about disentangling our current cultural frameworks of sex/gender roles" (Stone 2020, p. 54). Although bioarchaeologists are equally susceptible to introducing bias into their interpretations of skeletal markers, enhanced recognition of such preconceptions, including moving beyond assumptions of sex and gender binaries (e.g., Geller 2008; Moral 2016) and acknowledging the impact of intersecting gender, ethnic, sexual, and/or class identities on the body (Geller 2017; Kjellström 2014; Torres-Rouff and Knudson 2017; see also Cho et al. 2013; Crenshaw 1991; McCall 2005), can lead to productive assessments of the role of gender among migrants in the archaeological record. These insights can also help bioarchaeologists identify diachronic changes to gender roles and identity as a direct result of migrations and better evaluate the ability of past individuals to engage in mobility in the first place based on gender and other intersecting identities (Cresswell and Uteng 2008; Frieman et al. 2019; Subramanian 2008). In this way, bioarchaeologists have the potential to bridge the gap between anthropological theory and archaeological evidence for mobility and migration.

Contributions of Bioarchaeology to Mobility and Migration Studies

Despite anthropological observations of a complex continuum of temporary and long-term mobile and migratory behaviors, identifying these movements in the archaeological record remains a challenge. This is largely due to our inability to detect short-term or small/subgroup mobility archaeologically, as these behaviors rarely generated detectable forms of material culture or substantial changes to residential camps or settlements (Adams et al. 1978; Anthony 1990; Burmeister 2000; Cabana and Clark 2011; Tsuda et al. 2015). Conversely, large-scale or long-term migration in the past necessarily produced more considerable, perceptible changes to the archaeological record, particularly if significant boundaries (sociocultural, political, economic, ideological) were traversed (Burmeister 2000; Cameron 2013; Clark 2001; Tsuda et al. 2015). Nevertheless, though more archaeologically visible, major migrations occurred only infrequently relative to the commonality of localized mobility (Cabana and Clark 2011; Cameron 2013).

Because of this issue, it has long been thought that archaeologists cannot adequately recognize small-scale mobility or, in some cases, even larger-scale migratory movements that took place without accompanying, significant shifts in cultural remains. Even with the presence of material culture seemingly indicative of mobility, it remains difficult to tease apart whether foreign goods were simply traded across long distances or if local imitations were produced as part of cross-cultural emulation strategies (Rouse 1986; Stein 1999). As a result, the vast majority of human movement in the past is obscured from view, representing an important yet largely invisible aspect of human behavior and social organization among ancient populations. To overcome these challenges, we must pursue innovative ways of approaching mobility and migration using interdisciplinary perspectives and by developing new techniques that advance traditional anthropological approaches. Bioarchaeology in particular holds great potential for facilitating research on human movement and has been at the forefront of mobility research.

Bioarchaeology is well suited to examining mobile behaviors among past human groups by taking a fundamentally different perspective of scale than archaeological approaches. Bioarchaeologists (initially) collect data at the level of the individual (Agarwal 2016), while archaeologists generally examine the past at the community level, extrapolating evidence using archaeological features and material culture typically disassociated from specific persons and instead viewed as broadly representative of the collective. From bioarchaeological data come the compilation of individual life histories that document a detailed bionarrative from infancy into childhood and later adulthood (Zvelebil and Weber 2013). This osteobiographical perspective lends itself to examining smaller-scale movements undertaken throughout the life course (Hosek and Robb 2019; Stodder and Palkovich 2012). Moreover, the recognition of variations in mobility between individuals of the same community has the potential to identify intrasocietal, subgroup movements (e.g., logistical mobility, transhumance) previously unrecognized in archaeological groups (e.g., Bentley and Knipper 2005; Gerling et al. 2012).

Bioarchaeologists then assemble individual data points to construct more generalized patterns regarding diet, health, activity patterns, relatedness, and overall lifestyle within and across communities, populations, and generations as skeletal data are contextualized within the broader archaeological record. In this way, bioarchaeologists may recognize not only short-term or temporary mobility but also differentiate these movements from larger-scale migratory relocations. Bioarchaeologists subsequently rely heavily on group-level data produced by archaeologists to better frame biological evidence.

Addressing Migration in the Bioarchaeological Record

Numerous methodological approaches are used by bioarchaeologists to better evaluate the embodiment of mobility and migration among past populations. These approaches include body modification (cranial, dental, and infra-cranial), ancient DNA analyses, biodistance (craniometric, dental metric, and cranial and dental nonmetric trait) analyses, and radiogenic and stable isotope analyses.

Body Modification

Body modification among ancient peoples was a strategic, symbolic act in which individuals chose to permanently refashion their own (or others') physical bodies, not only for aesthetic purposes but to convey social meaning (Agarwal and Glencross 2011; Joyce 2005; Sofaer 2006). Through the intentional manipulation of one's biological form, an individual could display their belonging to a particular ethnic, kin, or status group, often in highly visible and unalterable ways. As group affiliation and social identity can be tied to the overt shaping of body parts by means of embodiment (Geller 2009; Joyce 2005; Meskell and Joyce 2003), it follows that those moving to new regions might exhibit modified skeletal features distinct from that of the local population, enabling bioarchaeologists to identify potential migrants.

Cranial Modification

The transformation of the head is perhaps the most studied form of body modification. Purposefully inflicted, socially sanctioned practices that reshaped the human skull have been observed cross-culturally over at least 13,000 years of human history (Zhang et al. 2019). The practice necessitates the intentional application of persistent pressure to the cranial vault during early childhood, typically using a combination of straps, pads, and/or boards secured at particular angles to encourage the redirection of skull development and eventual permanent modification (Antón 1989; Blom 2005; Tiesler 2014).

Parents or other caregivers, and not the young child who underwent these long-term procedures, would have been the primary drivers controlling the ways that cranial modification was carried out (Torres-Rouff 2020). This decision was not made in isolation but was instead driven by societal norms and power relations negotiated

in complex ways by and between community members. The end result of these negotiations was an intentionally shaped head that may have acted as a rite of passage to formally and symbolically initiate children as fully fledged members of the community or to protect a newly "ensouled" infant (Duncan and Hofling 2011, p. 203; Geller 2011; Tiesler 2014; Tiesler and Zabala 2017), or it may have delineated complex social affiliations including kin relationships, ethnicity, economic status, or social standing (Blom 2005; Hoshower et al. 1995; Lozada 2011b; Torres-Rouff 2002; Zhang et al. 2019). This forced assertion of social identity—physically inscribed onto the bodies and bones of these individuals and carried throughout the life course – would have been a powerful identifier for those migrating across sociocultural and political boundaries as they encountered other populations with unmodified skulls or different forms of cranial modification.

Dental Modification

Dental modification was a geographically and temporally widespread practice undertaken by many different cultural groups over thousands of years (Alt and Pichler 1998; Milner and Larsen 1991). Dental modification refers to the deliberate, non-therapeutic changes made to one or more teeth to alter crown morphology (via filing or notching), enamel color (dyeing), or tooth number (ablation), as well as to embed decorative elements into the labial surface (inlays) (Burnett and Irish 2017). In most cases, dental modification targets permanent anterior teeth, often with a focus on the more conspicuous maxillary dentition (Burnett and Irish 2017). Correspondingly, this practice was thought to signify aesthetic modification associated with culturally specific beauty standards, as a means of preventing harm or illness, or more symbolically and ideologically as an explicit marker of maturation (rite of passage), occupation, social status, gender identity, or group/ethnic/kin affiliation (Geller 2006; Larsen 2017; Mower 1999; Tiesler et al. 2017; Willman et al. 2016) that may distinguish locals from nonlocals as part of processes tied to mobility or migration.

Infra-Cranial Modification

Infra-cranial aspects of the skeleton may similarly be altered in response to culturally induced reshaping, which typically begins at a young age. Clinically and bioarchaeologically recorded alterations are largely confined to the manipulation (and hence, submission and ideological domination) of female bodies, including modifications to the neck (e.g., Chawanaputorn et al. 2007; Keshishian 1979), torso (Gibson 2015, 2017; Groves et al. 2003; Stone 2012), and feet (Berger et al. 2019; Cummings et al. 1997; Lee 2019). In addition to chronic pain and other complications, these practices served to *reduce* mobility among those whose bodies were reshaped; as such, it may be unlikely that infra-cranial skeletal modifications would act as productive indicators of movement among past individuals except under unusual circumstances.

Ancient DNA Analyses

In the last decade, ancient DNA (aDNA) analyses of human skeletal tissues have played an increasingly important role in investigations of migration among past populations, both in identifying individual migrants as well as revealing broader forms of interaction and movement between populations across wide geographic expanses (Nieves-Colón and Stone 2019). Ancient DNA refers to genetic material obtained from the cellular remains of dead organisms that is extremely degraded, fragile, and scarce (Raff 2019), with endogenous DNA typically comprising less than 1% of a sample extract (Pinhasi et al. 2015). Degradation occurs because of postmortem environmental conditions affecting these biomolecules, including temperature, humidity, soil and groundwater pH, exposure to oxygen or water, and microbe activity (Burger et al. 1999; Lindahl 1993; Misner et al. 2009; Smith et al. 2003), and because cells in a deceased organism are no longer capable of DNA repair (Raff 2019). This results in fragmented and chemically altered DNA (Briggs et al. 2007; Nieves-Colón and Stone 2019; Sawyer et al. 2012).

Nevertheless, under particular environmental conditions, fragments of endogenous DNA can remain preserved for thousands or even tens of thousands of years (Goodwin 2014; Lindahl 1993). Survival is enhanced by cooler temperatures and drier, anoxic conditions (Smith et al. 2003), as well as by the structure of skeletal tissue itself. The extraction of aDNA fragments is more often successful from dense cortical bone such as the petrous portion of the temporal, which can produce high aDNA yields, sometimes even in tropical environments (Gamba et al. 2014; Pinhasi et al. 2015).

Two different kinds of genetic material may be analyzed as part of aDNA studies of human skeletal remains. First, maternally inherited and haploid mitochondrial DNA (mtDNA) has long been favored by bioarchaeologists and molecular anthropologists. This is because many mitochondria, and thus many more copies of mtDNA, exist within a single cell as opposed to only two copies of nuclear DNA, making costly and labor-intensive recovery attempts more productive (Goodwin 2014; Nieves-Colón and Stone 2019; Raff 2019). The relative abundance of this type of aDNA, coupled with higher mutation rates and the absence of recombination, can reveal aspects of female-driven migration (e.g., exogamous marriage practices) and ensuing gene flow among populations in the past, which in turn may expose broader patterns of social organization shaped by mobility (Goodwin 2014; Nieves-Colón and Stone 2019). While a second genome, nuclear DNA, is present in far fewer numbers per cell and subsequently had been less successfully extracted and amplified in the past, recent advances in protocols surrounding decontamination and authentication, extraction, and sequencing (particularly next generation sequencing, or NGS) have now made this biparentally inherited genetic material more accessible to anthropologists (Nieves-Colón and Stone 2019; Raff 2019; Rohland and Hofreiter 2007; Shendure and Hanlee 2008). Additionally, like mtDNA, most of the Y chromosome (part of the nuclear DNA genome) does not undergo recombination, and although mutation rates are lower than in mtDNA, its polymorphisms can still be used to investigate male-based migrations and resultant admixture among ancient communities (Nieves-Colón and Stone 2019).

Prior to the advent of NGS, aDNA analyses involved the targeted sequencing of single loci for polymorphisms, or sites of genetic variability, with a focus on single nucleotide polymorphisms (SNPs) and short tandem repeats (STRs, also known as microsatellites) (Goodwin 2014). SNPs refer to common genetic variations at the level of the nucleotide resulting from DNA replication error and vary by around 85% between individuals (Goodwin 2014; Nieves-Colón and Stone 2019). STRs, on the other hand, are short allele sequences repeated in variable numbers between different individuals (Goodwin 2014). Recent technological advances associated with NGS now permit genome-wide analyses of SNPs as well as complete genome analyses, thereby enabling bioarchaeologists to ask more complex questions about kinship, admixture, and migration by examining numerous loci (Nieves-Colón and Stone 2019; Raff 2019). Consequently, aDNA analyses have revolutionized how we identify and assess ancestry and human movement. Nevertheless, caution must be taken in the interpretation of these data, which should be contextualized by associated archaeological and bioarchaeological evidence and strengthened by theory-driven anthropological perspectives.

Biodistance

Biological distance, or biodistance, analyses involve the measurement and/or morphological assessment of observable features of the skeleton, especially those pertaining to the cranium and dentition (Hefner et al. 2016). Following two assumptions—namely, that over time, populations exchanging genes become more genetically similar to one another, and that observed skeletal phenotypes are heritable and largely reflective of underlying genetic information—groups possessing similar metric and nonmetric traits engaged in gene flow as a result of interaction and migration, were more likely to share common ancestors, and are thus more closely related to one another than to others with more dissimilar means or trait frequencies (Larsen 2015; Relethford 2016; Stojanowski and Schillaci 2006). While phenotypic expression of these traits is thought to reflect both heritability and environmental influence, it is postulated that environmental impacts are generally slight and that these traits are primarily controlled by genetics (Cunha and Ubelaker 2020; Stojanowski and Schillaci 2006). This assumption has been corroborated by studies comparing population affinity data generated by nuclear or mitochondrial DNA with skeletal measures of biodistance (e.g., Herrera et al. 2014; Hubbard et al. 2015; Relethford 2004; Smith et al. 2016). While no trait is restricted to a single population, analyses of particular trait clusters can identify probable biological affinity (Cunha and Ubelaker 2020). Consequently, bioarchaeologists can use biodistance analyses to evaluate past mobility and migration through population interaction, and beyond this, better assess the formation and negotiation of ethnic or community identities.

Craniometrics and Dental Metrics

Craniometric and dental metric analyses rely on multivariate statistics to evaluate measurements taken on the skull and teeth (Dudzik and Kolatorowicz 2016; Hefner et al. 2016). As metric traits represent continuous and not ordinal variables, they are

generally considered a more objective means of assessing biological affinity between and among populations (Cunha and Ubelaker 2020). For the skull, bioarchaeologists rely on documented differences in facial and vault shape between human groups, as populations displaying similar craniofacial morphology are assumed to be more closely related (Buikstra and Ubelaker 1994). Measurements are taken using calipers between defined cranial landmarks (Howells 1973, 1989, 1995, 1996; see also Buikstra and Ubelaker 1994). For teeth, typical measures include buccolingual (crown width) and mesiodistal (crown length) dimensions, although definitions on how to take these measurements vary (e.g., Hefner et al. 2016; Kieser 1990; Moorrees and Reed 1964). Additional measurements outside of conventional buccolingual and mesiodistal distances have also been proposed (e.g., see Hillson et al. 2005).

Cranial and Dental Nonmetric Traits

Nonmetric traits refer to nonpathological features of the skeleton that are not quantified metrically but instead are assessed qualitatively through morphological observation (Pink et al. 2016). These traits may involve reduced or failed bone formation (hypostotic) or, conversely, excess deposition of bone (hyperostotic) (Ossenberg 1970). Such skeletal variants can manifest as variable numbers of foramina, the presence of accessory ossicles or persistent sutures, and ossification anomalies (Buikstra and Ubelaker 1994). Many of these traits vary along a quasi-continuous or ranked scale (e.g., 0–7) and are subsequently scored based on expression (Scott and Turner 1997). Other nonmetric traits are discrete in nature, meaning that they are scored not along a gradient but are simply described as either present or absent (Cunha and Ubelaker 2020). As with measurements taken on the skull and dentition, patterns of particular cranial and dental nonmetric traits are thought to reflect population affinity. Correspondingly, groups sharing higher frequencies of nonmetric variations are assumed more likely to have engaged in sustained gene flow stemming from mobility or migration and are thus more closely related to one another. In particular, dental nonmetric features are considered to be under tighter genetic control (Scott and Turner 1997), perhaps even more so in deciduous than permanent teeth (Paul and Stojanowski 2017). Because these traits appear relatively unaffected by sex or age, they are especially useful for assessing affinity among commingled assemblages in which individualized demographic information may not be forthcoming (Scott and Turner 1997). The phenotypic expression of polygenic cranial nonmetric traits is more complex, with variable heritability reported (Carson 2006; Falconer 1989; Sjøvold 1984). Nonmetric phenotypic features for crania (Buikstra and Ubelaker 1994; Hauser and De Stefano 1989; Ossenberg 2013) and dentition (Scott and Turner 1997; Turner et al. 1991) number in the hundreds and have been described in detail in the aforementioned references.

Infra-cranial Nonmetric Traits

Far fewer studies have focused on infra-cranial (or post-cranial) nonmetric traits than on cranial and dental morphology (Cunha and Ubelaker 2020; Hefner et al. 2016). This is because they are likely influenced not only by heritability but also by

sex, age, diet, and function, particularly as many of these bones are weight bearing and thus shaped by biomechanical forces (Buikstra and Ubelaker 1994; Stojanowski and Schillaci 2006; Wescott 2005). Greater promise for the utility of infra-cranial features may be found in intra-cemetery approaches to biodistance analyses, which rely on anomalous congenital conditions or otherwise uncommon traits (Barnes 1994, 2012; Stojanowski and Schillaci 2006). Nevertheless, as the majority of these traits occur in less than 2% of a typical human population and are often found on less-studied skeletal elements (e.g., hands, feet), fewer biodistance studies have been performed on the infra-cranial skeleton (but see Case et al. 2017). As such, while worthy of additional analyses, they are not discussed further here.

Radiogenic and Stable Isotope Analyses

Radiogenic and stable isotope analyses of skeletal remains facilitate investigations of mobility among past populations by relying on atoms incorporated into human tissues whose isotope ratios have particular geographic provenience made unique by natural, regional variations in local geology or hydrological systems. As skeletal tissues variably form and remodel at different ages, bioarchaeologists can use isotopes integrated into teeth and bone to track patterns of movement across the life course for an individual. From the sampling of multiple individuals, these isotopes subsequently permit the recognition of broader trends of mobility and migration across particular segments of society, including sex, gender, age, status, or occupation-based groups, or even patterns of movement involving entire communities.

The complexities of biogeochemical sampling of human skeletal tissues highlight an important methodological issue because of their potential impact on how human mobility and migration are evaluated and interpreted. For instance, while bulk samples from enamel and bone yield isotopic values that represent a long-term average derived primarily from foodstuffs and drink consumed during a years-long period of tissue formation, microsampling of skeletal tissues offers a potential avenue for more acute assessments of human movement in the past. Nevertheless, applications of intra-tooth sequential sampling using human enamel hydroxyapatite are few in number (e.g., Holt 2009; Lovell and Dawson 2003; Sandberg et al. 2012; Wright 2013), as the complexities of amelogenesis and enamel maturation coupled with fluctuating mineralization rates between enamel layers produce isotopic values reflective of longer-term averages rather than precise snapshots of short-term behavior (Balasse 2002; Balasse et al. 2002; Fisher and Fox 1998; Hillson 1996; Montgomery et al. 2010b; Passey and Cerling 2002; Sandberg et al. 2012; Suga 1979; Suga et al. 1979). Instead, discerning intra-individual diachronic change in movement may be better accomplished through bulk sampling of multiple tissues with established formation and remodeling rates for a single individual (Dupras and Tocheri 2007; Gregoricka 2014; Jørkov et al. 2009; Knudson et al. 2016; Sealy et al. 1995), tying into developmental frameworks associated with life course theory.

Despite issues related to diagenesis, well-preserved bone hydroxyapatite may offer an alternative means by which microsampling may more successfully be accomplished relative to enamel. Bone too forms incrementally, and while

continuous remodeling had previously led to the assumption that serial isotopic sampling of bone would not yield discrete, chronological data points useful for developing individual life courses (Bromage et al. 2009; Maggiano et al. 2019), more recent research suggests that unremodeled "pockets" of incremental layers of primary lamellar bone persist for many decades, thus holding considerable potential for revealing short-term patterns of mobility using high-resolution sampling (C. Maggiano et al. 2015; I. Maggiano et al. 2011, 2015). Additional work has been conducted on incremental dentin collagen sampling to discern short-term changes in diet and stress (e.g., Beaumont and Montgomery 2016; Craig-Atkins et al. 2018; Eerkins et al. 2016; Greenwald et al. 2016) and may hold some future potential for shedding light on mobility practices involving juveniles, as sudden changes in dietary intake (measured through carbon and nitrogen isotope values) could be indicative of their involvement in movement and the resultant consumption of isotopically different foods.

Radiogenic Strontium Isotopes

Strontium isotope ratios ($^{87}Sr/^{86}Sr$) provide a now-common bioarchaeological measure of human movements across the globe. Strontium-87 varies in regional abundance relative to the stable isotope ^{86}Sr, due primarily to underlying geologic differences in mineral age and type but also contributions from exogenous sources (Bentley 2006; Ericson 1985). Weathered bedrock releases strontium into surrounding soils and groundwater; due to its high atomic mass, $^{87}Sr/^{86}Sr$ ratios do not fractionate and pass unaltered into local plants and animals and, through their consumption, into humans (Beard and Johnson 2000; Graustein 1989; Hurst and Davis 1981; Price et al. 1994). Consequently, $^{87}Sr/^{86}Sr$ ratios derived from human teeth or bone that differ from regionally bioavailable strontium may be indicative of mobility or migration event(s) at different stages of the life course prior to death and interment.

Stable Oxygen Isotopes

Stable oxygen ($\delta^{18}O$) isotopes incorporated into human skeletal tissues reflect the geographic area in which these isotopes were ingested, enabling bioarchaeologists to assess past human movements. Regional differences in the amount of bioavailable oxygen isotopes from local meteoric and surface water ($\delta^{18}O_w$) derive from a composite averaging of multifaceted environmental contributors including air temperature, humidity, latitude, distance from the sea, and altitude (Dansgaard 1964; Gat 1996; Longinelli 1984; Luz and Kolodny 1985; Luz et al. 1984). Additional natural phenomena similarly affect local $\delta^{18}O_w$ values in complex ways, ranging from flowing rivers to evaporation and seasonal fluctuations in precipitation (Knudson 2009; Price et al. 2010). Human $\delta^{18}O$ body water values, in turn, are obtained primarily from the liquids that people drink, although other metabolic processes (Bryant and Froelich 1995; Kohn 1996; Longinelli 1984; Luz and Kolodny 1985; Luz et al. 1984) and cultural practices (Brettell et al. 2012; Knudson 2009; Lisowska-Gaczorek et al. 2020; Price et al. 2010) may also influence these values.

Other Isotopes

While strontium and oxygen isotopes are by far the most ubiquitous biogeochemical measures of mobility in the bioarchaeological literature, analyses of other isotopes may also contribute to discussions of past human movement. Like strontium, radiogenic lead isotope ratios (in bioarchaeology, primarily $^{206}Pb/^{204}Pb$, although many other ratios including $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ can also be evaluated) are found naturally in the underlying geology and vary regionally (Faure 1986; Komárek et al. 2008), which permits assessments of human mobility among past groups (Gale 1989; Gulson et al. 1997; Montgomery et al. 2000; Samuelsen and Potra 2020). However, some debate has arisen regarding whether these isotopes primarily become incorporated into human tissues through the consumption of food and water or, given the reduced ability of the body to absorb lead alongside food, if soil/dust inhalation and ingestion provide a more likely means by which these heavy isotopes are introduced (Kamenov 2008; Maddaloni et al. 1998; Turner et al. 2009; Underwood 1977). Moreover, measures of mobility based on geologic outputs are only effective when sampling pre-metallurgical populations, as societies with culturally induced lead exposure no longer possess ratios reflective of geographic residence, but cultural residence instead (Montgomery et al. 2005, 2010a). Such "cultural focusing" can be a useful means by which to distinguish occupational, status, or ethnic/cultural groups, as well as the presence of nonlocal migrants with differential exposure to lead isotopes (Montgomery et al. 2005, p. 135; Montgomery et al. 2010a). Similarly, stable carbon and nitrogen isotopes from bone collagen—traditionally used to evaluate dietary intake—have been employed as a supplementary measure of mobility, based on the premise that differential access to or cultural preferences for certain foods can support the identification of migrants and more broadly assist with investigations into group mobility, membership, and social identity (Cox and Sealy 1997; Gregoricka 2013b; Gregoricka et al. 2020; Sealy 2006).

The Bioarchaeology of Mobility and Migration in Action

Social and Ethnic Identities

Bioarchaeological studies have important implications for better understanding ties between social identity and migration in the ancient world. As encapsulated by embodiment theory, social identities may impact individuals biologically and can thus be inscribed onto skeletal remains (Joyce 2005; Sofaer 2006), acting as useful indicators of group membership among past populations where mobility or migration is suspected to have contributed to the overall composition of a community. It follows that the skeletons of those engaging in migration manifest these journeys as well as subsequent biological and social adaptations to their new location (whether temporary or permanent). This perspective is especially valuable when identifying local peoples as well as nonlocal migrants using bioarchaeological methods, as these discoveries may reveal particular ethnic cohorts within past communities.

Ethnicity has been variably defined by anthropologists. Generally, ethnic identity is based on real or fictive shared ancestor(s) (Jones 1997; Knudson and Stojanowski 2008) and/or defined by economic or social boundaries that determine membership and which must be continuously reaffirmed (Barth 1969). Under some conditions, ethnic groups may represent the most vulnerable or socially marginalized within the larger population, thus facilitating an examination of those who may otherwise be archaeologically invisible (Geller 2017; Joyce 2005; Sofaer 2006). In other cases, agential migrants may actively drive change in their post-migration residence, reshaping the social identities of those local to the region and even redefining the ways in which ethnicity and group membership are perceived. Zakrzewski (2011) sought to examine ethnicity and ethnic identity among those buried in a medieval Islamic cemetery (8th–11th century AD) in Ecija, Spain, hypothesizing that these individuals likely made up a biologically heterogeneous group composed not only of locals but possibly invading Berbers and Arabs from North Africa and the Middle East who conquered the region in the eighth century. After measuring 122 crania from both males and females, she found considerable craniometric variability at Ecija relative to comparative groups from Africa and Europe, suggestive of genetic heterogeneity characteristic of a diverse population whose inhabitants demonstrated biological affinities to populations on both continents. Zakrzewski (2011) concluded that the Arab conquest of Iberia best explains the observed diversity at the site, but correspondingly, that the expansion of Islam into the region may have served as a unifying factor in identity construction that overrode other biological or social aspects of identity as part of a complex intermingling of migration, religion, and conquest.

Additionally, Blom (2005) examined cranial vault modification among southern Andean populations (AD 500–1100) within the Tiwanaku sphere of interaction to assess mobility, group affiliation, and diversity among those inhabiting highland and lowland sites. She found that 100% of those with modification residing in lowland coastal regions (Moquegua Valley) exhibited the fronto-occipital style, while the majority (88%) of modified highland individuals in the Katari Valley (northeast of Tiwanaku) demonstrated the annular type. Situated between the two, the Tiwanaku Valley (including the capital city and large urban settlement of Tiwanaku) contained individuals exhibiting both styles in equal numbers (50% each). Blom (2005) interpreted these patterns as a sign of social and ethnic homogeneity among different regional populations outside Tiwanaku, likely a powerful means by which local identity was constructed and explicitly presented to convey cultural belonging. Conversely, diversity in vault shape at Tiwanaku suggests that this center represented a liminal and dynamic border area that drew diverse social groups who resided side by side and interacted with one another but, nevertheless, whose regional and ethnic identities were still clearly demarcated. Subsequently, bioarchaeological analysis of cranial vault modification revealed movement into the Tiwanaku core from both highland and lowland areas that traversed geographic borders but maintained social boundaries through the strong, tangible visuals of modified crania.

Nevertheless, these so-called markers of ethnic identity may have been a form of social mimicry in which those with less power attempted to emulate those with greater authority. For instance, Egyptian- and Nubian-style burials from Tombos in

ancient Nubia dating to the New Kingdom period (1550–1069 BC) revealed variable radiogenic strontium isotope ratios indicative of the presence of both locals and nonlocals (Buzon et al. 2007). Given Egypt's expansion into Nubia during this time, it was expected that both local Nubians and immigrant Egyptians had resided together at Tombos. Nevertheless, while some nonlocal strontium ratios were associated with burials using Egyptian features, a sizable number (n=31) of Egyptian-style burials contained individuals with local Nubian signatures. The authors subsequently interpreted these individuals as either the children of Egyptian migrants born and raised locally who would have incorporated local strontium ratios into their enamel, or as Nubians local to the area who were interred with Egyptian features (Buzon and Simonetti 2013; Buzon et al. 2007). This "Egyptianization" may have represented a highly visible means by which local Nubians established a relationship with the Egyptian administration and ruling elite, conveying their allegiances to the Egyptian empire even in death. More importantly, however, it illustrates how mortuary treatment can serve to maintain, negotiate, and manipulate the ethnic identities of deceased individuals and, in possibly mimicking the burial traditions of nonlocals, skew our interpretation of past migrations and subsequent interactions.

Similar issues may arise with a reliance on cranial modification as a strict measure of status or group identity. In evaluating the Omo M10 cemetery complex in the Moquegua Valley of southern Peru, Hoshower et al. (1995) proposed that those with lower socioeconomic status might have employed cranial modification to strategically confer social benefits to their children. Blom (2005), on the other hand, found no correlation between cranial modification and traditional measures of social status (ranging from grave goods to tomb architecture) within Tiwanaku society and instead linked cranial modification to group identity. Moreover, social norms of conformity may have prevented such cranial emulation from occurring in the first place, perhaps similar to strict edicts regarding donning Inca clothing and headdress specific to one's town, with punishment reserved for those who dressed outside these social boundaries (Blom 2005). Subsequently, it remains unlikely that imitations of body modification would have been undertaken despite the appeal to permanently link the bodies of one's children with those more ideologically, economically, or politically advantaged; instead, these modifications were likely socially policed by the local community in an effort to sustain internal boundaries (Torres-Rouff 2020).

Kinship Analysis and Postmarital Residence

Intra-cemetery (i.e., intra-site, or kinship) analyses, in which shared traits are thought to be indicative of a greater degree of relatedness between individuals, may enable bioarchaeologists to identify biological kin or family groups at a single site (e.g., Alt and Vach 1995; Stojanowski 2013) and, more pertinently to the bioarchaeology of migration, postmarital residence patterns (Lane and Sublett 1972; Pilloud and Larsen 2011; Stojanowski and Schillaci 2006). Despite the potential risks associated with migration, the sociopolitical or economic prospect of marriage may have been a significant motivating factor behind exogamous marriage among some past societies (Tung 2012). Such migratory practices, in conjunction with the ability of

bioarchaeologists to extract information about gendered behaviors, can shed light on engendered patterns of power and authority, inequality, socioeconomic status, and other socially differentiated and negotiated roles (Martin et al. 2013a; Pessar and Mahler 2003). Here, transnationalism and gender theory intersect, as these gendered mobility patterns are unlikely to be unidirectional. Instead, such patterns foster ongoing, long-term relationships between groups as part of broader social processes in which migrants continue to maintain relationships with their homeland (Brettell 2008, 2016; Glick Schiller 1995; Glick Schiller et al. 1992). Correspondingly, migrants must construct and navigate social identities influenced by both origin and post-migration cultures and environments, influences that indelibly affect skeletal remains.

Bioarchaeological approaches to kinship analysis and postmarital residence patterns more directly evaluate relatedness using the skeletons of the individuals who themselves may have migrated to a region as part of exogamous marriage practices, helping us avoid relying too heavily on oversimplified linkages between sex-specific grave goods and geographic origins or ethnic identity (e.g., Allen and Richardson 1971; Schillaci and Stojanowski 2003). The identification of nonlocals may not only reflect discernible patterns of matrilocality or patrilocality but, more broadly, speak to political and socioeconomic societal structures that have the potential to reveal complex intraregional social organization and interregional interactions (Schillaci and Stojanowski 2002). Nevertheless, while biological distance analyses necessarily rely on genetic relatedness to identify kin, this biological definition of affinity is decidedly Western and modern, and alternative, nonbiological kin structures (i.e., fictive kinship, fictive ancestry, social relatedness) may have held equal or greater importance among past populations (Gregoricka 2013a; Johnson and Paul 2016; Lozada 2011a; Meyer et al. 2012; Pilloud and Larsen 2011). Such relationships have been demonstrated in ethnographic work ranging from the *compadrazgo* of Hispanic communities (Foster 1953; Mintz and Wolf 1950) to the *!kun!a* (namesakes) of the Dobe !Kung (Howell 2017; Lee 1979, 2003), and have also been recognized among immigrant populations (Ebaugh and Curry 2000), LGBTQ+ communities (Weston 1991), and Black and White American families (Allen et al. 2011; Chatters et al. 1994).

Bioarchaeological evidence of postmarital residential mobility has been derived from craniometric and nonmetric analyses (e.g., Hubbe et al. 2009; Nystrom and Malcom 2010; Schillaci and Stojanowski 2003; Stefan 1999; Tomczack and Powell 2003; Velasco 2018), dental metric and nonmetric analyses (e.g., Alt et al. 1997; Cook and Aubry 2014; Prevedorou and Stojanowski 2017), and isotopic analyses (e.g., Bentley 2013; Bentley et al. 2005, 2012; Eerkins et al. 2014). At the coastal Early Bronze Age cemetery of Tsepi in Marathon, Greece, multivariate statistical analyses of cranial nonmetric variation as well as dental metric and nonmetric trait data revealed not only that the cemetery was organized into kin-specific areas with related females interred together, but that males exhibited more variation in cranial nonmetric traits than females, suggesting a postmarital residence strategy in which matrilocal females obtained male partners who migrated from other populations (Prevedorou and Stojanowski 2017). The authors contend that this practice of male exogamy in the Aegean may be explained by economics, as nonlocal males

could have driven interregional trade networks for local communities. Further, matrilocality was not uncommon in the region, particularly among island communities with economies dependent on maritime trade and subsistence (Prevedorou and Stojanowski 2017). Consequently, the cranial nonmetric biodistance analyses employed here demonstrate our ability to discern potential kin groupings and complex socioeconomic patterns of interaction and exchange (of goods *and* mates) instigated by migration, all of which provide critical insight into the maintenance and negotiation of social and biological identities.

Beyond phenotypic assessments of relatedness using biodistance analyses, aDNA analysis can also contribute in important ways to studies of kinship and postmarital residence using genotypic information (e.g., Alt et al. 2016; Amorim et al. 2018; Baca et al. 2012; Bolnick and Smith 2007; Cui et al. 2015; Drosou et al. 2018; Dudar et al. 2003; Haak et al. 2008; Knipper et al. 2017; Mendisco et al. 2018; Mittnik et al. 2019; Schroeder et al. 2019). At the Neolithic mortuary cave site of Treilles in Avreyon, France, nuclear DNA (including Y chromosome) and mtDNA successfully extracted from 29 individuals not only identified the presence of considerably more male burials than female but also revealed low Y chromosome haplotype diversity coupled with high diversity among mtDNA haplotypes (Lacan et al. 2011). These results suggest that males received preferential burial in the cave and that similar paternal lineages reflective of limited gene flow may indicate patrilocality (Lacan et al. 2011). This fits with the more diverse haplotypes exhibited among extracted mtDNA, indicative of the movement of females and not males as part of exogamous practices. These results were supported by later biogeochemical analyses of dental enamel, which revealed more variable radiogenic strontium isotopes ratios among Neolithic females than males both in France and across central Europe (Bentley 2013; Bentley et al. 2012). Together, these data establish the utility of aDNA analysis in identifying human movement and complementing other forms of bioarchaeological evidence for migration. More pertinently, this evidence highlights the role of female mobility as integral to maintaining Neolithic societal structures and cementing interregional alliances and economic networks.

Forced Migration and Enslavement

Bioarchaeological indicators of migration can offer valuable insight into not only mobility and subsequent social organization among communities in the past but also coerced movements and social control associated with enslavement (Blakey 2001; Harrod and Martin 2015). Such studies better contextualize the circumstances surrounding the lives and deaths of those captive or enslaved women, men, and children whose voices are rarely heard in historic records (Harrod and Martin 2015). In particular, bioarchaeology offers a direct means of assessing pathways of forced migration as part of broader investigations into the exploitation of enslaved or captive individuals. By ascertaining such pathways, theoretically grounded examinations of structural violence suffered by those forced to cross sociopolitical or cultural borders can commence, including subsequent

investigations into both physical violence and long-term stress (de la Cova 2012, 2017; Farmer 2004; Galtung 1969; Horevitz 2009; Klaus 2012; Nystrom 2014).

Previous studies have attempted to track coerced movements and the geographic origins of such individuals using radiogenic and stable isotopes (e.g., Bastos et al. 2016; Cox and Sealy 1997; Goodman et al. 2009; Laffoon et al. 2018; Price et al. 2006, 2007; Schroeder et al. 2009; Tung and Knudson 2011; White et al. 2000, 2002), dental modifications (e.g., Handler et al. 1982; Schroeder et al. 2014; Tiesler 2002; Wasterlain et al. 2016), biodistance analyses (e.g., Coelho et al. 2017; Wasterlain et al. 2016), and aDNA analyses (e.g., Barquera et al. 2020). For example, skeletons recovered from an area of urban disposal dating to the 15th–17th centuries AD in Lagos, Portugal, were accompanied by ornaments suggestive of African origins (Wasterlain et al. 2016). Observations of tooth modification in which the mesial and distal angles of both maxillary and mandibular incisors and canines were filed were akin to techniques practiced in sub-Saharan Africa, a supposition corroborated by craniomorphometric analyses of the same individuals. Together with contextual evidence including burial location and associated grave goods, these osteological data indicate that these were enslaved peoples captured and forcibly taken to Portugal. These individuals likely came from multiple regions in Africa that cannot yet be pinpointed given that numerous ethnic groups in western and central Africa modified their teeth in similar ways (Wasterlain et al. 2016). Nevertheless, the ability of dental modification to demarcate social identity, and thus an individual's status as a potential nonlocal, demonstrates the value of body modifiers in providing information on not only voluntary but coerced mobility that may contribute significantly to our knowledge of enslavement, colonialism, and structural violence.

Cranial modification may also expose coerced mobility associated with captivity, interpersonal violence, and warfare. Kurin et al. (2016) found that among the Late Intermediate period (AD 1000–1400) Chanka of the Andahuaylas highlands of Peru, those with modified crania suffered antemortem and perimortem cranial injury at considerably higher rates (55.7%) than those with unmodified crania (30.2%). They argued that this disparity was indicative of internal warfare within their polity, as cranial modification would have been an overt signal of group affiliation and would thus have made those individuals more susceptible to targeted, violent attacks. Additionally, mobility plays a key role in distinguishing internal from external warfare. Internal warfare is often characterized ethnographically and historically by the abduction of young women of childbearing age who suffer disproportionately from violent, traumatic injury relative to natal group females, while external warfare typically involves the migration of nonlocal men into a community to assist with warfare (Kurin et al. 2016). Among the Chanka, two young females (one of whom exhibited a modified skull) identified as nonlocal by radiogenic strontium isotopes both experienced cranial trauma, suggesting that while their captors sought nonlocal females, no particular group only consisting of individuals with modified crania were targeted (Kurin et al. 2016). This study highlights the importance of evaluating mobility when examining the nuances of past interpersonal violence and the ways in which cranial modification can shed light not only on group affiliation but on the interplay between violence, sex, and social identity.

Contact, Interaction, and Admixture

The bioarchaeology of contact following mobility or migration, as well as subsequent short-term reactions and long-term biological and social adaptations to such encounters (i.e., population replacement, admixture/gene flow, interpersonal violence, colonialism, imperialism), is strengthened by a deeper understanding of the role that mobility plays in patterns of interaction between two or more communities. For instance, considerable debate has long surrounded the population history of Southeast Asia, with competing hypotheses variably arguing for admixture with migrating East Asian Neolithic farmers (two-layered immigration hypothesis) or for continuity and relative genetic isolation of Indigenous Southeast Asian peoples, with little to no admixture (regional continuity model) (Matsumura and Hudson 2005). Matsumura and Hudson (2005) sought to test these hypotheses by examining dental metric and nonmetric traits from the teeth of more than 4,000 individuals from 42 prehistoric and historic sites across Southeast and East Asia. These measurements and features identified close affinities between early prehistoric Southeast Asian communities and modern Australo-Melanesian samples but revealed increasing admixture with East Asians over time, beginning in the early Neolithic and continuing into the subsequent Metal Age and modern era (Matsumura and Hudson 2005). These data bolster the two-layer immigration hypothesis in which the diffusion of agriculture prompted East Asians to migrate into Southeast Asia, where they subsequently interacted with Indigenous communities. This study highlights the ability of biodistance analyses to illuminate complex questions involving the impact of migration, not on the migrants themselves but on local Indigenous populations with whom such migrants came into contact. Such admixture would have certainly affected how individual and group identities were constructed and negotiated, signaling both a biological and social shift in self and group perception.

Methodological advances in the bioarchaeology of migration similarly permit more meaningful examinations of mobility and contact among commingled skeletal remains. Commingled collections present unique logistical challenges and are thus often understudied, despite representing a vast amount of untapped bioarchaeological data that provide key insight into human behavior among past groups (Adams and Byrd 2008, 2014; Osterholtz 2016; Osterholtz et al. 2014; Sheridan 2017). Ullinger et al. (2005) explored morphological variation using teeth from commingled assemblages in the southern Levant dating to the Late Bronze and Early Iron Ages, a contentious transitional period marked by considerable cultural change often attributed to migration and subsequent conquest, societal collapse, and population replacement. After comparing nonmetric trait variations between these collections and others in the Near East, Ullinger et al. (2005) found greater phenetic similarities between peoples from Late Bronze Age Dothan and Early Iron Age Lachish than between these and any other group in the broader region. These data were later corroborated by homogeneous strontium and oxygen isotope values at Tell Dothan, suggesting that these individuals were not highly mobile (Gregoricka and Sheridan 2017). Together, these studies indicate that population continuity (and not conquest and subsequent population replacement by invading Israelites or other immigrant communities) better characterizes this transition, and that the substantial changes

observed in the archaeological record during this time were primarily driven by local agents and not external forces. In this case, both dental nonmetric traits and isotope analyses were used to evaluate population mobility and interaction, and rule out migration as a driving force for change. These findings emphasize the importance of utilizing commingled assemblages to ensure more holistic assessments of human movement in the past, particularly in regions where commingling (whether intentional or unintentional) occurred regularly.

Recently, aDNA analyses have provided more definitive evidence of migration. Insights derived from these studies shed light on debates surrounding whether the diffusion of ideas and material culture was responsible for social change, or if the actual movements of people and subsequent contact and admixture acted as a primary driver. One of the most well-known and heavily studied migrations in the archaeological record occurred during the Early Bronze Age, when the nomadic Yamnaya herders of the Eurasian steppes were thought to have migrated westward into Europe, where they encountered populations of settled Neolithic farmers (Furholt 2018; Kristiansen et al. 2017). Such migrations—primarily posited because of an abrupt transformation in material culture, mortuary practices, and language—may have led to the reshaping of European demographics and the emergence of the Corded Ware culture (Furholt 2018; Kristiansen et al. 2017). In separate studies seeking to answer questions about a possible Yamnaya migration, its ties to the spread of Indo-European languages throughout the continent, and any subsequent genetic impact on European population structure, Allentoft et al. (2015) and Haak et al. (2015) examined whole genomes and genome-wide markers, respectively, from 170 individuals dating to the Neolithic, Bronze, and Iron Ages. Both studies revealed significant Yamnaya genetic contributions to ancestry among central Europeans ~4,500 years ago, suggestive of considerable admixture with local Neolithic farmers (Allentoft et al. 2015; Haak et al. 2015). These discoveries led Haak et al. (2015, p. 211) to describe this as a "massive migration" event, a phrase later criticized by Furholt (2018), who together with others (e.g., Heyd 2017; Kristiansen et al. 2017) argued that interpretations of genetic data need to better engage archaeological theory to avoid the pitfalls of simplistic and uninformative diffusion-migration dichotomies characteristic of traditional culture-historical paradigms. According to Furholt (2018), such binary perspectives fail to recognize the complexity of migration as a gradual and continuous process, an alternative interpretation of the genetic data strongly supported by archaeological evidence.

Climate Change

Climate change and resultant environmental degradation can influence the ways in which human communities engage with their landscapes, interact with nearby populations, and renegotiate their own socioeconomic structures (Robbins Schug 2011, 2020a). These communities adapt (with varying degrees of success) by employing variable, complex, and population-specific strategies to buffer themselves against shifts in climate (Morrissey 2015; Robbins Schug et al. 2018; Stojanowski and Knudson 2014). The bioarchaeology of resilience (Martin et al. 2013b) provides one

means of assessing the adaptive responses of local agents to environmental change, ranging from creating alliances (e.g., Harrod and Martin 2014) to engaging in interpersonal violence (e.g., Harrod and Martin 2014; Martin and Harrod 2020; Pillloud et al. 2020; Robbins Schug et al. 2012; Tung et al. 2016) or, of particular interest here, instigating mobility and migration. While climate stress does not inevitably or deterministically lead to outcomes of violence or changes in group mobility (Harrod and Martin 2014; Morrissey 2015; Robbins Schug et al. 2018), human movement and subsequent modifications to social organization can be viewed as a strategy by which past populations sought to actively cope with external environmental stressors.

Changes to mobility tied to climate change are perhaps best evaluated through isotopic analyses, as biogeochemical signatures provide a more direct measure of diachronic shifts in human movement over both an individual's life course and among community members within and across generations (e.g., Gregoricka 2016, 2020b; Knudson et al. 2015; Kusaka et al. 2012). At the site of Gobero in central Niger, radiogenic strontium isotope analyses were performed on individuals dating to the Early and Middle Holocene to evaluate the effects of aridity and climatic degradation on the movements of local communities (Stojanowski and Knudson 2014). The wetter and more humid Early Holocene revealed first-generation adult migrants who had eventually settled at Gobero, while juveniles buried at the site exhibited only local ratios consistent with a more sedentary lifestyle. Conversely, individuals dating to the more arid and climatically unstable Middle Holocene demonstrated more nonlocal strontium isotope ratios in both enamel and bone, suggesting that increased mobility may have served as an adaptive strategy to combat water and/or food insecurity during the most severe arid phases (Stojanowski and Knudson 2014). These results provide a clear example of the resiliency of human populations in the face of climate change and their ability to actively adapt to the pressures of climate stress. This study also highlights the ability of smaller-scale societies to more effectively adapt to climate stress due to the absence of rigid social hierarchies, potentially enabling an easier shift towards greater or lessened mobility in response to environmental change relative to more complex societies (Robbins Schug 2020b).

Disease Transmission

As individuals move, they inevitably bring with them not only their own cultural traditions and social identities but also biological agents including infectious diseases (or disease vectors) to their post-migration destination (Campbell and Crawford 2012; Findlater and Bogoch 2018). Mobility and migration subsequently play a major role in the geographic distribution of pathogens, not only today (e.g., Bayer et al. 2009; Field et al. 2010; Findlater and Bogoch 2018) but also in the past. Well-known historic examples of disease transmission following migration include the devastating introduction of smallpox to the Americas by European colonizers (e.g., Boyd 1990; Lindo et al. 2016; Merbs 1992) and the spread of Black Death throughout Eurasia (e.g., Andrades Valtueña et al. 2017; Spyrou et al. 2016, 2018). Major debate also continues to surround the origin and

spread of treponematoses and whether the disease originated in Afro-Eurasia, the Americas, or both (Baker and Armelagos 1988; Baker et al. 2020; Cook and Powell 2012; Meyer et al. 2002; Powell and Cook 2005). Nevertheless, bioarchaeological evidence of disease transmission is more challenging to assess, and few bioarchaeological studies have sought to directly link pathogen distribution and mobility patterns.

One such study by Roberts et al. (2013) sought to investigate the relationship between human mobility and the spread of treponematosis in late Medieval Hull, an English port city and center for international trade. Dental enamel from six individuals exhibiting treponemal lesions was analyzed for strontium and oxygen isotope ratios and compared to six control individuals whose skeletons demonstrated no evidence for treponemal infection to evaluate whether nonlocal individuals were more likely to have suffered from the disease. Although Roberts et al. (2013) identified a handful of migrants using both isotopes, no pattern was found linking childhood geographic origins to the expression of treponemal lesions. While those without lesions could have possibly contracted and died of treponematosis prior to the disease affecting bone (see Wood et al. 1992), initial results indicated that infected individuals could have contracted the disease in England and not abroad, and that migrants were not more likely to exacerbate the spread of treponematoses in England.

Ancient DNA can similarly illuminate how migration among human populations can drive the spread of infectious disease. Such patterns of co-mobility are particularly revealing in the aDNA of pathogens extracted from human teeth or bone. Andrades Valtueña et al. (2017) examined 563 human skeletal tissue samples from Late Neolithic and Bronze Age Russia as well as central and eastern Europe for signs of the *Yersinia pestis* bacterium. Together with *Y. pestis* genomes from a prior study in southern Siberia (Rasmussen et al. 2015), six additional genomes from Russia, Lithuania, Estonia, Germany, and Croatia were recovered, all of which belonged to a single and unique clade. Their resultant phylogenies suggested one of two possibilities: the *Y. pestis* bacterium entered central and eastern Europe numerous times within a 1,000-year period, or the plague arrived only once from central Eurasia in the Neolithic before later moving back to southern Siberia in the Bronze Age (Andrades Valtueña et al. 2017). To further evaluate the likelihood of each scenario, the authors turned to human genomic (Allentoft et al. 2015; Haak et al. 2015) and archaeological evidence from the same period. Ancient DNA evidence for the migration of the Yamnaya from the Pontic steppe into eastern and central Europe by the Early Bronze Age, coupled with archaeological changes in material culture and mortuary practices associated with contact and trade, coincide with the early appearance of *Y. pestis* in eastern Europe. This led Andrades Valtueña et al. (2017) to conclude that the second scenario, in which the plague traveled with the Yamnaya westwards into Europe, was the best interpretation for the aDNA *Y. pestis* genomes. Using aDNA from human and pathogen sources thus offers two independent lines of genetic evidence that together can help us reconstruct and refine archaeological interpretations of mobility among past populations.

Conclusions

Bioarchaeology has in many ways reenergized migration studies of past peoples over the last two decades. More than ever before, methodological and theoretical developments have facilitated new ways of reconstructing mobility practices using human skeletal remains. Improving our ability to identify both short- and long-term migration through observations of body modification, analyses of biological distance, and applications of biogeochemical and aDNA techniques has enabled us to move beyond the simple dichotomous classification of past individuals as either local or nonlocal and, instead, demonstrates the potential of bioarchaeology to reveal broader patterns of social organization, social and ethnic identities, fictive kinship, postmarital residence, nuanced gender roles and relations, detailed life courses, responses to climate stress, and pathways of disease transmission.

At the same time, far from exposing overarching, predictive models of mobility associated with particular forms of social organization or external factors including contact or climate change, bioarchaeology reveals that mobility and migration are inherently heterogeneous and complex social processes. Those individuals and groups that engage in migratory behaviors are not homogeneous or part of discrete, closed biological populations driven by a single-minded, collective agency (Furholt 2018). Instead, a variety of population-specific social, political, economic, and historical contexts, composed of a multifaceted array of internal and external stimuli, drive agential decisions taken by individual actors and social groups to engage in mobility or migration (Furholt 2018, 2019a; Kristiansen et al. 2017; van Dommelen 2014).

To get at such complexities and meaningfully capture past migration processes, as well as the versatility and resilience exhibited by those engaging in mobile behaviors, theoretical models of mobility must be integrated more fully into bioarchaeological investigations (e.g., Anthony 1990; Burmeister 2000; Furholt 2018, 2019b; Kristiansen et al. 2017). Embodiment, structural violence, life course, and gender theory all provide powerful bioarchaeological frameworks for the interpretation of skeletal data that are too often underutilized. Intersectional approaches that take into consideration the impact of interconnected and fluid social identities (sex, gender, age, status, ethnicity) on human movement are particularly imperative, as bodies undergoing migration processes are themselves complex amalgamations of biosocial experiences and cannot be fully understood otherwise (Geller 2017; Torres-Rouff and Knudson 2017; Yaussey 2019). As bioarchaeology continues to move forward in mobility and migration studies, such perspectives should be further linked to archaeological and anthropological theory as part of broader attempts to explain the diversity and dynamics of human movement, interaction, and identity construction. In particular, incorporating transnational theoretical concepts alongside embodiment theory may facilitate new and important insights into aspects of the ancient migration experience by enabling a more holistic examination of how hybrid social identities tied to mobility can biologically impact human bodies. Further contextualizing these

data with site, regional, and interregional archaeological records will also lead to a better comprehension of both short- and long-term migratory behaviors within and across cultures.

Bioarchaeological inquiry has clearly demonstrated that mobility and migration are not simply deviations from a purported "norm" of sedentism; instead, movement is an essential part of what it means to be human (Cabana and Clark 2011; Campbell and Crawford 2012; Greenblatt 2010; Tsuda et al. 2015). In concert with theoretical integration, bioarchaeologists must also move forward by more deeply and critically exploring the motivations behind *why* individuals and communities of the past engaged in these practices, as well as the subsequent *outcomes* of human movement on both individual actors and broader social structures (Anthony 1990; Cabana and Clark 2011; Campbell and Crawford 2012; van Dommelen 2014). Such investigations should necessarily include not only those who move but also those affected by incoming migrating groups with whom they interact (Tsuda et al. 2015; van Dommelen 2014). As bioarchaeologists are uniquely equipped to capture the biological, social, and genetic impacts inscribed onto or inherited within the body before, during, and after migration, this is one of the most promising avenues for enhancing our understanding of the motivations and consequences behind human movement in the past.

Demonstrating the relevance of bioarchaeology to mobility and migration studies must also remain an important goal for our discipline. Indeed, many archaeologists and bioarchaeologists alike have pointed out that investigating mobility and migration in the ancient world has very real and relevant applications to contemporary society (e.g., Baker and Tsuda 2015; Campbell and Crawford 2012; Tung 2012). One more obvious applied area of focus has been in forensic anthropology. Forensic techniques derived from bioarchaeology can aid in the identification of some of the many thousands of migrant bodies discovered along the Mexico-United States border through the development of biological (sex, age, stature, ancestry) and cultural (culturally specific personal effects such as clothing, religious iconography, etc.) profiles, as well as through DNA and isotopic analyses (Anderson et al. 2008; Juarez 2008; Kramer et al. 2020; Tung 2012). Such work seeks to not only bring closure to families with missing loved ones but also purports a broader goal of utilizing identifications to gain better insight into the motivations behind such decisions and behaviors in the first place (Anderson 2008).

Bioarchaeologists need to continue leading this charge by making our work on past mobility and migration more explicitly relevant, living up to the claims of significance and applicability we have set for ourselves by implementing changes that would affect and improve migration policy as well as predictive models for disease transmission or demographic shifts for the present. Important steps forward to achieve such relevance include publishing bioarchaeological papers in non-anthropological academic journal venues where they are more likely to get attention from those involved in contemporary issues of planning and policy making (Smith 2012, 2015; Stojanowski and Duncan 2015); writing in more accessible language (Tseng 2012) for science media outlets or popular press books targeting a broader audience (Stojanowski and Duncan 2015; see also De León 2015); exploring alternative means of outreach through podcasting (e.g., Rivera 2020), fictional osteobiographies

(Boutin 2011; Boutin and Callahan 2019), and social media (Killgrove 2019; Sheridan 2017); and promoting underrepresented voices as part of actively working to decolonize bioarchaeology (e.g., Blakey 2001; Geller 2017; Pérez 2017; Robertson 2018; Watkins 2018, 2020). Particularly as violence, sociopolitical and economic conditions, and environmental stressors continue to instigate migration in the modern world (e.g., Brown 2008), the consequences of such enormous demographic and ethnic shifts across political and cultural borders necessitate planning that would benefit from the *longue durée* of bioarchaeological insight.

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