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Article Title: Toward a Bioarchaeology of Urbanization: Demography, Health, and Behavior in Cities in the Past

Running Title: Toward a Bioarchaeology of Urbanization


## Abstract

Urbanization is one of the most important settlement shifts in human history and has been the focus of research within bioarchaeology for decades. However, there have been limited attempts to synthesize the results of these studies in order to gain a broader perspective on whether or how urbanization affects the biology, demography, and behavior of humans, and how these potential effects are embodied in the human skeleton. This paper outlines how bioarchaeology is well-suited to examine urbanization in the past, and we provide an overview and examples of three main ways in which urbanization is studied in bioarchaeological research: comparison of (often contemporaneous) urban and rural sites, synchronic studies of the variation that exists within and between urban sites, and investigations of changes that occur within urban sites over time. Studies of urbanization, both within bioarchaeology and in other fields of study, face a number of limitations, including a lack of a consensus regarding what urban and urbanization mean, the assumed dichotomous nature of urban versus rural settlements, the supposition that urbanization is universally bad for people, and the assumption (at least in practice) of homogeneity within urban and rural populations. Bioarchaeologists can address these limitations by utilizing a wide array of data and methods, and the studies described here collectively demonstrate the complex, nuanced, and highly variable effects of urbanization.

Keywords: urban-rural, biological consequences, paleopathology, demography, skeletal stress indicators

## Introduction

Urbanization, like the preceding transition to sedentism that accompanied the adoption of agriculture (what is often referred to as the Neolithic Revolution) is one of the most important settlement shifts that has occurred in the history of humans. Urbanization first occurred as early as 6,000 years ago in Mesopotamia (today, Iraq and Kuwait) (4300-3100 BCE), though the estimated dates of its origins depend in large part on how urban is defined (Bairoch, 1990; Childe, 1950; Reba, Reitsma, & Seto, 2016). Although urban living has existed for a relatively short period of time in the context of human history, it is rapidly becoming the predominant form of human settlement (United Nations, 2019; United Nations Population Fund, 2020). Further, given the interdependence of urban and surrounding rural areas, urbanization is increasingly, through direct and indirect means, shaping the lives of the majority of living people. Today, more than half of the world's population resides in urban areas, and though all countries are experiencing increasing urbanization, the process is occurring more rapidly in lower-income nations than in wealthier nations (Clark, 2003; United Nations, 2019).

Urbanization is one of three terms that are often used interchangeably but actually refer to distinct though related concepts (Clark, 2003). Urbanization is the increase in the proportion of people living in cities relative to rural areas, while urban growth refers to the increase in population size of those cities. Urbanism denotes the set of social and behavioral attributes of urban living that apply to the population residing in a city as a whole. Urban growth occurs based on natural increase and a net in-migration from other areas, while urbanization reflects the concentration of people living in urban centers rather than being spread across the landscape. According to Clark (2003), a geographer, urbanization happens as people migrate to cities, but it can also be a function of a declining rural population, which thereby increases the proportion of the overall population that lives in cities. The term urbanization, itself, can also be employed in different contexts with distinct meanings. As the historian De Vries (2006, pp. 11-12) highlights, urbanization may include demographic urbanization (the movement of people to urban settlements), behavioral urbanization (people adopting urban behaviors, ideas, and activities), and structural urbanization (shifts in societal organization).

*What is urban?*

One of the factors complicating studies of urbanization is the problem of defining what, exactly, "urban" is. From a diachronic perspective, at what point does a population shift from being rural to urban? What features clearly indicate that a population is urban? Is it, in fact, possible or desirable to clearly distinguish urban from rural settlements? Rather than applying a simple urban-rural dichotomy, which was adopted by the United Nations in the 1940s for statistical reporting and has since been used to study urbanization across disciplines (Champion & Hugo, 2004, p. 3), many scholars recognize that settlements fall on a continuum between the two and that drawing a distinct line between urban and rural is difficult in practice (Christenson et al., 2014; Corker, 2017; Dahly & Adair, 2007; DeWitte & Betsinger, 2020; Schell, 2018).

Nonetheless, one of the most commonly used criteria to identify an urban population is population size. However, there is no clear consensus regarding how many people is sufficient to warrant an urban designation, and definitions may be discipline-specific. For example, Chandler (1987), an historian, argues that, for those settlements dating from between 850 CE and 1850

CE, the urban designation should only be applied to communities with greater than 20,000 inhabitants for all global regions except Asia, in which the threshold is 40,000 inhabitants. Settlements that post-date 1850 in all locations worldwide, he argues, are urban if they have more than 40,000 residents. Likewise, Modelski (1999), a political scientist, uses population size to identify urban sites, but the thresholds in his scheme are different, with a minimum of 10,000 inhabitants between 3500 BCE and 1000 BCE; 100,000 inhabitants between 1000 BCE and 1000 CE; and 1,000,000 inhabitants after 1000 CE. While both researchers focus on population size as the prime signifier of "urban", they each use different variables in estimating those sizes (Reba et al., 2016). Moreover, these population size cutoffs do not take into consideration factors that are used by other scholars to define urban, such as the existence of craft specialization, the presence of fortifications or walled enclosures, the development of streets and permanent housing, or the establishment of bureaucratic entities, or based on the history and culture of the population (Bairoch, 1990; Reba et al., 2016). For example, currently in Norway, an area need only have 200 inhabitants to be considered urban (Reba et al., 2016, p. 4). Furthermore, defining urban based on population size is more difficult for early urban settlements. Population density estimates for these have typically been based on the space within a settlement's enclosures, the space occupied by buildings, and/or the estimate of occupation density (Bairoch, 1990, p. 22). However, there is a great deal of potential error for each of these parameters, which can affect the overall final population estimate.

Reba and colleagues (2016) (geographers and environmental scientists) note that a single country's definition of urban may also change over time. China for example, originally identified urban areas as settlements with statutory city designations, whereas more recently, urban infrastructure and population density are the key designators of "urban" (p. 4). Likewise, in discussing the origin of towns in England in the early Middle Ages, the historian Dyer (2002) argues that a town or urban settlement "…should have a permanent concentration of people, some hundreds at least, who made their living from a variety of non-agricultural occupations" and that "…occupational diversity was its most distinctive hallmark" (p. 58). Currently, in the United Kingdom, official city status is granted by the Queen; settlements compete for the honor of being granted official status, and it does not depend on any particular established criteria, such as population size (UK Cities, 2020). However, for census and analytical purposes, the UK Office for National Statistics defines a major town or city based on population size (of at least 75,000 people) (Office for National Statistics, 2019). The definitions of urbanization continue to vary from country to country today, impacting estimates of levels of urbanization and rendering them incomparable in some cases (Alkema, Jones, & Lai, 2013).

Much of the variability in definitions of "urban" is clearly a matter of scale. While it may be obvious that a settlement with 50,000 inhabitants is urban, early urbanization and urban growth would not have initially included such a large number of people in a single location. Therefore, in attempting to examine the earliest towns and the initial trends and impacts of urbanization, it is vital to include settlements with far fewer inhabitants. Urban areas do not suddenly appear fully formed with thousands of residents; they grow over time. Although settlements with far fewer inhabitants would perhaps not be viewed as cities in many contemporary settings, it is exactly these areas that were burgeoning and eventually developing into heavily populated cities in the past and that are an important focus of study, particularly if we are interested in the factors that promote urbanization and the outcomes thereof. Reba and colleagues (2016) argue that "multi-variable" urban definitions, rather than a hindrance to defining what is urban, actually "*improve"* their characterization (p. 4), as they underscore the complexity of what constitutes urban.

Archaeologists have long conducted research in urban contexts, and the field of urban archaeology itself emerged in the 1920s (Raja and Sindbæk 2020). A huge body of literature on the topic has emerged over the last 100 years, and the broad interest in urban archaeology has prompted the creation of a new journal, the *Journal of Urban Archaeology*, which launched in 2020. As is true for other fields focused on the topic, a common thread across the writings of urban archaeologists is the difficulty of defining "urban" and "urbanism". Smith (2016) distinguishes between demographic/sociological definitions (which emphasize size and heterogeneity and tend to be more useful for describing contemporary "Western" cities) and functional definitions (such as Trigger's (1972: p. 577) description of a city as a "settlement that performs specialized functions in relationship to a broad hinterland"), which are more relevant to archaeological studies of ancient cities (see also Smith 2020). According to Cowgill (2004), there is no single criterion, such as size or complexity, that is adequate for defining a city, and rather than attempting to determine which criteria will "clearly demarcate all cities from all noncities" and thinking of urbanism as a discrete category, promotes using a "somewhat fuzzy core concept" for cities (p. 526) and thinking of urbanism "as a cluster of variables that can be measured (if only roughly) on ordinal or interval scales" (527). Cowgill defines a city as "a permanent settlement within the larger territory occupied by a society considered home by a significant number of residents whose activities, roles, practices, experiences, identities, and attitudes differ significantly from those of other members of the society who identify most closely with "rural" lands outside such settlements" (p 526). Following Cowgill, Smith (2016, 2020) proposes a flexible "attribute approach", evaluating a settlement for the presence of various urban attributes (e.g., size, social impacts such as craft production or markets, fortifications), and recognizing that there is no specific set of attributes that universally define urban settlements. Raja and Sindbæk (2020: p 10) in their editorial for the inaugural issue of the *Journal of Urban Archaeology* write that the term "urban" potentially means very different things depending on context, but emphasize that urbanism "denotes ways in which people interact with settlements, with the environment, and with other people" and that "urban" is "a quality of social networks and institutions, as much as of settlements."

*Why Urbanize?*

The reasons for historical and continuing trends in urbanization vary, but have generally been characterized as economic or social (Clark, 2003; Mills & Song, 2020). Economically, it has been argued that agriculture and a food surplus are the necessary foundations for the formation and maintenance of urban areas and urbanization. From this economic perspective, past populations may have begun to agglomerate into smaller geographic areas once there was an abundant and predictable food supply, including an annual surplus, that was not only sufficient to support all inhabitants but that also enabled some individuals to pursue non-agricultural activities. Those who began to engage in some sort of craft specialization, such as pottery-making or blacksmithing, could obtain food supplies by trading their goods or services and were thus able to shift their efforts full-time away from subsistence activities. Maintenance of an urban settlement and promotion of urban growth required sustained food production in and supplies of other materials from surrounding rural areas (Betsinger, 2007; Clark, 2003). This demand for food and raw materials was accompanied by a need within the city for non-food goods and services, attracting more individuals into the urban setting. For example, in 11$^{th}$-16$^{th}$

century London, a variety and increasing number of labor and employment opportunities – including work for servants, masons, carpenters, and merchants – drew people to the city from the rural hinterland (Dyer, 2002). In addition to an economic "pull" of migrant to cities, in some cases individuals were pushed to leave rural areas, especially in instances of crop failures or loss of livestock (Walter & Schofield, 1985), which reduced the need for rural laborers and required individuals and families to find other ways to make a living. Severe economic hardships related to rural land shortages and a lack of export crops may have also functioned to "push" people out of rural areas and into urban settlements (Nwanna, 2004).

The other major explanation for urbanization is a social one. As Clark (2003) argues, urban settlements are the "…product of human relationships and lie in the interpersonal ties that encourage people to congregate in space" (42). The benefits of relatively large numbers of people living and working in close proximity – including security, ease of defense, and social assistance – may have drawn people to burgeoning urban settlements. As population sizes grew, administrative and political authorities would have been required, and religious, military, and bureaucratic systems would have been established to enable a large number of people to live in a small geographic area (Betsinger, 2007; Lampard, 1955). The social benefits of living in a larger group may have drawn people to urban areas irrespective of the economic opportunities. In all likelihood, however, a combination of economic and social factors, including "push" and "pull" phenomena, likely led to the development of towns and cities. Moreover, motivations to move to urban settlements likely varied among individuals and among geographic areas in the past as much as they do currently.

*Is Urbanization Good or Bad?*

There is no simple answer to the question of whether urbanization is generally positive or negative. Some argue that regardless of time period, urban settlements have a "higher quality of life than non-urban places, manifested through more opportunities and more services" (Reba et al., 2016, p. 4). While it may be true that cities typically offer more services and economic opportunities than rural areas, it is less clear whether cities necessarily provide a better quality of life. There are many factors and variables to consider that influence the effects – economic, biological, psychological, and social - that urbanization has on individuals and the larger population. In contemporary settings, both positive and negative outcomes have been documented for a variety of populations, and in many cases, urbanization produces a mix of effects that do not impact all individuals within the population uniformly (Harpham, 2009). For example, standards of living are better in urban areas in many locations (e.g., Azam, 2019; Bui & Imai, 2019; Fang & Sakellariou, 2013; Storper & Scott, 2016; Thu Le & Booth, 2014; see comprehensive discussion in DeWitte & Betsinger, 2020). However, these benefits may not be equally enjoyed by everyone in the population. In Sub-Saharan Africa, where urbanization is currently increasing (Leon, 2008; United Nations, 2019), people who move to the cities often find themselves living, at least initially, in urban slums, experiencing chronic under- or unemployment (Dyson, 2011; Ezeh et al., 2017; Rains & Krishna, 2019; Razzaque et al., 2020). Higher standards of living in urban areas may be a function of greater economic opportunities, better access to health care, and better sanitation and water infrastructure (Chaudhury & Roy, 2017; Matthews et al., 2017; Zhang et al., 2017; see DeWitte & Betsinger, 2020), but this may not be true for all societal classes. Some studies have demonstrated higher life expectancy and survivorship or lower risks of mortality, which are broad measures of overall health, for those living in urban settlements (Chen & Yang, 2014; DeWitte & Betsinger, 2020; Gage, 2005; Harpham, 2009; Islam et al., 2017; James & Cossman, 2017), but once again, these benefits of urban living may not be equally experienced by all groups.

Negative outcomes have also been found for those living in urban communities. Urban settings, characterized by higher population densities, are ideal for the maintenance and spread of infectious diseases that are transmitted directly from person to person in close proximity (e.g., tuberculosis), through contaminated water supplies (e.g., cholera), and by insect and other animal vectors that thrive in and near cities (e.g., Chagas disease) (LaDeau, Allan, Leisnham, & Levy, 2015). This is especially true in lower-income nations that may have problems related to the construction and maintenance of systems for sanitation, waste-removal, and storage and delivery of clean drinking water. Accumulations of garbage and waste can lead to outbreaks of a variety of infectious and parasitic diseases (e.g., Alirol, Getaz, Stoll, Chappuis, & Loutan, 2011; Armelagos, Brown, & Turner, 2005; Galea & Vlahov, 2005; Krystosik et al., 2020; see discussion in DeWitte & Betsinger, 2020). In addition to the spread of communicable diseases, food insecurity can also plague urban residents, especially the poorest (Codjoe, Okutu, & Abu, 2016; DeWitte & Betsinger, 2020; Joshi et al., 2019; Roberts, Osadare, & Inem, 2019). Given the synergistic effect between nutrition and disease, an insufficient food supply exacerbates the problems of infection and disease (Katona & Katona-Apte, 2008; Scrimshaw, 2003; Wolowczuk et al., 2008). Environmental pollutants, including outdoor air pollution, exposure to heavy metals, and light and air pollution, also pose a substantially greater risk to populations living in urban settings, endangering health both directly and indirectly by contributing to risk factors for diseases (Magnusson, 2013; Shifaw, 2018; Shepherd, Dirks, Welch, McBride, & Landon, 2016; Strosnider, 2017; Yu et al., 2019; see discussion in DeWitte & Betsinger, 2020). For example, studies have indicated that air pollution is associated with elevated risks of death from Covid-19 (Conticini, Frediani, & Caro, 2020; Wu, Nethery, Sabath, Braun, & Dominici, 2020).

These studies of contemporary urbanization expose the myriad effects of urban living today and are crucial for identifying urban factors that threaten or contribute to economic, physical, and mental well-being and for informing intervention strategies aimed at improving peoples' lives. However, they do not provide insight into the experiences and consequences of urbanization at its origins nor over time, nor whether the positive and negative outcomes (and intra-population variation in those outcomes) observed today may have parallels in the past. Though the urban areas that exist today are extraordinarily variable, they do not represent the entire suite of urban conditions that people experienced in the past. For example, many urban areas today are industrialized or post-industrial, but given that the Industrial Revolution began in Europe in the 18$^{th}$-century, the characteristics of life in modern industrialized cities represents a small fraction of the whole of human urban experiences over the last several millennia.

Bioarchaeology is both ideally suited to and necessary for the investigation of whether and how urbanization affected past individuals and populations. Human skeletal remains, though subject to their own unique sources of bias, provide us with a much richer representation of human life in the past than is available from historical documents. Bioarchaeological analyses can provide a much deeper perspective than historical data, which is clearly more limited temporally. Even for those contexts for which we have good historical data, bioarchaeological analysis can reveal the experiences of people who are either entirely missing or not fully or accurately represented in those documentary sources. Through the examination of the embodied experiences inscribed at the individual level, bioarchaeology can achieve greater resolution of the effects of urbanization in the past than is possible through historical or archaeological analysis. Further, bioarchaeology is inherently interdisciplinary, and by integrating multiple lines of evidence (on diet, pathological conditions, growth, migration, etc.) can contribute to multiscalar analyses, informing our understanding of urban life in the past from the "simplest" level of the life course of single individual up through regional and inter-regional comparisons.

## Bioarchaeological Studies of Urbanization

Many bioarchaeological studies of urbanization have been conducted over the past several decades, and they typically focus on a single population or geographic area. Bioarchaeological studies can be grouped into three broad categories: studies comparing urban and rural populations, studies examining urbanization at a particular point in time, and studies examining the effects of urbanization over time. We acknowledge that the following overview of bioarchaeological research focuses on studies that have been published in English; this focus is entirely the result of our language proficiencies and does not reflect in any way the value of research on this topic published in other languages. We recognize that our survey of the literature does not include all the important bioarchaeological research that has been done in the context of urban environments, as we have limited this review to studies that explicitly engage with topics of urbanization and urbanism. Thus, our paper focuses primarily on published research identified using the following search criteria: 1) for journals that publish a relatively high proportion of bioarchaeological studies (*American Journal of Physical Anthropology, Bioarchaeology International, International Journal of Osteoarchaeology,* and *International Journal of Paleopathology*), we used the search term "urban*", 2) for Google Scholar, PubMed, and journals that publish a lower proportion of bioarchaeological studies (*American Antiquity, American Journal of Human Biology, Antiquity, HOMO: Journal of Comparative Human*

*Biology, Journal of Archaeological Science,* and *Journal of Archaeological Science Reports*), we used the search terms "bioarchaeology" and "urban*." Given these criteria, we may have inadvertently excluded published studies on bioarchaeology in the context of past cities that did not use the word "urban" in their text. This search yielded a total of 292 references, heavily weighted toward journal articles, and as shown in the geographic distribution of these studies in Table 1, the majority of them (nearly 57%) focus on European sites. We think this reflects a genuine disproportionate focus on Europe in bioarchaeological studies of urban settlements and urbanization published in English and is not simply an artifact of our literature search strategy. The disproportionate focus on European cities in the bioarchaeological literature reflects, at least in part, relatively good preservation conditions for human remains in European contexts coupled with availability thereof resulting from rescue archaeology associated with reconstruction efforts to repair damage that occurred during World War II as well as infrastructure improvements (e.g., subway and underground parking construction) (Pendery 2012).

*Urban vs. Rural*

Urban-rural comparisons are commonly employed in bioarchaeological studies, though, as often acknowledged by the authors, such a comparison can be limited by a number of factors. As Schell (2018) argues, "[t]he urban – rural contrast, as a dichotomous typology, makes the greatest and the weakest assumption of homogeneity within each type" (107). Based on findings from modern contexts, it is clear that rural and urban settlements each have a high degree of internal heterogeneity, which can be observed in contemporary populations and extrapolated to the past. For example, social hierarchies frequently characterize cities, which can include highly impoverished people as well as those at the top of the socioeconomic ladder and everyone in between. Rural settings can also be diverse; for example, not all people residing in contemporary rural settings are involved in agricultural activities, and this might also be true for past populations, though perhaps to a lesser degree (Schell, 2018). Schell's arguments are not new, however, as Mumford (1961) emphasized the individuality of cities, and Bairoch (1990) warned against oversimplification in studying urban settlements. However, despite the heterogeneity that exists in urban and rural settings, it is not necessary to completely do away with urban-rural comparisons, as there may be fundamental differences in lived experiences that are worth investigating. Another possible confounder in urban-rural comparisons is rural-to-urban (or the reverse) migration, which, depending on the characteristics of the migrants, may either blur distinctions between the two settings or bias the results (e.g., if successful migrants tend to be healthy) and thus complicate interpretations. Context is paramount, and ideally all such comparisons would be able to account for class or socioeconomic differences, the effects of migration, and other factors. However, it is not always possible to do so. For example, though it is generally recognized by bioarchaeologists that isotopic analyses that can be used to identify migrants, these analyses are destructive and, therefore, not always feasible or desirable. Despite these drawbacks, studies of urban versus rural populations have provided important insights that have broader implications. Many of these studies have addressed a variety of questions, including, but certainly not limited to: Is "health" or stress[1] better or worse in urban vs. rural contexts?; What hazards exist in urban and rural environments that might result in discernable differences in traumatic injuries between the two settings?; What are the demographic

[1] We acknowledge the difficulties inherent in operationalizing "health" in a way that is applicable to the kinds of data available to bioarchaeologists (see Gage & DeWitte, 2009; Reitsema & McIlvaine, 2014; Temple & Goodman, 2014). We use the term "health" here to encompass a variety of disease states, physiological stressors, or other factors that might have shaped frailty in the past, and are aware that some scholars whose work we characterize as addressing health or stress might disagree.

differences, if any, between urban and rural settings?; Are there differences in activity patterns between urban and rural populations, and how are these structured by age, sex, status, or ethnicity?; What does the variation in skeletal "health," "activity," and diet between urban and rural contexts tell us about social organization and structures, such as marginalization, within those settings?

Stress Indicators, Demographic Patterns, & Growth

Bioarchaeological studies comparing rural and urban samples have been conducted employing a wide variety of bioarchaeological data. As can be seen in Table 2, some of the most common approaches in these studies are the assessment of stress indicators, such as linear enamel hypoplasia (LEH), porotic hyperostosis, and cribra orbitalia, as well as indicators of vitamin C and D deficiencies. Several studies engage explicitly with the concept of frailty or use demographic measures of health, such as survivorship and risk of mortality, while others examine stature and patterns of growth to assess general "health" in the population. The results of such studies are far from consistent. Some studies indicate worse conditions in rural settings. For example, Rohnbogner and Lewis (2017) examine nonadults from Roman Britain ($3^{rd}$-$5^{th}$ centuries CE), assessing indicators of stress and vitamin deficiency. The results indicate poor childhood health in general across the region, but especially among rural children. Gamble (2020) finds similar results with a study of microscopic dental defects (accentuated striae of Retzius) and survivorship in one urban and two rural Danish cemeteries ($11^{th}$-$16^{th}$ centuries CE). There is evidence of significantly higher rates of stress and reduced non-adult survivorship in the earlier rural sample compared to the urban sample, whereas there are no significant differences observed between the urban and contemporaneous rural sites.

By contrast, several studies yield results that suggest urban living was more detrimental. Walter and DeWitte (2016) find in their analysis of adult mortality and survival in medieval (12th-16th centuries CE) rural and urban England that urban adults experienced higher risks of mortality and reduced survivorship compared to rural adults (see also Ives & Humphrey, 2020). Nagaoka and colleagues (2019) combine mortality data with stress indicators in a Japanese sample, finding a higher proportion of deaths at young ages in the urban sample compared to the rural sample during the Edo Period (1440-1730 CE) (see also Nagaoka & Hirata, 2007).

Some studies yield contradictory results, suggesting there may be differences over the life course or differences due to social status. Lewis and Gowland (2007), for instance, compare patterns of infant mortality between urban and rural cemeteries in medieval and post-medieval England (850-1859 CE), and the results reveal a rural site had the highest proportion of neonatal deaths (presumably from endogenous factors such as congenital anomalies or low birth weight), whereas the London sample had the highest proportion of post-neonatal deaths (due to exogenous environmental factors such as infectious disease or malnutrition) (also see Betsinger, DeWitte, Justus, & Agnew, 2020). Palubeckaitė, Jankauskas, and Boldsen (2002) investigate patterns of LEH between a rural Danish sample and elite and non-elite Lithuanian urban samples (12th-18th centuries CE). Their results indicate that the rural population had the highest morbidity and mortality, the urban non-elite population experienced high morbidity but lower mortality, and the urban elites had the lowest morbidity and mortality.

Multiple studies (e.g., Kaupová, Brůžek, Velemínský, & Černíková, 2013; Mays, Brickley, & Ives, 2008; Primeau, Homøe, & Lynnerup, 2019; Szeniczey et al., 2019) also yield results that suggest no differences between urban and rural settings. For example, Mays, Prowse, George, and Brickley (2018) investigate vitamin D deficiency between urban and rural sites across the Roman Empire of Europe, northern Africa, and western Asia ($1^{st}$-$6^{th}$ centuries CE), finding no association between vitamin D deficiency and settlement type. Kaupová and colleagues (2014) also identify no difference in nonadult stress indicators and weaning between urban and rural samples in a $9^{th}$-$10^{th}$ century CE Czech population.

Infection and Disease

In comparisons of rural and urban settlements, investigations of specific diseases and infections can elucidate differences in environmental conditions, pathogen exposure, and pathogen load. Infectious diseases such as tuberculosis (TB) and leprosy are frequently associated with urban living (Roberts & Manchester, 2005; Stone, Wilbur, Buikstra, & Roberts, 2009); however, this may not always be the case. Similarly, studies of maxillary sinusitis and respiratory infections are an important avenue of inquiry, as urban environments are often associated with poor air quality, and exposure to air pollution is considered one of the leading environmental health risks (Flies et al., 2019; Orru, Ebi, & Forsberg, 2017; World Health Organization, 2014). An emerging area of inquiry within bioarchaeology that provides essential information on infection and pathogen load is archaeoparasitology, the study of parasite eggs or larvae that have been preserved in archaeological contexts. Results of such studies also provide a confounding picture with no clear patterns emerging overall for urban vs. rural contexts.

Kelmelis, Kristensen, Alexandersen, and Dangvard Pedersen (2020) investigate the prevalence of leprosy and TB in multiple urban and rural sites in medieval Denmark (1120-1536 CE). Their results suggest a complicated relationship between these diseases and settlement pattern, with rural and transitional settlements having higher rates of leprosy compared to urban settlements, but no significant different in TB rates among settlement types.

In contrast, Lewis and colleagues (1995) examine maxillary sinusitis in late medieval rural and urban populations from northern England, finding a significantly higher rate in the urban sample. Likewise, in a comparison of rural and urban sites at a number of locations in North America, the United Kingdom, and Nubia, Roberts (2007) notes significantly higher rates of maxillary sinusitis among urban inhabitants. Shin, Seo, Shim, Hong, and Kim's (2020) review of infection rates between multiple urban and rural settlements over a millennium in South Korea similary finds urban conditions were apparently detrimental to health, as there were significantly higher parasite loads in urban settings.

Some studies have revealed a lack of difference in infection rates between urban and rural settlements. For example, Krenz-Niedbała and Łukasik (2016) investigate maxillary sinusitis in nonadults from urban (10$^{th}$-14$^{th}$ centuries CE) and rural (14$^{th}$-17$^{th}$ centuries CE) sites in Poland, finding no significant differences between settlement types. Bernofsky (2010) also examines maxillary sinusitis in conjunction with rib lesions in rural and urban samples from England dating from the Iron Age through the post-medieval periods. The results indicate urban samples did not have consistently higher rates of respiratory disease.

Oral Health

Studies of oral health, which are used in dietary reconstruction or to assess the effects of diet, are frequently employed in examining urban-rural differences as consumption patterns may vary by settlement type. Moreover, as nutrition and disease are synergistic, issues with food supply or nutritional deficiencies will exacerbate the impact of infection and disease (Katona & Katona-Apte, 2008; Scrimshaw, 2003; Wolowczuk et al., 2008); that is, oral health may reflect systemic health conditions. As with the categories detailed above, the results of such studies are inconsistent. Several studies indicate urban living resulted in worse oral health. Rohnbogner and

Lewis (2016), for example, examine dental caries and LEH in nonadults from multiple urban and rural settlements in Roman Britain (1st-5th centuries CE), finding higher rates of carious lesions as well as higher rates of carious lesions co-occurring with LEH among urban nonadults. Garcin and colleagues (2010) find contradictory results in their study of dental caries and LEH in nonadults from early medieval (9th-10th centuries CE) Moravian and Frankish samples. The frequencies of LEH were lowest in one of the rural samples (though the two rural sites had the highest rates of the most severe forms of LEH), but frequencies of caries were lowest in one of the urban samples.

Griffin (2017) finds that the direction of urban-rural differences in oral health (i.e., dental caries, antemortem tooth loss, calculus, dental abscess, and periodontal disease) reversed over time in Britain with urban inhabitants initially having better oral health than rural inhabitants (Roman Britain), but by the late medieval period, oral health is better among the rural samples. Nystrom (2013) compares rates of caries, periapical abscesses, and antemortem tooth loss in a rural, 19th-century CE free Black cemetery to those in contemporaneous urban almshouse, middle- and upper-class European, and free Black and enslaved Black cemeteries from the Northeastern United States. The results are complex and do not neatly point to a consistent pattern clearly indicative of variation in environment, diet, discrimination, or other biosocial factors. Perrone (2014) analyzes oral health indicators along with other markers of stress in urban and rural British populations from the post-medieval period (1550-1850 CE), finding no differences between the urban and rural locations for most skeletal markers.

Stable Isotopes

In addition to oral health, diet has also been assessed directly via isotopic analyses to determine if and how dietary patterns differ between urban and rural populations. Reconstruction of diet through oral health and isotopes reveals a great deal of variation between rural and urban populations (see Table 2). For example, based on carbon and nitrogen isotope ratios, Zhou and colleagues (2019) found that rural inhabitants in the Eastern Zhou Dynasty, China (770-221 BCE) ate less wheat, but similar amounts of meat compared to urban inhabitants (within the urban center, nobles ate substantially more animal protein than commoners). Hermes and colleagues (2018) analyze these isotope ratios in samples from urban and non-urban contexts associated with the Silk Road in Central Asia ($2^{nd}$–$16^{th}$ century CE). The results reveal significant dietary differences between urban and nomadic populations reflecting localized food production systems associated with the former and greater dietary diversity for the latter. Isotopic analysis of medieval ($12^{th}$-$16^{th}$ centuries CE), coastal Estonian samples by Aguraiuja-Lätti and Lõugas (2019) reveals significant differences in nitrogen and sulfur isotope ratios, consistent with a lower intake of higher trophic level protein in the rural population; this might reflect dietary differences between the urban and rural people themselves or of the livestock in those settings.

Traumatic Injuries

Comparisons of traumatic injuries between rural and urban environments can yield insights into the differential effects of setting-specific activity patterns, environmental hazards, and military activities. However, the results from multiple studies do not clearly indicate whether rural or urban settings are more hazardous. For example, Judd and Roberts (1999) examine long bone fractures in urban and rural British samples ($10^{th}$-$12^{th}$ centuries CE) and find a higher rate of fractures among rural farmers compared to urban craft specialists. This pattern is also found in a study of stress and accidental fractures of the postcrania in Poland during the same period by Agnew, Betsinger, and Justus (2015). By contrast, Conversely, Collier and Primeau (2019) compare trauma in rural and urban cemeteries from medieval Denmark (1050-1536 CE), and find that individuals in the urban sample faced a higher relative risk of trauma and that the distribution of traumatic injuries across the body differed between the samples. Mant's (2018) study of 19th-century admissions records to London Hospital (urban) compared to provincial records (rural) similarly reveals a greater proportion of admissions (of children) with traumatic injuries to London Hospital.

Activity Patterns

While traumatic injuries provide some insight to activity patterns in the past, other types of data, such as osteoarthritis and cross-sectional geometry are also utilized in comparisons of urban and rural samples. Unsurprisingly, the results of these studies fail to yield conclusive patterns. However, it is important to note that far fewer studies of data reflective of activity patterns have been undertaken compared to other types of data. Analysis of metatarsal geometry in medieval England reveals stronger and larger metatarsals in rural compared to urban individuals, likely reflecting a lifetime of hard, physical activity in rural settings (Wilson, De Groote, & Humphrey, 2020). Similarly, Saers and colleagues (2017) analyze lower limb cross-sectional geometry in pre-industrial Dutch populations, and the results suggest similar levels of physical activity in urban and rural populations, but greater terrestrial mobility (at least for males) in the latter.

Agarwal (2012) compares age- and sex patterns of bone loss between urban and rural samples from medieval England, finding greater bone loss in urban settings. Holck (2007), however, finds no significant differences in bone mineral density (used to assess osteoporosis) between urban and rural samples from medieval Norway. Contradictory results are found by Becker (2019), who applies a "taskscape", multiscalar approach to interpret intra- and inter-community variation in patterns of osteoarthritis among inhabitants of cities and their counterparts in agriculturalist and pastoralist colonies in the Tiwanaku state (500–1100 CE) of Bolivia and Peru. Distributions differed both between city and colony and between males and females within each context.

Multiple Indicators

Many researchers employ a wide variety of skeletal data to compare urban and rural samples. Once again, the patterns that emerge are not consistent and vary according to type of data, time period, and geographic location, underscoring the importance of context in drawing inferences. Osipov and colleagues (2020) study body size, cross-sectional geometry, and carbon and nitrogen stable isotopes in samples from the Spanish island of Ibiza, dating to the Late Roman–Early Byzantine to the Islamic period (300–1235 CE). The results reveal smaller body size and lower levels of habitual loading in the rural sample compared to urban samples. Gowland, Caffell, Newman, Levene, and Holst (2018) also yield results suggesting rural settings were more detrimental to overall health. Their study of nonadults in $18^{th}$-$19^{th}$ century CE northern England finds equivalent rates of metabolic disorders and oral health between urban and rural populations, but rural nonadults exhibited greater growth disruption and more evidence of respiratory disease. By contrast, Lewis (2016) finds evidence that urban dwellers are more negatively affected in a study of the impact of work on health in urban and rural settings from 151 English sites (900-1500 CE) through analysis of infection, trauma, respiratory disease, and stress to the joints and spine.

Several studies employing multiple indicators yield inconsistent results, including differences across the life course. For instance, Redfern, DeWitte, Pearce, Hamlin, and Egging Dinwiddy (2015) examine indicators of stress, disease, and oral health in their study of rural and urban settlements in Dorset, England between the 1st and 5th centuries CE. They found urban adults had higher survivorship and lower risks of mortality than their rural counterparts, while urban subadults experienced a higher mortality risk than rural peers (see also Redfern, 2020).

Summary

Overall, when considering urban-rural studies utilizing various biological markers, no single trend emerges. While some results indicate conditions were worse in rural areas, others reveal urban settings were more problematic. Additionally, some studies yield contradictory results, e.g., with advantages or disadvantages differentially affecting only some segments of a population, and others find no distinct differences. The heterogeneity of settlement types, the continuum between urban and rural sites, and the multifactorial nature of many of the data types employed emphasize the necessity of context in making interpretations and drawing conclusions. For example, research on infectious disease, parasitic infection, and respiratory illness illustrates that there is no regular pattern between urban and rural settlements, as other factors may confound prevalence rates and the overall results. While several of these studies indicate urban environments put people at greater risk of illness, it is by no means a universal finding. Studies of oral health in many of the studies considered here yielded evidence of urban-rural differences; however, collectively they do not strongly indicate poorer oral (or general) health conditions in urban or rural contexts, nor do they reflect consistently distinct dietary patterns in contemporaneous urban and rural areas. While in some urban settings, the populace likely relied on food supplies provided by the surrounding countryside, others may have been involved in more extensive long-distance trade, resulting in a divergence of diet between urban and rural settings. Complicating this are issues related to geographic location, mobility (of human inhabitants or their livestock), economic conditions, social status, sex, and age.  Moreover, these results emphasize the need to utilize multiple lines of evidence, as different data sources can yield distinct and, potentially, contradictory results. They also suggest that attention should be paid to the ways in which selective mortality might affect differences (or lack thereof) in estimated health across the lifespan and, therefore, complicate interpretations of such data. Despite the limitations of this research, however, these studies have created a compelling narrative about urbanization, which dispels the notion that it is an entirely positive or negative transition.

*Urban settings*

Some bioarchaeological studies of urbanization do not engage in a comparison of urban and rural sites. Instead, they examine patterns either within a single urban setting, in some cases comparing sex or age groups or those buried in different locations or mortuary contexts within the settlement, or between urban sites with a region (see Table 3). There are a variety of questions that such studies address when comparing sub-populations within urban settings, such as: What type of variation, if any, exists among sub-populations?; Do males and females experience comparable levels of stress, trauma, or other health indicators?; How does social status impact the overall effects of urban living?; Does high social status necessarily buffer individuals from potential negative effects?; How does age affect the consequences of urban living?; How are migrants integrated or not into urban life following migration? Studies addressing these questions and more are especially useful in demonstrating the variability within urban settlements and in illustrating the lack of uniformity of experience among those living in a city.

Stress Indicators, Demographic Patterns, & Growth

As with urban-rural comparisons, studies exclusively focused on urban samples often examine stress markers, vitamin deficiency, patterns of growth, and demographic measures. Comparisons across status levels have yielded results that often suggest poorer health outcomes for those of the lowest social status, although closer examination reveals the results are more nuanced. For example, Zhang and colleagues (2016) examine stress markers during early urbanization in the Late Shang Dynasty of China (1250-1046 BCE), comparing non-elites buried in cemeteries and refuse pits, with the latter possibly reserved for sacrificial or enslaved individuals. The results reveal similarly high rate of LEH for both burial types, but those buried in refuse pits had higher frequencies of cribra orbitalia and periosteal new bone formation.-Reedy (2020) compares stress indicators and survivorship in nonadults from urban populations in Industrial-era England, Portugal, and Italy, representing different socioeconomic statuses. Low status nonadults had the highest rates of stress markers; however, survivorship was comparable among all status levels.

Comparisons of males and females in urban settings have also yielded variable results. Cho and Stout (2011) histologically examine age-associated bone loss in males and females in Imperial Rome (c. 100-300 CE), finding females experienced greater rates of bone loss with age. Zhang and colleagues (2016) found higher levels of stress among females in the refuse pits, while Reedy's (2020) results indicate more evidence of stress and higher risks of mortality among males.

Examination of regional variation in urbanization's impact provides insight to the heterogeneous experiences among populations and individuals. Newman, Gowland, and Caffell (2019) compare the prevalence of stress indicators and growth patterns between northern and southern urban sites in England (1711-1856 CE), finding minimal differences in growth patterns. Differences in vitamin D deficiency and other stress markers were found, with a northerly site having the highest rates, likely due to lower UV radiation, differences in child labor practices, and changes in breastfeeding patterns. Gernay (2015) examines developing urban centers from England, France, and Belgium (12th-18th centuries CE) and finds no differences among the sites with respect to stature, cribra orbitalia, and LEH.

Differences among and within urban sites may also be related to religious and medical practices. Lewis' (2010) study of Christian-style vs. pagan burial types in an urban Romano-British site (3rd-5th century CE) reveals evidence of scurvy and rib fractures only in the Christian-style burials, which might reflect the outcomes of religious practices (e.g., fasting and corporal punishment). Hagg, Van der Merwe, and Steyn (2017) assess stress markers and fluctuating asymmetry in their analysis of urban Dutch sites (c. 18th–early 20th century CE), one representing the general population and the other a psychiatric hospital sample. The frequencies of the stress markers and the magnitude of the fluctuating asymmetry were similar between the samples, indicating similar levels of stress for the two urban subpopulations.

Infection and Disease

Infectious disease, parasitic infections, and respiratory illness have also been studied within and between urban populations. Toyne, Esplin, and Buikstra (2020) consider TB in an early urban center of Peru (800-1535 CE). The results indicate that urban features such as close contact among residents likely facilitated the spread of respiratory infections such as TB. Boyd (2020) examines the effects of status on respiratory stress in 18th-19th century London, finding no differences in maxillary sinusitis and rib lesions between middle- and upper-class communities, suggesting these populations were exposed to similar levels of respiratory hazards. Sundman and

Kjellström (2011) compare chronic maxillary sinusitis between males and females in a medieval (ca. 970-1530 CE) urban center in Sweden. The results show among males, which may be related to the types of labor in which they were employed.

Fonzo, Scott, and Duffy (2020) investigate parasite load through archaeoparasitological analysis of the 18th century CE urban Fortress of Louisbourg in Nova Scotia, Canada, observing a high prevalence of infection likely due to the living conditions associated with a settlement undergoing rapid urbanization. Knorr and colleagues (2019) identify intestinal parasites from latrines in urban areas of Islamic medieval Spain (10th-11th centuries CE) and Portugal (12th-13th centuries CE), finding that despite the documented hygienic practices that were being employed, parasitic infections continued to be an issue, which may have been related to the use of human feces as fertilizer. Likewise, Williams and colleagues (2017) document intestinal parasites from a latrine in a Roman Turkish bath complex (2nd-5th centuries CE), which suggest food and water contamination were an ongoing problem despite sanitation improvements.

Oral Health

Considerations of oral health in conjunction with stress markers also yield important information about urban communities. Analysis of occlusal wear, tooth size, and dental health (e.g., LEH, caries, antemortem tooth loss, calculus, etc.) at Harrapa (c. 2550-2030 BCE) reveals greater molar occlusal wear in males and higher prevalence of most pathological lesions in females (Lukacs, 2017). Perry and Lieurance (2020) examine oral health and LEH in nonadults at Petra (1st century BCE–1st century CE), in modern-day Jordan, to elucidate frailty and dietary patterns within the city. The results indicate that LEH and dental calculus were more frequent in the “elite” façade tombs, which the researchers argue reflect survival of childhood stress episodes.

Stable Isotopes

Isotopic analysis may also yield important information about dietary patterns within and among urban populations. Dietary and weaning reconstruction within and between urban sites enables researchers to assess cultural practices, which may not be consistent from one city to the next or within the same urban center. Craig and colleagues (2009) assess dietary diversity between males and females using $\delta^{13}C$ and $\delta^{15}N$ data in the Roman coastal city of Velia (c. 1$^{st}$ - 2$^{nd}$ centuries CE), and find that diets were not uniform within the city, with males eating greater quantities of marine resources. Henderson, Lee-Thorp, and Loe (2014) assess the long-term health effects of early diet and weaning in males and females of Industrial-Era London (c. 18$^{th}$-19$^{th}$ centuries CE) with incremental dentine analysis. The results suggest a greater susceptibility of males to nutritional deprivation (Henderson, Lee-Thorp, & Loe, 2014; see also Nitsch, Humphrey, & Hedges, 2011 regarding patterns of breastfeeding in 18$^{th}$-19$^{th}$ century London). Tsutaya, Kakinuma, and Yoneda (2020) investigate weaning patterns in 18$^{th}$-19$^{th}$ century Japan, and the results suggest that the end of weaning was earlier than expected.

Comparisons of status differences in urban sites have yielded a variety of results. Diets appeared to have varied little in a Late Iron Age/Early Roman period urban center in England, but by the Late Roman period, diet varied by status (Richards, Hedges, Molleson, & Vogel, 1998). Microdebris analysis of dental calculus and $\delta^{13}C$ and $\delta^{15}N$ data also reveal dietary variation by socioeconomic status and occupation (more animal and marine fish protein consumed by wealthier people) in post-medieval London (c. 1523-1854 CE; Bleasdale et al., 2019). Jørkov and Gröcke (2017) similarly find isotopic differences based on status in Industrial-era Copenhagen, but only for males.

Isotopic analysis of migration is important for understanding how immigration and emigration can alter an urban population, as well as identifying who migrates and what that reflects about larger sociopolitical factors or conditions. For example, Toyne and colleagues (2014) analyzed the isotopes of Moche elites (c. 100-850 CE), finding evidence of patrilocal residence patterns. Peacock and colleagues (2019) integrate evidence of vitamin D deficiency with oxygen isotopic data for an urban Roman site in Switzerland (1st-3rd centuries CE), finding residential mobility affects risks of vitamin D deficiency. Chenery, Müldner, Evans, Eckardt, and Lewis (2010) combine isotopic data on diet and residential mobility to assess variability within the population of Roman Gloucester (c. 2nd century CE). While there were no local dietary or mobility patterns, there was evidence of considerable diversity in the geographic origins of inhabitants of the urban center in general (see also Redfern, DeWitte, Montgomery, & Gowland, 2018 regarding the health of migrants vs. locals in Romano-Britain). Killgrove and Montgomery (2016) find that migrants were predominantly men and children, and that diets changed following migration in Imperial Rome (c. 1st-3rd centuries CE). Tung and Knudson (2011) discover that the Wari Empire site of Conchopata, Peru (c. 600–1000 CE) was inhabited primarily by people local to the area, and that the presence of non-local signatures may reflect captive-taking for military and ritual purposes.

Traumatic Injuries

Studies of trauma within and between urban sites can also reveal the lived experience of varying subgroups within the larger population. Ives, Mant, de la Cova, and Brickley (2017) survey several predominantly lower socioeconomic status urban sites in England (dating to the 18th–19th centuries CE) for evidence of hip fractures in males and females; males were more frequently affected and were more likely to exhibit healing than females (see also Mant, 2019).

Similarly, sex differences in the distribution of fractures in an urban Roman site in Hungary ($1^{st}$-$4^{th}$ century CE) is interpreted as reflecting the more hazardous and strenuous occupations of males; patterns of treatment and healing, however, were similar between the sexes, suggesting equal access to care and similar injury management between the sexes (Gilmour et al., 2015).

Social status may also impact patterns of traumatic injuries. Gagnon and Castillo (2020) compare patterns of antemortem and perimortem violence between burials in a ritual space and burials in a community cemetery at a Moche site in Peru (200-900 CE). More individuals buried in the ritual space had signs of interpersonal violence, most of which was well healed, suggesting that variation in lived experiences of ritual violence are reflected in the spatial distribution of burials at the site. Krakowka (2017) investigates evidence of violent trauma at several urban locations in medieval (1050-1550 CE) London, including parish, monastic cemeteries, and inmate cemeteries. The results indicate that all aspects of London society experienced violence to some degree, with males more often displaying violent trauma.

Activity Patterns

Like traumatic injuries, activity patterns can provide important insight to heterogenous experiences of urban inhabitants. Utilizing data such as osteoarthritis, entheseal changes, and cross-sectional geometry, such studies explore how status and sex can impact activity patterns. Zhang and colleagues (2017) examine patterns of osteoarthritis between males and females in a Late Shang dynasty (1250-1046 centuries BCE) urban population. The results suggest a sexual division of labor and demonstrates a wide variety of activities of urban inhabitants. Wesp (2020) analyzes biomechanical stress via cross-sectional geometry of the humerus in populations of colonial Mexico City (c. 1521-1821 CE). By not dividing the data by sex, the data revealed more categories of stress, reflecting greater variation in the performance of manual labor, than would have been discerned assuming a strict male-female dichotomy. Palmer and Waters-Rist (2019) compare entheseal changes, as markers of physical activity, across socioeconomic status within a Belgium urban site (late-15th to late-18th century CE) but found no significant associations.

### Multiple Indicators

Studies of urban settlements using a range of skeletal data have also been employed to examine the range of variation in lived experiences for inhabitants (e.g., Bourbou, 2018; Kjellström 2020; Lewis, 2011; Scott et al., 2020). Watkins (2012) examines the effects of poverty on degenerative joint disease, trauma, and cause of death in a study of almshouse residents and the general African American population in 19th-20th century Washington, DC, finding that both populations suffered negative biological consequences of impoverishment and inequality, though the nature of those consequences varied. Scott, Danforth, MacInnes, Hughes, and Fonzo (2020) examine two 18th century CE French urbanized colonies in North America, comparing stress indicators, musculoskeletal markers, oral health conditions, and stature, finding minimal differences. Novak, Martinčić, Strinović, and Šlaus (2012) consider stress indicators, oral health, infectious disease, osteoarthritis, and traumatic injuries in a late medieval (12th-15th centuries CE) population in Croatia. The results suggest an overall good quality of life, although some indicators reflect the declining sanitary conditions at the settlement. Kjellström (2020) combines skeletal data with ancient DNA and isotopic analyses in the late 10th century CE urban settlement of Sigtuna, Sweden and argues the city was far more diverse than indicated by the burials, with evidence of varied ancestry, long-distance mobility, and second-generation immigrants.

### Summary

Collectively, the various studies of urbanization, including intra- and inter-city comparisons, emphasize the necessity of such studies in informing our understanding of the effects of urban living. As with the urban-rural comparisons, these studies reflect the high degree of heterogeneity of experience and biological impact from living in cities and towns. While some urban settings are clearly associated with ill effects on general health and longevity, many studies reveal a more nuanced association between urbanization and its biological implications. For example, studies of infection and illness demonstrate how they are influenced by both the natural and built environments in urban settings. While urban settlements in the past are often associated with poor sanitation, garbage and waste accumulation, and pollution of the local water supply, the location of an urban center also matters, as the natural environment can generate additional health hazards. Many of the studies reveal the high degree of variability within and between urban settlements, with socioeconomic status, geographic location, temporal period, natural environment, cultural norms, sex, and age all affecting how and whether urban living creates stressful conditions and negatively influences health. The results of studies comparing sub-populations within an urban settlement warn against aggregating samples such as these, as the diversity of experience can be obscured.

*Urbanization Over Time*

The third and final category of bioarchaeological studies of urbanization explores the effects of urbanization on a population over time (Table 4). By examining a single context over time, these studies benefit from the ability to control for environmental and or climate conditions and can face fewer issues associated with cultural variation that might affect regional comparisons. As with the other categories, however, social stratification, migration, and other sources of heterogeneity might confound studies of urbanization over time. Regardless, a variety of questions can be addressed by such analysis, including: Does increasing urbanization result in more evidence of ill health?; and How are urban inhabitants affected by or how do they respond to crises such as climate change and imperial expansion? Diachronic analysis has the potential to shed light on the effects of urbanization as the process intensifies, including increasing population size, more or intensified changes to the built or natural environments, further development of craft specialization, and the continued evolution of military, bureaucratic, and other authorities.

Stress Indicators, Demographic Patterns, & Growth

Like rural-urban comparisons and research exploring patterns with urban sites, analyses of stress indicators, growth, and paleodemography are commonly employed in diachronic studies of urbanization and, likewise, produce mixed results. For example, Scott and Hoppa (2018) examine stress indicators with increasing urbanization in Denmark ($13^{th}$-$17^{th}$ centuries CE), finding an associated increase in stress. Sołtysiak (2015) also finds evidence of increasing stress represented by higher rates of LEH during periods of rapid urbanization in Syria (3900-2100 BCE). By contrast, Dangvard Pedersen and colleagues (2020) examine the impact of long-term urbanization by investigating mean ages-at-death over a millennium (800-1800 CE) in the town of Ribe, Denmark. The results show an inconsistent pattern of changes in mean age-at-death in conjunction with urbanization. Sparacello, Vercellotti, d'Ercole, and Coppa (2017) find no overall change in stature in relation to urbanization trends in their study of Iron Age Italy (800-27 BCE).

Infection and Disease

As with comparisons of urban and rural sites and studies of urban centers, investigations of urbanization over time also incorporate infectious disease. As urbanization continues and population size and density increase, exposure to environmental pollutants and spread of infectious pathogens are expected to intensify. Dangvard Pedersen, Milner, Kolmos, and Boldsen (2019a) compare temporal rates of TB in a medieval-to-early modern Danish urban center. The results indicate a temporal increase in TB, which may be a function of the effects of urbanization. Betsinger and DeWitte (2017) combine stress marker and paleodemographic data with infectious disease to examine the impacts on health with increasing urbanization in medieval Poland (10$^{th}$-13$^{th}$ centuries CE). They find no temporal change in infectious disease and stress markers, but that there was a significant increase in risk of death as urbanization intensified.

Oral Health and Stable Isotopes

Urban environments, while reliant on agricultural productivity from surrounding areas, may also acquire food through trade or limited production within cities themselves. Additionally, an increase in social stratification may lead to distinct differences in dietary patterns within a population. By examining indicators of diet and weaning patterns over time, it is possible to assess whether diet shifted as urbanization increased. For example, Ullinger, Sheridan, and Guatelli-Steinberg (2015) examine temporal patterns of oral health, including dental caries, antemortem tooth loss, and dental wear, at the Early Bronze Age (3500-2300 BCE) site of Bab edh-Dhra' in modern Jordan. The results indicate a shift in diet as antemortem tooth loss increased and dental wear decreased. Walter, DeWitte, Dupras, and Beaumont (2020) also find evidence of changing diet with increasing urbanization in their stable isotope analysis of an urbanizing population in medieval (1120-1539 CE) London. Britton and colleagues (2018) explore infant diet and weaning patterns in Scotland (12$^{th}$-15$^{th}$ centuries CE), finding a decrease in breastfeeding length as urbanization increased.

Traumatic Injuries

Studies of traumatic injuries have also been utilized to explore urbanization intensification. Robbins Schug, Gray, Mushrif-Tripathy, and Sankhyan (2012) investigate cranial trauma over time at Harrapa in southern Asia (3300-1300 BCE), which experienced rapid urbanization, finding a temporal increase in trauma. Conversely, Šlaus, Novak, Bedić, and Strinović, (2012) examine traumatic injuries in the eastern Adriatic region of Europe from the 2nd to the 16th centuries CE. In contrast with other diachronic studies of urbanization, this region experienced a decline in urbanization, which was found to be associated with an increase in traumatic injuries. Cohen and colleagues (2014) document yet a different pattern in their study of cranial trauma over a 6,000-year period in the southern Levant, suggesting that urbanization did not have an impact on interpersonal violence.

Activity Patterns

Studies of long bone shapes or morphology have also been utilized in diachronic studies of urbanization, as they may elucidate how urbanization affects terrestrial mobility and activity patterns. For example, Sołtysiak (2015) investigates early urbanization and mobility in Syria between the Late Chalcolithic (3900-3600 BCE) and the Early Bronze Age (3300-2100 BCE), finding higher degrees of mobility among males during the earlier period characterized by rapid urbanization. By contrast, Brzobohatá, Krajíček, Velemínský, and Velemínská (2019) find evidence of reduced mobility with increasing urbanization in their study of tibial curvature patterns over several millennia within the Czech territories.

Multiple Indicators

Several studies of the effects of urbanization over time examine a wide variety of skeletal data in order to gain a more holistic understanding of whether and how urbanization impacted biology. For example, Arcini (1999) compares paleodemography, stature, oral health, degenerative joint disease, infectious disease, and traumatic injuries across three temporal periods (990-1536 CE) in Lund, Sweden. The results suggest increasing interpersonal conflict, a shift in diet, and an increase in infectious disease as urbanization intensified. Similarly, in Redfern's (2008) study of paleodemography, stature, oral health, and infectious disease in Iron Age and Roman Britain (4$^{th}$ century BCE–4$^{th}$ century CE), the results reveal temporal changes in all categories, reflecting a decrease in overall health with urbanization. Pérez Rodríguez, de León, and Tuñón (2017) find a more nuanced association between urbanization and changes in health. They compare patterns of stress indicators, oral health, trauma, and degenerative joint disease from the Late Formative to Early Classic periods (300 BCE – 500 CE) in Cerro Jazmín in Mesoamerica, finding that the effects of urbanization varied by age group.

Summary

When considered together, these diachronic studies of urbanization reveal patterns that are compatible with the other two categories of study, as urbanization does not necessarily result in increasing rates of stress, disease, or other markers of ill health over time. Instead, the effects of urbanization are mediated by many other factors, including the natural and built environments, the composition of the population, social hierarchy, migration, and how urbanization itself changes. For example, mobility is not uniformly affected, because factors, such as the local environment, location of important resources, and activities in which people are engaged all affect the overall degree of mobility. Similarly, research on oral health and isotopes reflect the complicated relationship between diet and urbanization, which is highly reliant on local environment, cultural norms and customs, and access to foods across society. Finally, it is important to note that these studies also underscore the complexity of not only the effects of urbanization but of the urbanization process itself, as in some cases, urbanization can slow or be reversed to some degree, which may also produce a unique mix of biological impacts.

*The Future of the Bioarchaeology of Urbanization*

This overview focuses primarily on bioarchaeological studies that have been published in peer-reviewed journals and edited volumes, but we would be remiss, given our interest in where the field is headed in the future, if we did not also highlight some of the work of early career scholars focusing on urbanization. A search of thesis databases, using the terms "bioarchaeology" and "urban," revealed (at the time of writing) dozens of masters and Ph.D. theses deposited recently addressing this topic (we acknowledge that given the inexhaustive nature of these search terms and that our search privileges English language scholarship, we are undoubtedly overlooking important work). Many theses published in the last two years address the same themes that have dominated the bioarchaeology of urbanization over the past few decades, i.e., urban-rural differences or intra-urban variation in patterns of health or stress (e.g., Casna, 2019; Davies-Barrett, 2018; Duffy, 2018; Hodson, 2018; Parker, 2019; Walker, 2020), diet (Petersone-Gordina, 2018), growth (e.g., Stark, 2018), traumatic injury and violence (e.g. Peacock, 2019; Wolin, 2018), migration (Barkmeier, 2020), and activity patterns (e.g., James, 2018).

Recent scholarship is engaging fruitfully and creatively with social theory, technologically advanced methodologies, and multiscalar approaches. For example, Cormier (2018) integrates strontium isotope analysis, mortuary analysis, and osteobiography in a study of migration and identity among urban Mayan elites (c. 2000 BC – 900 AD), finding that most elites were local to the region under consideration and highlighting the importance of ancestor veneration. Barkmeier (2020) also addresses migration, using biological distance analysis and the framework of embodiment to examine patterns of migration under feudalism in medieval England. Bullion (2018) applies geometric morphometric analysis to human remains from several sites in 7$^{th}$-14$^{th}$ century CE Uzbekistan to examine social identity practices and reproductive barriers (or lack thereof) across rural and urban contexts in the context of the rise of Turkic political dynasties and the spread of Islam, and finds that increased urbanism might have promoted shared identity and genetic homogeneity.

Some recent work has addressed resilience or frailty, and several studies highlight the effects of socioeconomic status in moderating the effects of urban environments, in some cases producing seemingly paradoxical results (following the reasoning of Wood, Milner, Harpending, & Weiss, 1992). For example, Barca's (2020) study of trauma and disease in 18$^{th}$-century London reveals higher rates of trauma and pathological conditions in lower status residents, though the survival of many low-status individuals with traumatic injuries into old age provides evidence of their resilience. James (2018) finds that the process of urbanization in North Abydos, Egypt (1069–332 BCE) resulted in various childhood stressors, but that high status buffered the effects thereof.

In general, the trends revealed by these and other recent theses are encouraging, and suggest that there will be a much-needed expansion – geographically, temporally, and culturally – in the coverage of future bioarchaeological studies of urbanization. The lines of evidence and the theoretical approaches being used by these scholars promise to reveal crucial information about the heterogeneity (and its effects) that exists within and between urban areas in the past.

Discussion

The question, then, is what can be concluded about the impact of urbanization for populations in the past and, thus, for contemporary human populations? The answer is that there is no single, simple, all-encompassing conclusion. Instead, the effects of urbanization are varied, nuanced, and time-, place-, and population-specific. Local features of the environment and climate as well as specific cultural aspects affect how and to what degree urbanization impacts a population or subpopulations. For example, seasonal flooding, which is place-dependent and becoming an increasing risk in many areas of the world because of global warming, may affect the spread within an urban area of human feces and the parasites they contain, thereby resulting in a large proportion of the population being exposed to and, potentially, re-infected by various parasites (Shin et al., 2020). Further, not all residents of an urban setting necessarily experience the same effects. Social status and economic standing impact vulnerability to or buffering from many of the consequences outlined in these studies (e.g., Barca, 2020; James, 2018; Reedy, 2020; Zhang et al., 2016). In particular, economics plays a critical role in mediating the effects of urbanization, as higher economic standing may mitigate many of urbanization's potential negative effects, while lower economic status can exacerbate the effects especially for the most vulnerable members of the population. In a study of modern populations, Liddle and Messinis (2013) explore the causal relationship between urbanization and economic growth, concluding that the relationship between the two depends on the overall economic status of the country at the time of urbanization. They note that in high-income countries, urbanization causes economic growth, thereby improving circumstances for many of the residents, while in low-income countries, the relationship is less straightforward. Jedwab and Vollrath (2015) note that this transformation to "urbanization without [economic] growth" (Fay & Opal, 1999) occurred in the late 20th century, when urbanization shifted from the richest nations to the poorest ones, which is where rates of urbanization are highest today (UNPF, 2020). In developing nations, some initial economic growth has led to increased rates of urbanization and migration from rural to urban settings for economic opportunities. However, the high rate of urbanization is not matched by economic development, and many of these burgeoning cities lack the infrastructure to support those migrating there (Cohen, 2006). If there are more migrants than jobs, the unemployed, not infrequently, end up living in urban slums with poor housing that is lacking in sanitation, leading to increased exposure to infectious pathogens. The lack of access to nutritious food and to medical care interact synergistically with higher susceptibility to exposure to pathogens, exacerbating the situation and resulting in high infection rates. This heterogeneity of experiences is reflected in the skeletal record as well. Those who are most impoverished are likely to suffer the greatest negative impacts, while those in the highest socioeconomic status are buffered from them. Assessing this variation in skeletal samples is more complicated, however, as markers of social status within a population are not always discernable.

The comparison of urban and rural populations is also fraught with complicating factors that can be difficult to identify and thus control for in analyses. One issue, in particular, that impedes straightforward interpretations of skeletal data is migration: humans frequently move about their landscape, migrating from rural to urban settings or vice versa, and/or moving between rural settlements or between cities (Redfern, 2020). Further, there is variation by age, gender, culture, and other factors in levels and rates of migration and the length of residency following migration. Bioarchaeologists must confront the problems of identifying locals vs. nonlocals in urban contexts, controlling for return migration to rural areas or general fluidity in movement into and out of urban centers, and how to make interpretations in cases where we are unable to do so. Urban skeletal samples likely include migrants from rural areas, and recent migrants, in particular, likely have biological characteristics and skeletal evidence of disease and stress that are more reflective of the rural environments from which they originate rather than the settings in which their remains were recovered. Ultimately, the potential failure to detect migrants to urban areas leaves us with the question of whether all individuals who are interred in an urban cemetery were lifelong, permanent residents of the city and thus truly representative of urban lived experiences, or whether some of them spent their childhoods in rural areas or migrated to the city relatively late in life such that their skeletally embodied experiences actually reflect non-urban conditions. Further, if people who leave cities for rural areas (and ultimately are buried elsewhere) are not a random sample of urban inhabitants, how does their absence from urban skeletal samples affect our interpretation of the aggregate patterns estimated from those samples? Parallel questions exist for individuals in rural cemeteries who might have lived part of their lives in urban contexts before moving to and dying in rural settlements (e.g., Gowland et al., 2018), complicating the patterns of skeletal data observed in rural cemeteries. Unless the patterns of migration within a population have been established or a method is employed to identify migrants within a skeletal sample, the degree to which bioarchaeological data are impacted is unknown.

Fortunately, it is possible to identify migrants in a skeletal sample using isotopic, biodistance, and genomic data. For example, Petersen, Boldsen, and Paine (2006) detect two different groups residing in a medieval Danish town based on stature and craniometric variability, one of which was mostly composed of migrants. They suggest their findings reflect a "selective" migration from rural areas to the town. This selective migration may result in what is known as the "healthy migrant" phenomenon in which those who migrate to a new locale are at least initially healthier than native-born residents (Chen, 2011; McDonald & Kennedy, 2004; Parker Frisbie, Cho, & Hummer, 2001). This is arguably a function of selectivity among migrants; younger, healthier individuals are more likely to successfully migrate, especially if their goal in moving is to engage in labor (Lu, 2008; Lu & Qin, 2014). If, as it has been argued, rural areas have lower rates of stress, disease, and other markers of ill health while urban areas have higher rates, the movement of "healthy" migrants to urban areas will potentially obfuscate estimates of urban-rural differences in the observed, aggregate data if efforts are not taken to identify migrants. Failure to identify migrants also precludes studying the existence and extent of this important phenomenon in the past. Recent work also shows the promise of using genomic data to estimate population-level rates of migration. Klunk and colleagues (2019) use large-scale genomic analysis to explore demographic shifts in $14^{th}$ century CE Europe, following the Great European Famine and the Black Death, and reveal evidence of a high frequency of female migration during this period. The increasing application of ancient DNA and isotopic methodologies in bioarchaeology in general means that it is at least theoretically possible that the issue of migration can be substantively addressed to a greater extent in the future.

Another issue, as discussed in the introduction, is the treatment of sites as being either strictly urban or rural, rather than considering that a continuum exists between these two or that there is a high degree of variation both within sites and among settlements of the same category (Champion & Hugo, 2004; Schell, 2008). Moreover, as Champion and Hugo (2004) note, there may be no clear dividing line between urban and rural areas due to urban sprawl, and, in modern societies, individuals may live in one place and work in the other. Studies of single urban settlements alone also have significant limitations, as not all urban centers within a country or region will experience urbanization at the same pace or to the same extent, thus making it difficult to infer the biological impact on larger, regional scales. The variation in composition of the populace, environment, local resources, types of labor, and other factors between urban sites of the same region or country can result in drastically different experiences and resulting skeletal impact. As Gamble notes (2020), it is likely urbanization is characterized by regional patterns rather than a single, comprehensive set of changes that affects all populations in the same way.

Another issue many bioarchaeologists face is a lack of appropriate contemporaneous rural comparison samples. Very often bioarchaeological data are available because excavations are done in advance of construction and redevelopment projects, which are more common in urban compared to rural areas. A lack of rural comparison samples clearly impedes efforts to determine whether patterns of health, stress, trauma, diet, etc. observed in urban contexts are truly characteristic of urbanism and distinct from conditions in non-urban areas. Bioarchaeologists interested in the transition to urbanization or the consequences of increasing urbanization can also be limited by poor chronological control, which undermines the resolution necessary to detect temporal trends in skeletal assemblages and to associate those with other phenomena of interest (e.g., climate change). As is true for bioarchaeological studies in general, studies of urban contexts is hampered by potentially biased samples. The opportunistic nature of urban excavations associated with construction projects often means that cemeteries in those contexts are not excavated in their entirety.

Ultimately, one of the very few unambiguous conclusions to be drawn from our survey of the literature is that urban settings are heterogenous. Regardless of time and space, there appears to be variation in the experiences of urban inhabitants based on biology and dimensions of identity such as age, sex, social status, and place of origin. Ideally, we would be able to examine all of these dimensions of potential difference with respect to health, stress, activity, identity, and so forth, but many of these are often not observable to us using skeletal data or burial context (particularly given limited abilities to conduct biogeochemical analyses). We are thus confronted with the conundrum that the aspects of urban environments that so intrigue us as anthropologists – complexity and varied experiences – are inherently difficult to examine via human skeletal remains.

Despite the limitations inherent to studies of urbanization, bioarchaeological research continues to provide a rich record of how settlement pattern can affect biology and behavior more broadly. The apparent contradictory nature of some of the results detailed in this paper does not and should not indicate that such studies are futile. Instead, these studies help elucidate the complex ways in which living in urban settings might affect an individual's lived experiences and a population's overall "health," demography, and social organization. They also demonstrate the necessity for highly contextualized studies that hold as many parameters as possible constant to avoid obscuring potentially informative patterns. For example, stable isotopic analyses to identify locals vs. migrants may not only provide information on population movements in a region, but when integrated with other skeletal data, can also potentially be used to examine the biological and social consequences of migration and how they vary. In addition, the biology of the population plays a significant role in whether urbanization creates positive, neutral, or negative effects. When a population as a whole is regularly exposed to certain pathogens, for example, some degree of acquired immunity may be maintained. For example, Barnes, Duda, Pybus and Thomas (2011) find that the frequency of an allele that provides resistance to pathogens such as *Mycobacterium tuberculosis* is positively correlated with the duration of urbanization; the longer urbanization has been occurring, the more frequently this advantageous allele appears in the population. This might suggest that populations that have been urban for a longer period of time may have less evidence of chronic infectious disease than newly urbanized populations. Bioarchaeological studies exploring the effects of urbanization on a population over time may provide some insight to this topic.

The bioarchaeological research outlined here is essential as urbanization is an ongoing transition, especially in economically vulnerable populations. As would ideally be done in many areas of bioarchaeology, now that many of the methods (e.g., isotope and trace element analysis and ancient DNA analyses) necessary for uncovering variation in diet, migration, and other phenomena have been established and have achieved sufficient rigor and resolution, there should be better integration of multiple lines of evidence in studies of the bioarchaeology of urbanization. For example, scholars interested in the health status of or risk of violence experienced by migrants to cities and how those differs (or not) from those of locals might fruitfully integrate data on stress markers, traumatic injuries, specific infectious diseases, isotopes informative about mobility, and ancient DNA. Integration of DNA, sex, and socioeconomic status data might reveal details about disease ecologies in urban areas and allow for an examination of the heterogeneity that might have existed in terms of exposure and susceptibility to pathogens.

To improve our understanding of the variation that has existed in the conditions and consequences of urbanization, ideally there would be more globally representative coverage of bioarchaeological studies, to the extent possible. Fully achieving this goal is limited by variation in preservation conditions across the regions in which urbanization has occurred (e.g., see Pfeiffer (2020) regarding the general rarity of archaeological discoveries of well-preserved human skeletons across Africa) and variation in resources available for, or perceptions regarding the appropriateness of, bioarchaeological excavation. We also, once again, acknowledge that our survey was limited to English-language publications, and thus the field would benefit from expanded coverage of relevant studies published in other languages.

Bioarchaeological research on urbanization would also benefit from an increase in trans-disciplinary discussion with public health experts, urban planners, and historians, who also investigate the effects of urbanization, which Smith (2010) has argued for in archaeology. As of 2009, more than 50% of the world's population resides in urban settlements (United Nations, 2019). The United Nations predicts that the world's estimated population growth of 2 billion people in the near future will almost exclusively happen in urban areas, with more than 5 billion people living in urban areas by 2030 (United Nations, 2019; UNPF, 2020). Urbanization today has many potential benefits, including economic growth, social mobilization, and the empowerment of women. With greater access to education and health care, there is an associated decline in birth rate, with women in urban areas having fewer children (UNPF, 2020). Despite these benefits, there are important drawbacks as well, most notably high rates of poverty and a steady increase in inequality and related issues of "exclusion, vulnerability and marginalization" (UNPF, 2020). The effects of urban sprawl include further marginalization of impoverished people, pushing them to remote parts of the city, often in slums with their associated unhealthy conditions. By 2012, there were more than 850 million people living in urban slums. While urbanization trends continue, the growth of urban slums also increases, usually as a result of "decisions to limit poor people's access to cities" (UNPF, 2020). Through bioarchaeological studies of the ways in which urbanization affects populations in the past, there is an opportunity to apply this knowledge to contemporary settings.

Toward a Bioarchaeology of Urbanization

Bioarchaeological investigations of urbanization, whether comparing urban and rural sites, examining urban intra- and inter-site difference, or exploring urban centers diachronically, provide important insights into the consequences of one of the most important settlement shifts in human history. We see bioarchaeology as playing an important role in achieving the goals that have been articulated by urban archaeologists. For example, Cowgill (2004: p. 528) writes that ancient cities "cannot be well understood without taking explicit account of individuals - their practices, perceptions, experiences, attitudes, values, calculations, and emotions". This "explicit account of individuals" is at the very heart of bioarchaeology; regardless of the scale of analysis at which a bioarchaeologist is ultimately interested in exploring, data collection begins with the skeletal remains of individual people, and we have the potential to make crucial links between urban contexts and the embodied experiences of the people who lived within them. Raja and Sindbæk (2020: p 11) write that "Above all, archaeology needs to develop approaches to urbanism in terms of social networks, in addition to the settlement patterns and civic institutions that have been highlighted in much previous research….To obtain new answers, fundamental questions concerning human history must translate into investigations concerning such matters as material morphology, phase relations, geochemistry, biology and age, and their interrelationships." They argue that this requires the development of a new level of interdisciplinarity. In our view, bioarchaeological research is crucial to truly achieving much of what they view as necessary developments in the larger field of urban archaeology – i.e., bioarchaeologists are uniquely qualified to provide information about social networks, biology and age, and other variables that give us crucial insights into lived experiences within the cities whose material (rather than biological) remains have been the primary focus of research since the emergence of urban archaeology in the 1920s. Bioarchaeologists have access to information, available via few or, indeed, no other sources (depending on context), about what people were truly doing in past cities: what food and other resources they had access to and what that meant about their social or religious identities, how they were interacting with one another, where they lived prior to migrating to urban centers and how they were treated once they arrived in cities, how they were making a living, how people in cities varied in their chances of surviving, how hazards and benefits were spatially and socially organized, and more.

Bioarchaeological studies employ a wide array of methods and data, yielding a range of results, which collectively demonstrates the complexity of this transition and how it affects humans. They also enable us to draw a number of important conclusions about urbanization. First, urban and rural sites are highly heterogeneous in terms of the population composition, the physical environment, and the sociocultural norms and customs. Second, this high degree of heterogeneity means that there are no universal outcomes associated with urbanization. Many factors can mitigate the effects of urbanization or can increase a population's susceptibility to them, including the pace of urbanization and the degree to which it occurs, as well as economic development and the environment. Third, as in all bioarchaeological research, context is essential, as are attempts to control for confounding factors, such as migration. Finally, bioarchaeological research into urbanization, as outlined here, has identified some of the most important population features that should be taken into consideration to explain observed patterns, including socioeconomic status, sex, and age. Ongoing studies of urbanization continue to expand upon what we have already learned and promise to yield important results in the future that are applicable not only to studies of past populations, but also to contemporary populations that are undergoing and experiencing the effects of urbanization today.

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