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Bioarchaeology and the Skeletons of the Pre-Columbian Maya

Andrew K. Scherer[1]

Abstract This review explores the past two decades of research on ancient Maya skeletons. The focus is on how this work has contributed to our understanding of health, diet, social change, inequality, migration and mobility, war, violence, and ritual practice, with special attention given to recent methodological developments and debates in the bioarchaeology of the Maya. This review essay highlights the most recent findings in the bioarchaeology of the Maya and how those results were achieved. The essay concludes with suggestions for future research and highlights areas of potential collaboration that have been underutilized to address broader anthropological questions.

Keywords Maya · Demography · Health · Diet · Mobility · Embodiment · Violence · Ritual practice

Introduction

The recovery of human bone is inevitable in the archaeology of the Maya. They are deposited in burials and caches, scattered in construction fill, in caves, and at the bottom of cenotes (sinkholes), and reworked as trophies or other worked implements. The certainty of encountering human remains is ensured by the location of Maya burials throughout the built (and unbuilt) environment, from the loftiest pyramids to the humblest house groups. Many of my colleagues grumble at the prospect of finding burials—they are complex deposits filled with fragile bone and other delicate objects that require much time and energy. Yet there is no

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✉ Andrew K. Scherer
andrew_scherer@brown.edu

[1] Department of Anthropology, Brown University, Box 1921, Providence, RI 02912, USA

denying the wealth of information that burials contain regarding the life and death of the ancient Maya. The mortal remains of the Maya also are a vital reminder of the humanity of the Maya, something easy for archaeologists preoccupied with artifacts, ecofacts, and buildings to forget.

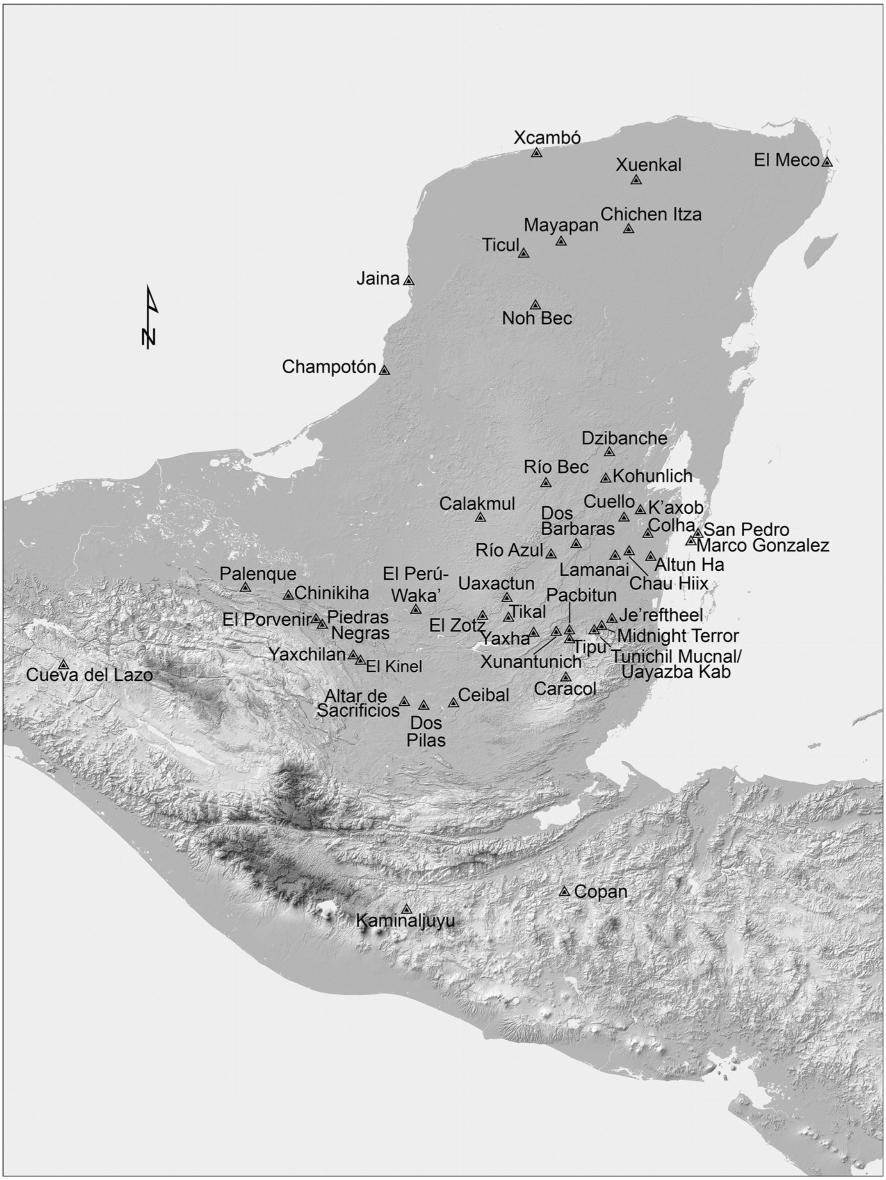

Fig. 1 The Maya area with sites mentioned in the text (map by A. Scherer and C. Golden). The highlands of Chiapas and Guatemala constitute the southernmost region, the southern lowlands are the central region (from Dos Pilas to Dzibanche), and the northern lowlands consist of the Yucatán peninsula (from Champotón to the north)

In this review I consider recent work on bioarchaeology in the Maya area (Fig. 1), focusing especially on the two decades since the publication of the groundbreaking edited volume *Bones of the Maya: Studies of Ancient Maya Skeletons,* edited by Whittington and Reed (1997). During this time there has been a veritable explosion of bioarchaeological research in the Maya area. This surge corresponds to the overall growth of bioarchaeology around the globe in the past twenty years (Larsen 2015). For this paper I focus on scholarship that pertains directly to the study of Maya skeletons. Research on the greater mortuary environment is relevant but beyond the scope of this essay (recent synthetic publications include Eberl 2005; Fitzsimmons 2009; McAnany 2013). Prior surveys of Maya bioarchaeology have been prepared by Wright (2004) and Cucina and Tiesler (2005; Tiesler and Cucina 2014). In the years since *Bones of the Maya*, a number of important edited volumes have been published that focus on Maya/Mesoamerican bioarchaeology or include contributions from bioarchaeologists working on broader mortuary issues: diet and subsistence (Staller et al. 2006; Staller and Carrasco 2010; White 1999), migration and mobility (Cucina 2015a), violence (López Luján and Olivier 2010; Tiesler and Cucina 2007), cranial shaping (Tiesler and Lozada in press), practices pertaining to the postmortem treatment of the body (Ciudad Ruiz et al. 2003; Cobos 2004; Malvido et al. 1997; Serrano Sánchez and Terrazas Matas 2007; Wrobel 2014a), and the royal tombs of Palenque (Tiesler and Cucina 2006).

Since this article is written in English I cite English-language versions of research that has been published in English and Spanish and cite Spanish-language publications that have no English equivalents. The bibliography of recent literature has some of that Spanish-language literature, including edited volumes, from 1998 to the present.

My original intent in preparing this essay was to organize it based on research questions, not methodology. Yet with few exceptions, the majority of bioarchaeological studies of the Maya in the past two decades rely on a single or few closely related methodological approaches to answer research questions appropriate to those methods. Nevertheless, in my discussion I highlight what broader anthropological research questions have been engaged, or could potentially be engaged, using data from Maya skeletons. Although we have learned much about the Maya from the study of their skeletons, a great deal more could be learned with greater collaboration with non-bioarchaeologists. Here I highlight progress that has been made on the topics of health, diet, social change, inequality and difference, migration and mobility, body modifications, war, violence, and ritual practice. At the end of each section I summarize what has been learned from the recent study of Maya skeletons and offer suggestions for future research. Research on sex estimation, age estimation, and paleodemography is not covered in this review due to limits of space.

Reflecting research trends in Maya archaeology, the majority of bioarchaeological studies have focused on the Classic period (AD 250–900). Within the Classic period, fewer skeletons are available for the Early Classic period (AD 250–600) than for the Late Classic period (AD 600–900). Moreover, few skeletons are available from the Preclassic (2000 BC–AD 250) and Postclassic (AD 900–1517) periods.

Paleopathology: Health and Diet

Bioarchaeological approaches to individual health can be classified into three categories: assessments of cumulative health and wellness, identification of acute episodes of stress, and the reconstruction of specific antemortem diseases. The reconstruction of diet relies primarily on observations of skeletal and dental pathologies that correlate with diet and the analysis of stable isotopes of carbon and nitrogen. I summarize these methods as they have been applied to the study of Maya skeletons and review recent studies of ancient Maya health and diet relative to Wright and White's (1996) important assessment of the role of human biology in the causes and consequences of the Classic period collapse.

Population-level differences in growth and development are generally used to assess cumulative health and wellness. Measurements of long bones are used to reconstruct adult height, which at the population level serves as a good proxy for the overall quality of childhood health and diet (Bogin 1999; Eveleth and Tanner 1990; Steckel 1995; Tanner 1989). Bioarchaeologists working with Maya skeletons have long relied on Genovés' (1967) regression formulas, which were developed using measurements of long bones from modern cadavers of primarily indigenous ancestry from central Mexico. Inconsistencies have, however, been noted in the results, depending on which formulas are employed, prompting Angel and Cisneros (2004) to revisit Genovés' original data (in consultation with Genovés) and develop updated equations that should be used for the estimation of stature of Maya skeletons. Genoves' approach requires complete long bones to calculate stature, which is a problem with highly fragmented samples. Wright and Vásquez (2003) have developed standards to estimate long bone length from fragmentary remains that have proven useful in circumventing this issue. The formulas developed by Wright and Vásquez are based on measurements of contemporary Maya skeletons from forensic contexts in Guatemala.

Acute episodes of stress are identified in skeletal and dental tissues based on the temporary arrest of growth during episodes of malnutrition, illness, or both (Goodman 1993; Goodman and Armelagos 1989; Goodman et al. 1988; Larsen 2015, p. 7). In studies of the Maya, such research has focused primarily on observations of dental tissue, including macroscopically observed linear enamel hypoplasia and microscopically documented Wilson bands and striae of Retzius (Danforth 1997; Whittington 1992; Wright 1990, 1997b).

Periostitis is the most common skeletal pathology and results from the abnormal ossification of the periosteum following inflammation from traumatic injury, local infection, or systemic bacterial disease (Weston 2012). If bacteria, particularly *Staphylococcus aureus,* spread to the bone itself, osteomyelitis may result and is identified by osseous sheaths that envelop the bone (involucrum), pits (fistula) that form to drain pus, and focal areas of bone death (sequestrum) (Aufderheide and Rodríguez-Martín 1998). It is possible to reconstruct whether the periostitis or osteomyelitis observed in dry bone was caused by disease that was active at the time of death or if the lesions are from an older pathology from which the individual had recovered prior to death.

A wide range of bacteria may have been responsible for the periostitis and osteomyelitis noted in Maya skeletons, including S*taphylococcus* sp., *Treponematosis* sp., and possibly *Mycobacterium tuberculosis* (Aufderheide and Rodríguez-Martín 1998; Ortner 2002). Only in some cases is the pattern of bony pathology sufficiently specific to determine the underlying disease process that produced the lesions. Treponematosis will often affect many long bones at the same time, especially the forelimbs and lower legs (Cook and Powell 2012; Hackett 1976; Powell and Cook 2005b). Of the four recognized treponemal infections (pinta, yaws, endemic syphilis, and venereal syphilis), yaws (*T. pallidum pertenue*) is endemic to tropical regions and likely accounts for most of the cases of treponematosis observed among Maya skeletal samples (Wright 2006, p. 197). However, endemic syphilis also seems to have been present in greater Mesoamerica (Mansilla and Pijoan 2005; Mansilla et al. 2000; Mayes et al. 2009).

Tuberculosis spreads from the pulmonary region and primarily affects the skeleton as periosteal lesions of the ribs and osteolytic destruction of vertebral bodies, especially the thoracic vertebrae (Roberts and Buikstra 2003). Few if any convincing cases of tuberculosis have been identified for the pre-Columbian Maya. Absence of the disease, poor skeletal preservation, or even resistance to the disease (perhaps from iron deficiency) have all been suggested to explain the lack of bony evidence for tuberculosis among the Maya, although none of these hypotheses can be validated with certainty (Wilbur and Buikstra 2006).

Porotic hyperostosis and the (possibly) related condition, cribra orbitalia, are also especially common in Maya skeletal series (Saul 1977; Whittington and Reed 1997b; Wright and Chew 1999). Porotic hyperostosis is identified as pitting of the ectocranial surface with expansion of the underlying diploë (Angel 1966). Cribra orbitalia also is identified as pitting and diploë expansion but specifically within the eye orbits. Porotic hyperostosis has long been linked to anemia (Angel 1966). Among the pre-Columbian Maya, anemia from a deficiency in iron has long been hypothesized as the chief cause of porotic hyperostosis (Saul 1977; Walker 1986; Whittington and Reed 1997b). This deficiency in iron may have resulted from a dietary shortage of the element, an insufficient absorption of dietary iron, or internal bleeding from persistent parasitism (Saul 1977; Walker 1986; Whittington and Reed 1997b). My colleagues and I found a general association among porotic hyperostosis, dental caries, and elevated $\delta^{13}C$ (see below) across the Maya lowlands, which we suggest substantiates the link between a maize-rich diet and porotic hyperostosis in Maya skeletons (Scherer et al. 2007). There is a recent debate, however, in the greater biological anthropology literature as to whether iron deficiency anemia can (McIlvaine 2015; Oxenham and Cavill 2010) or cannot (Rothschild 2012; Walker et al. 2009) cause porotic hyperostosis. Those who dismiss iron deficiency suggest instead that hemolytic or megaloblastic anemia is the most likely culprit, the latter resulting from deficiency or malabsorption in vitamin B12, folic acid, or both.

Scurvy is another metabolic disorder that may manifest in the skeleton. A shortage of Vitamin C during childhood may result in poorly formed connective tissue that easily fails, causing hemorrhaging and an inflammatory response that ultimately produces pitting of the surface of bone (Ortner et al. 2001; Ortner and

Ericksen 1997; Ortner et al. 1999). Few cases of scurvy have been definitively identified for the Maya. In our study of the skeletons at Piedras Negras, we identified no cases of scurvy (Scherer et al. 2007). At Cuello, Saul and Saul (1997) misattribute scurvy to a combination of periostitis and periodontoclasia, pathologies that can result from a wide variety of other disease processes. The overall paucity of scurvy among the pre-Columbian Maya is not surprising because most Maya populations had access to sufficient dietary vitamin C (e.g., chilies, tomatoes, avocados, papaya, and other fruits). Nevertheless, incidences of scurvy have been identified at select sites. Wrobel (2014b) reports a child's skeleton with lesions that are consistent with scurvy from the Late Postclassic period at Uayazba Kab Cave, Belize. White and colleagues (2006) report that 58% of the skeletons at the coastal Belizean sites of Marco Gonzalez and San Pedro demonstrate lesions consistent with scurvy. They believe that dietary deficiency alone cannot explain this high incidence and suggest that disease synergy with anemia (perhaps triggered by parasitism) was a contributing factor.

Observations of dental pathology have proven especially important for the reconstruction of ancient Maya health and diet (Whittington 1999; Wright 1990, 1997b). Among the most important are dental caries, pits, and cavities that form as a result of bacterial demineralization of enamel by acids produced during the bacterial fermentation of carbohydrates (Newbrun 1982). Maize was, of course, the principal carbohydrate eaten by the Maya. Maize that was ground and processed into dough (tamales, atoles, etc.) inevitably contributed to caries formation. Nevertheless, simple sugars, especially fructose, are the easiest carbohydrates for bacteria to ferment, and the pre-Columbian Maya also consumed fructose as fruit and honey. Although the latter has been suggested to reduce tooth decay through antimicrobial properties (Atwa et al. 2014; Molan 2001), the results of experimental studies on rats confirmed the cariogenic properties of honey (Bowen and Lawrence 2005). In a novel study of incidence of caries formation, Vega Lizama and Cucina (2014) compared the prevelance of caries in a contemporary Yucatán community that generally follows a traditional Maya diet to that of a population with greater access to industrialized processed food. They found a higher incidence of caries in the community that consumed more industrialized processed foods.

A variety of congenital diseases affect the skeleton and a range of pathologies have been noted among the pre-Columbian Maya. At Tikal, Wright (2011) identified a skeleton from the Early Classic period that had abnormal bones of the feet and lower leg consistent with congenital bilateral talipes (clubfoot). Incidences of such pathologies present interpretational challenges when attempts are made to contextualize individuals that express such disorders (Dettwyler 1991). Based on observations of sculpture and stuccowork at Palenque, Robertson and colleagues (1976) proposed that Pakal and other members of the royal dynasty suffered from clubfoot, polydactyly, and other deformities. Analysis of the skeletons of Pakal and other members of the dynasty, however, has found no such deformities (Romano 2006). Neoplasms also are occasionally identified in Maya skeletal samples. Bartelink and Wright (2011) identify two cases of benign mandibular tumors at Late Classic period Tikal.

The poor preservation of Maya skeletons has been a serious hindrance for the identification of pathological conditions. Nevertheless, the Maya data are relevant for understanding the evolutionary history of disease at the global level, especially since from the perspective of bioarchaeology it represents one of (if not the) most intensively studied tropical regions of the world. For example, the origin of venereal syphilis continues to be a source of debate (Cook and Powell 2012; Powell and Cook 2005a). The Maya area was one of the first regions of the New World contacted by Europeans and could be a possible source for the spread of the condition, although no pre-Columbian skeletons with lesions pathognomonic of the venereal form of the disease have been documented in the region. Similarly, the absence of tuberculosis in the Maya region is intriguing in that it has been identified in other parts of North and South America.

Stable Isotopes: Diet

Arguably the single most important development in Maya bioarchaeology in recent decades has been the reconstruction of ancient diets using measurements of stable carbon and nitrogen isotope ratios (Gerry 1993; Gerry and Krueger 1997; White 1997; White and Schwarcz 1989; Wright 1997a). Among the Maya, $\delta^{13}C$ (the ratio $^{13}C/^{12}C$ reported relative to the standard, Vienna Pee Dee Belemnite) is interpreted to chiefly reflect consumption of maize, a C4 tropical plant that has an elevated $\delta^{13}C$ signature relative to the other plants on the ancient Maya menu, which are characterized by a C3 photosynthetic pathway. $\delta^{15}N$ (the ratio $^{15}N/^{14}N$ reported relative to the standard, atmospheric N_2) measures a trophic effect. That is, these ratios can be measured in animal tissue to reconstruct an organism's trophic position with $\delta^{15}N$ increasing further up the food chain. Therefore, among the pre-Columbian Maya, $\delta^{15}N$ measures overall level of carnivory as well as variable participation in more simple (terrestrial) and complex (marine) trophic webs. Soil conditions, however, also can affect the $\delta^{15}N$ of plant foods consumed (Ambrose 1991; Amundson et al. 2003; Ugan and Coltrain 2011), an issue that has not been adequately evaluated for the Maya area.

In all dietary isotopic studies of Maya bone, researchers measure $\delta^{13}C$ and $\delta^{15}N$ in collagen. Some scholars also measure isotopic ratios in bone apatite since spacing in collagen and apatite $\delta^{13}C$ can be used to better understand patterns of meat consumption; collagen carbon ratios primarily reflect carbon routed from protein sources, whereas carbon in apatite is derived from the total diet (Mansell et al. 2006; Metcalfe et al. 2009; White et al. 2001b). Apatite, however, is more prone to diagenesis than is collagen, which is a concern for poorly preserved Maya skeletons (Wright and Schwarcz 1996). Isotopic ratios also are measured in Maya tooth enamel to reconstruct infant diet and weaning practices (Williams et al. 2005; Wright and Schwarcz 1998).

Regional variability in Maya diets has been summarized in recent years (Powis et al. 1999; Scherer 2015a; Scherer et al. 2007; Tykot 2002). The general picture that has emerged is that the Maya consumed significant quantities of maize, although inland populations in the southern lowlands seem to have eaten more maize than their counterparts on the coast and in the northern lowlands. The Belizean coastal sites of Marco Gonzalez and San Pedro are notable exceptions that demonstrate significant $\delta^{13}C$ enrichment, although those values may instead reflect consumption of reef fish that have high $\delta^{13}C$ values (Williams et al. 2009), an issue that complicates the interpretation of $\delta^{13}C$ for coastal populations (Schoeninger and DeNiro 1984; Somerville et al. 2013). Generally, the highest $\delta^{15}N$ values are observed for coastal Belize sites, which reflect consumption of marine fish and shellfish whose tissues are elevated in $\delta^{15}N$. Among the inland sites of the southern lowlands there is some variability within each region (central Petén, Pasión River, Usumacinta River), which suggests that patterns of carnivory among these populations were affected by local, microenvironmental differences in available animal foods, inequality in access to hunting and fishing territory, different hunting and fishing practices, and variability in trade networks (e.g., access to imported dried fish). As an example of this variability, although located only 50 km apart, skeletons from Chinikiha on average demonstrate greater $\delta^{15}N$ enrichment relative to those from Piedras Negras, suggesting greater consumption of freshwater fish at Chinikiha (Montero López et al. 2011; Scherer et al. 2007). The difference is perhaps partially explained by how easy (or difficult) the nearest river sources were for fishing. Chinikiha is located near the slow-moving Arroyo Chinikiha, whereas Piedras Negras is on the banks of the fast-moving Usumacinta River. The complicated political dynamics of the Usumacinta River basin also may have affected access to food resources in ways that we have yet to comprehend. Understanding the impact of political economy on diet is a challenging but fruitful avenue of future inquiry for Maya bioarchaeology, especially when integrated with other regional studies of subsistence, economy, and political history.

Health, Diet, and Time

Years ago, scholars suggested that the political failure of southern lowland polities in the ninth century AD may have been triggered in part by a decline in health and diet as a result of unstable population sizes, overreliance on maize agriculture, and environmental crisis (Culbert 1988; Santley et al. 1986; Willey and Shimkin 1973). In formulating such an explanation for collapse, a few key osteological studies that seemed to show worsening health at select sites were cited as evidence for a decline in the quality of life across the southern lowlands over the course of the Classic period (Haviland 1967; Saul 1972). Synthesizing the available bioarchaeological evidence of the time, Wright and White (1996, p. 188) observe that no such universal decline is evident in the bioarchaeological data and that “the Maya appear to have experienced a health burden that is not out of line with that of other complex preindustrial cultures” and that “few data tie health stress directly to food consumption” (Wright and White 1996, p. 188). Moreover, they found a lack of a consistent trend in the paleodietary data and suggest that a combination of local environmental and political factors best explain local changes in subsistence patterns. They conclude that “the implicit coupling of ecology with disease and nutrition in ecological models of the collapse is not upheld by the human biological data" (Wright and White 1996, p. 188).

Wright and White reached their conclusions after an exhaustive overview of the bioarchaeological data available at that time, finding that the incidence of porotic hyperostosis (anemia) is highly variable among Maya skeletal samples and significant temporal changes are not evident in the data. Moreover, Wright (1997b) found no temporal changes in enamel hypoplasia. The Pasión River region (Dos Pilas, Seibal, Altar de Sacrificios, and other sites) shows no temporal changes in periostitis (Wright 2006), whereas Copan shows a decrease in the prevalence of lesions (Whittington 1989). Wright and White (1996) found that some sites show declining maize consumption from the Late to Terminal Classic period, whereas other sites demonstrated no appreciable change. Around the time Wright and White published their review, Danforth (1994, 1999) synthesized data on Maya stature and found no consistent temporal trend in stature across the Maya lowlands. Overall the sample sizes are so small that it is difficult to use stature for assessing chronological trends in health among the ancient Maya.

More recent work on Maya health confirms Wright and White's conclusions regarding a lack of consistent trends across the Maya area. Preclassic period incidences of enamel hypoplasia and periostitis from Cuello (Saul and Saul 1997) and K'axob (Storey 2004) are comparable to previously reported Classic period data and to newly reported data from the Classic period Yucatán site of Xcambó (Cetina Bastida and Sierra Sosa 2003, 2005; Méndez Colli et al. 2009), whereas the Postclassic Yucatán site of El Meco demonstrates lower incidences of enamel hypoplasia (Ortega Muñoz 2007, tables 3 and 4). The general impression is that enamel hypoplasia and periostitis were persistent conditions in all time periods in the Maya area, but no one period of time or region was particularly worse than others. Incidences of porotic hyperostosis are more variable, with both Preclassic K'axob (Storey 2004, table 6.7) and Cuello (Saul and Saul 1997, p. 35) demonstrating lower incidences of the condition than is typical of most Classic period sites summarized by Wright and White (1996, table 1) and evident in more recent studies at Xcambó (Cetina Bastida and Sierra Sosa 2005, p. 670) and Piedras Negras (Scherer et al. 2007, p. 90). The highest incidences of porotic hyperostosis in the Maya area are at Copan and the Pasión and Usumacinta River regions during the Classic period. Sites in Belize demonstrate less porotic hyperostosis, which could relate to dietary differences (e.g., less maize consumption, as noted above from the isotopic data) or less parasitism in those populations (Scherer et al. 2007, pp. 94–95).

Wright and White (1996) also note a lack of consistent temporal trend in the dietary stable isotopic data. Continued bioarchaeological research confirms that observation among lowlands of Maya sites. Peak maize consumption at Piedras Negras was in first half of the Late Classic period (AD 620–750), with a slight decline (returning to Early Classic period levels) in the years before and after the Classic collapse (AD 750–850) (Scherer et al. 2007). What is most striking about the early Late Classic period at Piedras Negras is the general homogeneity of dietary signatures in regards to both $\delta^{13}C$ and $\delta^{15}N$, consistent with high levels of maize consumption and a dietary preference for terrestrial meat. In contrast, many of the values from the subsequent phase diverge significantly and show decreased maize consumption and especially increased reliance on riverine meat sources. The lack of evidence for environmental degradation and the overall high levels of rainfall in the western lowlands led my colleagues and I to interpret these dietary changes as evidence of a breakdown in the system of food production, tribute, and redistribution within the kingdom of Piedras Negras (Scherer and Golden 2014b; Scherer et al. 2007).

Metcalfe and colleagues (2009) explored dietary trends at the northern Belizean sites of Chau Hiix, Altun Ha, and Lamanai and found that although signatures at these three sites are for the most part comparable, the dietary trends are not. From the Late to Terminal Classic periods Chau Hiix and Lamanai show a slight increase in mean maize consumption, whereas Lamanai shows decreased δ^{13}C. By the Postclassic periods, all three sites show substantially different diets, with Chau Hiix and Lamanai demonstrating significant δ^{13}C enrichment, whereas Altun Ha demonstrates a decrease in mean δ^{13}C. Mean δ^{15}N is for the most part stable at all three sites, although Chau Hiix demonstrates a gradual decrease over time.

Looking at dental caries at the northern Yucatán site of Xcambó, Cucina et al. (2011) note an increase in dental caries in the Late Classic period relative to the Early Classic period. They caution, however, against a simplistic interpretation that attributes this change to an overall increase in maize consumption and suggest that a combination of other factors, such as the overall increased consumption of food or shifts in the menu with the introduction of additional cariogenic food types, may better explain the increase in carious lesions at Xcambó. Synthesizing data from coastal sites in Quintana Roo, Ortega Muñoz (2015) found a relatively constant incidence of porotic hyperostosis and dental caries from the Classic to Postclassic periods, suggesting relative dietary stability and temporal consistency in the burden of anemia.

In sum, two decades of bioarchaeological research has done little to undermine the veracity of Wright and White's statement that there is no evidence for universal declining health and dietary change over the course of the Classic period. Yet the myth of the starving, diseased Maya of the Late and Terminal Classic period remains hard to shake as nonbioarchaeologists continue to reference nonexistent evidence in their statements about the Classic period collapse. For example, one scholar recently acknowledged the existence of Wright and White's synthetic study and yet disregarded their careful synthesis of the data in favor of nonbioarchaeological commentaries that perpetuate the myth of declining health and the Maya collapse (McMichael 2012, p. 4734): "Archaeological studies, too, have identified three periods of social stress, architectural decline, and violent conflict close in time to the three "paleo-climatic" droughts (Gill 2000). Those studies [unlike some earlier research (Wright and White 1996)] reported an increased prevalence of nutritional deficiencies and child-age skeletons during the drying period, along with apparent instances of survival cannibalism (Coe and Koontz 2006; Harrison 1999)." McMichael misrepresents all of the cited sources; Gill's book is not based on original research and in referencing the skeletal evidence for changing health he selectively cites work that predated Wright and White's synthetic study and ignores their paper entirely. "Survival cannibalism" in the wake of drought was never suggested by Coe and Koontz or Harrison, and there certainly is no evidence that the Maya ate people to stave off starvation.

This is not to say the bioarchaeological data have been entirely ignored, as a number of scholars have cited the absence of a consistent diachronic pattern in ancient Maya diet and health in their own models of environment and sociopolitical change (Beach et al. 2015, p. 11; Iannone et al. 2014, p. 65; O'Mansky 2014, p. 161–162; Scherer and Golden 2014b, p. 213). As Beach et al. (2015, p. 25) observe, greater integration of diverse datasets is necessary to better understand human–environment dynamics in the Maya area. This will require closer collaboration among specialists working on climate, environment, subsistence, and health at the same site in a fashion similar to research in the Pasión River region (Dos Pilas, Ceibal, Altar de Sacrificios, and other sites) of Guatemala (Demarest 1997, 2006) but with new methodologies and theoretical frameworks not then available and with a temporal framework that goes beyond the Classic period collapse. Nevertheless, one of the persistent challenges in such multidisciplinary work is arriving at archaeological, paleoenvironmental, paleoclimatic, and bioarchaeological data that operate at comparable time scales.

Diet and Social Difference

The assessment of variability in diet among different Maya peoples within the same community has been of longstanding interest for bioarchaeologists. The dimension of social status has received the most attention. One of the challenges, however, is how to define social status among the ancient Maya, particularly for individual skeletons. Most scholars rely on data from the mortuary context, following the assumption that differences in the location of graves, elaboration of burial architecture, and the quantity and quality of goods should correlate with social status. However, opinions vary among bioarchaeologists (and archaeologists) as to how best analyze these data. Some scholars employ quantitative analyses; others favor qualitative approaches. I elaborate a few of those approaches here to highlight the differences and to discuss findings in terms of inequality, diet, and health.

For the Pasión River region of Guatemala (Dos Pilas, Ceibal, Altar de Sacrificios, and other sites), Wright (2006) tabulates an array of mortuary attributes that she broadly classifies as structural association, skeletal position, grave morphology, and grave furniture. She incorporates these data in a range of univariate and multivariate analyses, ultimately using complete linkage cluster analysis to generate site-specific burial groupings that at least in part relate to status. At Altar de Sacrificios she found that in the Late Classic period elites seem to have had greater access to meat relative to nonelites, but otherwise she found little differentiation among the different burial groups at Altar. For Ceibal she found little difference in dietary isotopes among the different burial groups. At Dos Pilas Late Classic period nonelites seem to have consumed less meat than elites.

Tiesler (1999, pp. 105–106) identifies social status using modified criteria from Krejci and Culbert (1995), where each burial is scored for the presence of prestige variables that include funerary chamber, more than three ceramic vessels, cinnabar, ear flares, stingray spines, more than 20 beads of jade and shell, presence of accompanying bodies, sarcophagus, mask, glyphs, pearls, objects of obsidian and chert, and mosaics. She defines six categories of burial ranging from those with no offerings to interments with more than six prestige variables. Tiesler (1999) classified the majority of the 382 burials that she studied for her dissertation in the first of her two categories and in subsequent research she treated groups with no offerings or only one prestige variable as "commoners" and the remaining burials as "privileged." Using these criteria, Cucina and Tiesler (2003) considered social differences in dental pathology at Calakmul, Dzibanche, and Kohunlich and found that elite males demonstrate fewer dental caries relative to elite females and nonelites of both sexes. They attribute this difference to greater meat consumption among elite men. They also found that elites experienced a greater incidence of antemortem tooth loss.

Rather than follow a priori assumptions regarding the relationship between social status and mortuary variability, Wright (2003) explored differences in isotopic signatures relative to a variety of mortuary variables to determine if presence or absence of certain burial features corresponded to differences in diet at Tikal. The Tikal isotopic sample is largely nonroyal and Late Classic period in date. For most mortuary variables Wright found no differentiation in isotopic signature. The most noticeable distinction is between extended and flexed burials, the latter demonstrating decreased δ^{15}N. Wright (2003, p. 186) notes a similar pattern at Dos Pilas. Although the significance of these two body positions is not well understood, it may be that by virtue of occupying more space, extended burials at Tikal and Dos Pilas were individuals of greater significance within their respective households or lineages. Wright also notes a difference in maize consumption among burials from small residential groups as compared to larger complexes at Tikal. However, the distinction is largely based on four bone samples from small group complexes, whereas most of the other burials from this category have dietary signatures that overlap with those of the larger architectural complexes.

At Altun Ha, White et al. (2001b) acknowledge the complexity of reconstructing status from mortuary contexts and instead compare isotopic values across architectural complexes. For the Late Classic period they found that occupants from near the core of the site (Zone C) had enriched δ^{13}C relative to skeletons from more peripheral contexts, which they suggest indicates greater access to maize in the apparent elite context. At Caracol, Chase et al. (2001) observe that Late Classic period skeletons from tombs in the site epicenter show elevated δ^{13}C and δ^{15}N, whereas Late Classic period skeletons from other parts of the site show a far more heterogeneous dietary signature, with many individuals depleted in either δ^{13}C or δ^{15}N relative to the tomb skeletons. Metcalfe et al. (2009) admit similar uncertainty regarding status at Chau Hiix, Belize, distinguishing with confidence only a probable Early Classic period ruler who was found inside of a tomb. They compared this individual's diet to that of decedents from comparable tombs at Early Classic Lamanai and Altun Ha and note that all three probable rulers have diets distinct from one another and to other burials from their respective sites. When they looked for dietary differences among individuals with burial goods versus those with little to no offerings, they found none.

My colleagues and I (Scherer et al. 2007) took a qualitative approach to the assessment of status for burials at Piedras Negras, identifying royal burials as those with inscriptions that named those individuals as such and commoners as the burials from modest architectural contexts with little to no grave goods. Between those two groups, we recognized likely nonroyal elites as individuals with some prestige goods from significant architectural complexes and important commoners as those individuals from modest contexts but with greater elaboration of their graves and burial goods. Royal and elite diets demonstrated high maize consumption and some variability in patterns of meat consumption, though for the most part having signatures that suggest the meat they consumed was for the most part terrestrial fauna. A significant number of nonelites at Piedras Negras show the same dietary pattern. Thus, temporal differences, not status, likely explains much of the dietary variability at Piedras Negras.

Gender (as inferred from biological sex) was another important dimension of difference in Classic Maya society. As Wright (2003, pp. 178–179) observes, a number of sites demonstrate greater consumption of maize by males than females, including Copan (Reed 1998), Pacbitun (White 1997), Altun Ha (White et al. 2001b), and the Pasión River region (Wright 1997a). At Piedras Negras mean δ^{13}C and δ^{15}N are elevated for men relative to women, suggesting greater consumption of maize and terrestrial meat resources among men (Scherer et al. 2007); however, the number of individuals for which sex could be estimated is small (4 males, 7 females) and the differences are not statistically significant. At Altun Ha, White and colleagues also found that males were enriched in δ^{15}N, which they interpret as perhaps reflecting greater consumption of marine resources by men. Similar δ^{15}N enrichment was observed for Postclassic and early Historic period males at Marco Gonzalez (Williams et al. 2009, p. 51); otherwise diets of males and females at Marco Gonzalez were similar, as they were at nearby San Pedro. Isotopic studies at Chau Hiix found no statistical difference in male and female diets (Metcalfe et al. 2009).

To better understand how diet varied by gender across sites and through time, White (2005) considered isotopic signatures at a series of Belizean sites (Altun Ha, Cuello, Lamanai, Pacbitun, Marco Gonzalez, and San Pedro) that included samples from Preclassic through Historic times. Sample sizes are small, varying between 3 and 13 individuals for each site–sex–time period combination, and thus no statistical comparisons are possible. Nevertheless, White was able to make some useful observations. At many sites, mean male δ^{13}C was enriched relative to females, which White (2005, p. 372) suggests reflects the higher status enjoyed by men versus women since this trend also correlates with status differences at many of the same sites (i.e., elites were enriched relative to nonelites). White also considers snacking and association of certain food types with gender as another possibility. Travel also may be a factor as portable maize-based foods (tamales, pozole, etc.) are the primary foods consumed when men are away from the home today (e.g., when working in the milpa). White found that mean male δ^{15}N is also consistently higher than the female mean, which suggests that Maya men had access to more meat, or different types of meat than Maya women.

Overall, there do appear to be dietary differences among people of different social status and gender within a given Maya community, yet the pattern of those differences is variable. Dietary variability within a population was likely a result of a wide variety of factors that differed from community to community, depending on what foods were available and in what quantities. In synthesizing data from published Maya isotopic studies, Somerville and colleagues (2013) note that overall elite diets tend to be more varied through time than are commoner diets. These results suggest that where dietary variability does exist, it is the elite members of Maya society that were more likely to have options in regards to what they did and did not eat. In contrast to status difference, there does seem to be a trend for greater maize and meat consumption among ancient Maya men, although the difference between the mean isotopic values for each sex is rarely statistically significant. Continued dietary isotopic work on sites with larger samples is necessary to determine if some of the trends noted by White and others are statistically significant.

One of the primary challenges in interpreting these data is that we do not have a clear understanding of Maya systems of food production and distribution, much less how economic strategy varied across the region and through time. We do know that foodstuffs appear to have been exchanged at markets and also given as tribute to Maya kings (Martin 2012; Masson and Freidel 2013; Tokovinine and Beliaev 2013). Yet we do not understand who had access to these markets nor to whom tributary goods were redistributed. Instances of dietary homogeneity (as at Piedras Negras during the early half of the Late Classic period) could point to an integrated system of exchange that involved all members of society. Yet additional data from multiple sources are needed to substantiate such arguments, and bioarchaeological data are rarely consulted in studies of ancient Maya economies. Greater interest has come from scholars interested in social difference among Maya households (Robin 2003, p. 324).

Mobility of Ancient Maya Individuals and Populations

In recent years, bioarchaeologists have employed heritable characteristics of the skeleton and measurements of oxygen and strontium stable isotope ratios to reconstruct migration and movement among ancient Maya populations. Of the two, research on heritable traits—commonly referred to as biological distance (biodistance) analyses—has the deeper history (Austin 1970, 1978; Pompa y Podilla 1984, 1990). Scholars conducting biodistance analyses of the Maya have relied exclusively on dental morphometrics (as opposed to cranial morphometrics) due to poor skeletal preservation and the complicating effects of cranial modification.

Studies of heritable characteristics of the skeleton have been used to examine structure within Maya populations in order to identify whether burial populations included individuals from variable backgrounds, to identify nonlocal individuals, and to look for evidence of immigration. Rhoads (2002) examined dental metric and nonmetric variation at Copan to identify the presence of subpopulations based on lineage or status and to determine if non-Maya populations were present in this community in the southeastern frontier of the Maya area. She found that the Copan pocket was relatively homogenous regardless of settlement location and social differences, although she did identify two lineages based on differences in tooth size. At Postclassic Ixlu, Guatemala, Duncan (2011) noted that three decapitated crania had supernumerary premolars (a rare dental trait among the Maya), which he interprets as evidence that these apparent sacrificial victims were biologically related. At Lamanai, Wrobel and Graham (2015) found evidence for discontinuity between Postclassic period elites and those of the Classic period, perhaps evidence of immigration at the site. Jacobi (2000) analyzed dental metrics and nonmetrics of skeletons buried at the early colonial period community at Tipu, Belize, and found the population was relatively homogeneous and none of the dead were of Spanish descent.

More common than population-specific analyses is the study of patterns of biological affinity among communities across the Maya area (Cucina 2015b; Scherer 2007; Wrobel 2003) or between the Maya area and elsewhere in Mesoamerica (Aubry 2009). These studies reconstruct general population history and identify particular episodes of migration. I conducted a study of both dental nonmetric and metric data from sites in the southern Maya Lowlands and found low levels of among-group variation and a lack of correlation between biological and geographic distance, which I interpret as evidence of sustained gene flow among Maya populations throughout the Classic period (Scherer 2004, 2007). From their analysis of contemporary modern Maya mitochondrial DNA, Ibarra-Rivera and colleagues (2008) found similar evidence for high levels of gene flow among past Maya populations. Based on dental metric and nonmetric variation among Maya and central Mexican skeletons, Aubry (2009) found that sites within the Maya area showed greater affinity to one another than to those from outside the region.

Despite overall homogeneity among Maya populations, careful consideration of the groupings derived from multivariate analyses provides evidence for biological affinities among sites and regions. Cucina and colleagues (Cucina 2013, 2015b; Cucina et al. 2003a, b, Coppa et al. 2008a, b, 2015; Cucina and Ortega Muñoz 2014; Cucina and Sierra 2003; Cucina and Tiesler 2004, 2008a, b) have done the most extensive work, collecting dental nonmetric data from across the Maya area, particularly the northern lowlands. Although different clustering methods produce slightly different results, Cucina (2015b, pp. 75–76) found that generally most coastal Yucatán sites cluster among themselves and with sites in Belize; most inland sites also cluster together. Cucina also found patterns that are interesting in light of Maya political history. For example, Calakmul and Dzibanche consistently group together in his analyses (Cucina 2015b, p. 80), which would suggest that the epigraphically documented movement of the *Kaanul* dynasty from Dzibanche to Calakmul (Martin 2005; Velásquez García 2008) involved some form of gene flow—either a single migration or perhaps ongoing movement of people between these two centers. Moreover, Cucina finds that Calakmul demonstrates affinity with sites to the north, in the Río Bec and Chenes regions of southern Campeche and Quintana Roo. Other notable groupings include the pairing of Tulum and Cozumel on the coast and the clustering of the northern sites of Jaina, Xcambó, Chichen Itza, and Mayapan (Cucina 2015b, p. 81). Champotón (coastal Campeche) and the Puuc region (northern Campeche) also consistently pair together and are otherwise outliers from the rest of the Maya sample (Cucina 2015b, p. 81).

In regards to population continuity in Belize, Wrobel and Graham (2015) found that Early Postclassic period elites from Lamanai demonstrate a number of morphometric discontinuities with Late and Terminal Classic period elites, which they suggest may indicate the elite segment of Early Postclassic Lamanai was nonlocal in origin. In his regional comparisons, Jacobi (2000) found that the dental morphology at Historic period Tipu was different than that of other Belizean sites including Lubaantun and Lamanai. Although the picture is incomplete because of problematic sample sizes, the general picture that is emerging for Belizean population history is that although parts of the region were occupied continuously since Preclassic times, multiple episodes of immigration (and presumably emigration) are suggested by the biological data.

Stable isotopic approaches to mobility are a relatively recent development in Maya bioarchaeology (White et al. 2000, 2001a; Wright 1999). These analyses involve either the measurement of $\delta^{18}O$ ($^{16}O/^{16}O$) or $^{87}Sr/^{86}Sr$, primarily from tooth enamel, to determine whether individuals spent their infancy and early childhood at a location different from their place of burial. Enamel $\delta^{18}O$ is understood to primarily reflect the $\delta^{18}O$ of water that was imbibed at the time the tissue formed. Enamel $^{87}Sr/^{86}Sr$ appears to be largely characterized by $^{87}Sr/^{86}Sr$ of foods consumed. Different standards are used for $\delta^{18}O$ depending on whether oxygen is measured in carbonate or phosphate (White et al. 2000; Wright and Schwarcz 1998). Strontium isotope ratios are not measured against a standard. The advantage of isotopic approaches to mobility is that they can be used to identify an individual migrant. The disadvantage is that they cannot detect locally born descendants of immigrants, can only identify movement across oxygen or strontium zones, and can only reveal nonlocality if the particular segment of enamel analyzed was formed at a foreign location (i.e., the method does not sample an entire childhood but specific points in development). The earliest isotopic studies of mobility in the Maya area utilized either oxygen or strontium exclusively (Price et al. 2007, 2014; White et al. 2000; Wright 2005b); more recent studies have incorporated both lines of evidence (Price et al. 2010; Wright 2012; Wright et al. 2010).

At Copan, Price and colleagues found that some individuals were nonlocal based on both strontium and oxygen isotopes, yet they also report that the observed ratios provided inconsistent results for some individuals, which they suggest "raise questions about the utility of oxygen isotopes" (Buikstra et al. 2004; Price et al. 2010, p. 30). However, this may be too simplistic an interpretation of both approaches. A chief methodological concern in both types of analysis is the definition of "local." Generally, scholars define the expected local range based on isotopic measures of animal and plant tissue, soil, rock, and water considered against the range of signatures evident in the archaeological human bone and teeth. "Foreigners" are identified as individuals who fall outside the expected range and/or are statistical outliers. Yet the baseline data and the distribution of human data do not always perfectly coincide. For example, at Tikal, Wright noted that the mean and mode for human strontium isotope ratios were slightly above what is expected based on measures of local animal bone, shell, and rock samples. She suggests this discrepancy could be due to the regular consumption of imported salt by the ancient inhabitants of Tikal (Fenner and Wright 2014; Wright 2012, p. 340). Similarly, evaporative effects and other factors can enrich local oxygen isotope ratios in liquids above what is expected based on local precipitation. My colleagues and I tested oxygen isotope ratios of a variety of contemporary water sources across the southern lowlands, with multiple samples coming from the same locale in different years (Scherer et al. 2015). Overall, we observed stability in water signatures, which is promising for oxygen isotopic studies of mobility. Yet we did find that some small basins demonstrated an evaporative effect resulting in enriched δ^{18}O, though the extent is relatively small and should not confound studies of mobility as long as researchers are cognizant of the scale and direction of the effect. Such complicating factors as consumption of imported salt consumption or the imbibing of enriched water could explain some of the inconsistencies with “local” and “foreign” oxygen and strontium ratios within a single individual noted by Price and colleagues for Copan. Some of these discrepancies involve individuals who were identified as local based on their observed strontium ratio yet demonstrated enriched oxygen isotopic values above the local expectation (Price et al. 2010, fig. 12). The most parsimonious explanation is that, as children, these elite individuals drank from local water sources distinct from those used by most Copanecos yet consumed locally produced food similar to the rest of the population.

Much of the initial isotopic work in the Maya area was preoccupied with the origins of Early Classic Maya royalty and the question of whether some of these lords spent their childhoods at the great city of Teotihuacan in central Mexico (Buikstra et al. 2004; Price et al. 2010; Wright 2005b). To date, isotopic studies of Maya royal skeletons have yet to identify a king or queen who spent time in central Mexico as a child. However, some Early Classic elites have been shown to have spent part of their childhood at other places in the Maya area, beyond where they were buried, including the putative remains of K’inich Yax K’uk’ Mo’ of Copan (Buikstra et al. 2004; Price et al. 2010). At Early Classic period Kaminaljuyu, a site with clear material connections to central Mexico, good evidence for mobility is demonstrated by both strontium and oxygen isotopic data (White et al. 2000; Wright 2013b; Wright et al. 2010). However, that movement was primarily between Kaminaljuyu and the Maya lowlands and only a single individual, someone who was born and died at Kaminaljuyu, appears to have travelled to central Mexico at some point in their life (Wright et al. 2010, p. 175). At Palenque, the strontium isotope ratios of the remains of Pakal, the Red Queen, and an apparent sacrificial victim found in the queen’s tomb all indicate a local origin (Price et al. 2006).

More recently, scholars have focused on larger isotopic samples to look at overall population-wide patterns of mobility. Price and colleagues (2014) found that at the Copan elite architectural complex 10J-45 and neighboring groups as many as 44% of individuals may have spent part of their childhoods elsewhere. The majority of these burials seem to date to the Early Classic period. In her study of strontium and oxygen isotope ratios of 65 skeletons from throughout Tikal, Wright (2012) found that between 11 and 16% of the individuals spent part of their childhood outside of the central Petén. These nonlocal signatures come from both elites and nonelites, and the greatest percentage is from the Early Classic period. Freiwald and colleagues (2014) determined that 23% of skeletons sampled from the Belize Valley had nonlocal signatures relative to the places they were buried; at the site of Xunantunich many of the individuals who spent part of their childhood away from the community nevertheless received similar mortuary treatments as those who spent their entire lives at the community. However, they also found that there was a tendency for individuals with strontium isotope ratios consistent with the central Petén region to have been buried in atypical burial positions and graves.

In light of the different resolutions and scales of mobility measured by biodistance and isotopic analyses, recent research that integrates the two methods has demonstrated the complementary utility of both approaches. Wright and I looked for temporal differences in population structure at Tikal and found that the biggest change in dental morphometric variability occurred during the Early Classic period, which we attribute to an influx of migrants during that time period (Scherer and Wright 2015). These results echo Wright's finding that immigration at Tikal was highest during the Early Classic period. Comparing the results of dental nonmetric and strontium isotopic analyses from the Noh Bec region of the Yucatán Peninsula, Cucina et al. (2015) found similar results with both approaches, highlighting that the migration they detected seems to have primarily occurred among inland and western coastal communities of the peninsula, with little evidence for exchange with northern coastal settlements or from areas farther away.

Overall, the emerging picture is that the Maya were mobile people throughout their history, with particular pulses of movement or exchange in certain places and times, such as the Early Classic period in the central Petén region (northern Guatemala) and Kaminaljuyu or more or less any time period in Belize. Various episodes of political reorganization, such as the founding and collapse of royal dynasties in the Classic period, likely in part explain this movement. Yet persistent movement is evident throughout the Classic and Postclassic periods, presumably triggered by trade, political restructuring, and other factors that required people (and even populations) to move across the landscape.

Despite the important insights gained from these studies of mobility, there has been relatively little integration of bioarchaeological evidence for mobility with broader archaeological reconstructions of trade, movement, and exchange. There are a few exceptions. For example, recent reviews of research at Teotihuacan note the attempts to reconstruct movement between the great central Mexican city and the Maya area (Cowgill 2008, p. 968; Nichols 2015, p. 18). Golden and I (Golden and Scherer 2013, pp. 404, 427) highlight the relative mobility of Maya populations as one of the challenges to be overcome in Classic period systems of governance. Smith and Schreiber (2006, p. 26) comment on the potential utility of isotope studies for reconstructing pre-Columbian migration history but conclude that "most interpretations of these data, however, are far more tentative and equivocal than archaeologists would like, and they will remain hypothetical until the analytical methods are refined further and combined with more extensive archaeological evidence."

Indeed, future bioarchaeological studies of migration and mobility will need to be more tightly partnered with broader archaeological lines of inquiry, arguably a trend that has already begun. After all, understanding individual and population-level movement is critical for broader reconstructions of ancient Maya political history. These data can be used to probe a variety of issues such as the argument for persistently mobile populations during the Preclassic period (Inomata et al. 2013, 2015), the potential movement of nonelite populations throughout Maya history (Inomata 2004), the travels of elite children as testified in the epigraphic record (Houston 2009, p. 159), and elite marriage alliance. The latter has recently been proposed in an isotopic study by Somerville et al. (2016) at Pusilha, Belize. Indeed, distinguishing between royal children (boys, judging from the epigraphic record, Houston, personal communication 2016) raised as "guests" of foreign royal courts and the movement of woman as part of marriage alliances are interesting topics that warrant further investigation with isotopic data.

Crafted Bodies

Cranial shaping and tooth modification (including filing and drilling) have long been of interest to researchers studying Maya skeletons (Hooten 1940; Stewart 1941). Work on cranial shaping has generally used the typologies devised by Dembo and Imbelloni (1938), while research on dental modification follows the typologies developed by Romero Molina (1970, 1986). In recent years scholars have begun to push past simple tabulations of modification types and have begun to explore the significance of these acts. As a result, bioarchaeologists working in the Maya area have begun to engage literature pertaining to the anthropology of embodiment (Csordas 1990; Mascia-Lees 2011) and with indigenous concepts of the body, relying especially on evidence from epigraphy, iconography, and ethnohistory in both the Maya area (Houston 2001; Houston and Cummins 2004; Houston and Stuart 1996, 1998; Houston and Taube 2000; Stuart 1988, 1996; Taube 1998, 2003, 2004, 2005) and elsewhere in Mesoamerica (López Austin 1988).

Tiesler has conducted the most expansive and synthetic work on both tooth modification (Tiesler 2001; Tiesler et al. 2002, 2005) and head shaping (Tiesler 1998, 2002, 2010, 2011, 2012a, 2013b, 2015; Tiesler and Cucina 2010, 2011, 2012a; Tiesler et al. 2009), the latter of which has recently been compiled in two volumes (Tiesler 2012b, 2013a). Tiesler documented 1,793 crania with head shaping from across the Maya area using a detailed typology that she devised based on Dembo and Imbelloni's system (1938). Tiesler looks at how head shaping varies across time and space in the Maya area and probes the potential motivations for head shaping, which she suggests relate to "head shapes as visible emblems," "the performance of head shaping," and "organoplastic motifs." Tiesler (2012a, p. 17) suggests depictions of different Classic Maya supernaturals perhaps motivated some head shapes. Young gods such as the Maize God are shown with the tabular oblique head form; other supernaturals, like Chaak, have the erect head form, and the skeletal Death Gods have unmodified crania. The degree of variability varies across the Maya area. In the western Maya lowlands (Piedras Negras, Yaxchilan, Palenque), for example, the tabular oblique head form is ubiquitous regardless of status, sex, or kingdom (Scherer in press).

Tiesler's second theme highlights how the performance of head shaping served as an act that socialized and humanized the infant's body's, a point echoed by Geller (2011a). I explore similar concepts and suggest that Maya head shaping was an important first rite of passage for Maya infants and, like many such rites, the endurance of discomfort may have been an important dimension of the process (Scherer 2015a, pp. 26–29, in press). Tiesler (2013a, pp. 18, 22–23) cogently points out that in some sense cranial shaping speaks to maternal tradition, as it was almost certainly the mothers and other female caretakers that placed and adjusted the shaping devices.

Tiesler's third theme pertains to Maya concepts of the body, health, and wellness that have generated much recent attention among bioarchaeologists. Drawing on López Austin's (1988) work on Aztec *tonalli* (souls) and Maya ethnography (Boremanse 1998; Guiteras-Holmes 1961); Tiesler (2012a, p. 47, 2013a, pp. 142–147) suggests that head shaping was done to ensure that the spiritual energy did not escape the body, which could lead to illness or death. There is, however, no textual or iconographic evidence that indicates the ancient Maya perceived the head as the locus of souls. Rather it seems the orifices of the head were understood as openings through which spiritual essences could pass (Houston and Taube 2000, p. 267). Among contemporary Maya, souls are understood as "others," and the self is the conscious rationality of the head that manages those souls (Gossen 1975; Groark 2009; Pitarch 2010, 2012).

Duncan and Hofling (2011) similarly suggest cranial deformation was a way to protect children from illness and soul loss and point also to metaphoric parallel in Mayan terminology for human bodies and houses. They also note that among the contemporary Maya both bodies and houses require rituals to ensure ensoulment (Vogt 1992). However, it is unlikely that cranial modification was understood as the equivalent of placing a roof as the human-house analogy does not seem to have been bidirectional in ancient times. That is, humans are not like buildings. Rather, buildings are like human bodies. Classic period text and imagery include numerous depictions of anthropomorphized buildings, such as the famous "Dazzler" pot from Copan (Bell et al. 2004, plate 7; Taube 1998, fig. 20). In contrast, humans are for the most part not depicted as buildings in Classic period imagery, and there is little evidence to suggest they were understood as such. The one exception is a metaphoric overlap among royal headdresses, censers, and architectural masks that seems to pertain quite specifically to notions of divine embodiment and the *axis mundi*, as opposed to more general body concepts (Taube 1998, p. 466). Rather, vegetation was the predominant metaphor for the Maya in terms of understanding the form and operations of the human body. Thus, Classic period shaping of the head and adornment of the body likened human bodies to plants, particularly maize (Houston et al. 2006, p. 45; Schellhas 1904).

As the ancient Maya used head shaping to initiate the process of humanization, they seem to have completed it with the modification of the teeth. Teeth were modified only around the end of the teenage years or perhaps at the end of the first *winikhaab* (commonly known as the *k'atun*, a cycle of time equivalent to roughly 20 years), despite the anterior teeth erupting by the end of the first decade of life (Scherer 2015a, p. 30; Tiesler 2013a, p. 21). In that sense dental modification may have been understood as a rite of passage to adulthood, and the pain involved with such a practice may have had special relevance (Geller 2006). A variety of interpretations have been offered to explain the different shapes of tooth modifications. The shaping of teeth also seems to speak to notions of the self and soul (Scherer 2015a). The most common dental modification in many Maya skeletal samples is the *ik'* style: lateral notching of the central incisors coupled with filing of the lateral incisors to form a single tau. This motif has long been recognized as emblematic of wind or breath, understood by the Maya as the force of life (Blom et al. 1933). Another common type involves filing the incisors short and notching the canine, perhaps emblematic of animal canines.

A persistent misunderstanding among Maya scholars is that head shaping and tooth modification were privileges of the elite (e.g., Harrison-Buck et al. 2007, p. 79; McKillop 2004, p. 267). Bioarchaeologists working throughout the Maya area have shown that this is not the case. Both the elite and nonelite modified their crania and teeth, and there is no particular head shape or tooth pattern that was restricted to individuals of high status or of a certain sex (Scherer 2015a; Tiesler 2013a, pp. 21–22; Williams and White 2006). An exception is that Classic period inlays of precious materials like jade, pyrite, and hematite are associated with elites.

I expect Maya body modifications will continue to draw the attention of bioarchaeologists, in part because this work articulates well with current work on indigenous understanding of body, self, and souls as well as broader anthropological theories of embodiment. Moreover, scholars are now beginning to consider body modifications comparatively across the Americas (Tiesler and Lozada in press), and this would certainly be a fruitful line of inquiry at a global level.

War and Trauma

Long buried is the notion that the ancient Maya were pacifists (Demarest et al. 1997; Webster 1999, 2000). Nevertheless, the causes and circumstances for violence among the ancient Maya remain an area of active research (Inomata 2014; Inomata and Triadan 2009; O'Mansky and Demarest 2007; Scherer and Golden 2009, 2014a). In the past two decades, bioarchaeology has become a vital element in the greater study of pre-Columbian war, violence, and sacrifice (Barrett and Scherer 2005; Berryman 2007; Duncan 2005, 2009a, 2011; Massey and Steele 1997; Scherer and Verano 2014; Serafin 2012; Serafin et al. 2014; Storey 2014; Tiesler and Cucina 2012b). Nevertheless, contributions from the Maya area remain limited compared to central Mexico (Chávez Balderas 2010, 2014; Pijoan Aguadé et al. 1989; Román Berrelleza and Chávez Balderas 2006; Spence and Pereira 2007; Spence et al. 2004; Sugiyama et al. 2013; Sugiyama 1989, 2005) and especially South America (Arkush and Tung 2013; Murphy et al. 2010, 2014; Toyne 2015; Toyne and Narváez Vargas 2014; Tung 2007, 2008, 2014; Verano 2001, 2008). This is in part due to issues of poor Maya skeletal preservation but also relates to the postmortem deposition of victims of violence, many of which did not enter the mortuary program through "typical" funerary rites.

Osteological evidence for warfare includes antemortem trauma (healed wounds evident in the skeletons of people who survived combat) and perimortem trauma (injuries observable in those who did not survive) (Knüsel and Smith 2013; Martin and Anderson 2014; Symes et al. 2013; Walker 2001). Osteologists generally classify trauma into four categories: blunt force, sharp force, projectile, and miscellaneous (Ortner 2002; Symes et al. 2013). Blunt and sharp force injuries are most likely to be observed among Maya skeletal remains. An implicit assumption in many bioarchaeological studies is that much of the visible antemortem trauma was the result of intercommunity interpersonal violence. Yet ethnographic work reminds us of other dimensions of trauma including accidental injury, corporal punishment, and domestic abuse (Harrod et al. 2012). The identification of perimortem blunt force trauma among Maya skeletons is problematic, as such injuries are characterized by bone fragmentation that is not always easy to distinguish from the postmortem damage that is especially common among poorly preserved Maya skeletons. In that regards, we are undoubtedly underestimating incidences of perimortem blunt force trauma in our skeletal samples. Sharp force trauma is less ambiguous and forms the bulk of our evidence for perimortem violence among the Maya. Nevertheless, care must be taken to not confuse lesions made by obsidian and chert weapons with postmortem damage caused by rodent gnawing or sloppy excavation.

Tiesler and Cucina (2012b) conducted one of the few systematic studies of skeletal trauma, reporting on antemortem and perimortem trauma from 1,103 intact frontal bones from 63 skeletal series. The majority of lesions they identified were healed antemortem blunt force injuries, consistent with slingshot injuries or similar blows to the head. They hypothesized that injuries related to close combat should be more common on the left side of the skull (assuming predominantly right-handed attackers). However, they found no such trend in the data. The lack of clear patterning in cranial trauma points to a range of possible causes for these injuries: war-related combat, interpersonal violence, and accidental injury (Tiesler and Cucina 2012b, p. 173). They also found no significant chronological trend but did note that female crania of the Early Classic period had a higher percentage of traumatic injury than males, whereas male crania of the Late Classic period evidenced a greater incidence of traumatic lesions than females of the same period. In their summary, they noted that crania from the Sacred Cenote at Chichen Itza exhibited a greater incidence of traumatic lesions than other Maya skeletal series, suggesting that the cultural context of deposition is important in regards to expectations for the identification of violence among the ancient Maya. This issue is especially important as we have little understanding of the fate of the bodies of those slain in battle and those who were (presumably) sacrificed after conflict. Moreover, we still have a poor grasp of ancient Maya fighting forces in terms of status, sex, and formal combat training (Webster 2000, p. 99).

Serafin and colleagues (2014) conducted a similar survey of cranial trauma but limited their study to sites from the northwestern Yucatán Peninsula. Their sample consists of 116 “relatively complete crania” from 14 archaeological sites, with the majority (75) coming from Mayapan (Serafin et al. 2014, p. 142). In contrast to Tiesler and Cucina, Serafin and his coauthors do find that a majority of lesions were located on the left side of the crania, which they suggest is evidence that many of these injuries were sustained in combat. We must be cautious, however, in how we interpret such results. Although a side bias in skeletal trauma is inconsistent with accidental injury (which should be side random), an absence of side bias can be explained by other factors. A backhanded swing with a club (or similar implement) by a right-handed assailant would be more likely to impact the right side of the victim's head. Similarly, we should not expect injury from projectile weapons (e.g., sling stones) to favor a particular side of the crania. In other words, the side bias in traumatic injury may suggest that the majority of wounds were not sustained in random accidents, yet the absence of traumatic side bias is not definitive evidence that the majority of injuries were accidental. Since the majority of crania in their sample are Postclassic, it is difficult to draw any conclusions regarding temporal trends in violence. They did find that males demonstrated a higher incidence of traumatic injury than females. Serafin et al. note that most of the injuries they observed were small depressed antemortem lesions, similar to those noted by Tiesler and Cucina. They suggest, however, that some of these lesions could have been caused by arrows and other projectiles, although the bias toward the left side of the head (many near the zygomatic process of the frontal bone) may be better attributed to clubs with protruding knobs (Serafin et al. 2014, p. 144).

Continued work on the bioarchaeology of Maya war is needed but will always be hampered by poor skeletal preservation. The southern lowlands in particular have been inadequately surveyed for traumatic injury. Moreover, greater attention is needed for the analysis of isolated skeletal elements recovered from nonburial contexts, some of which are likely trophies taken from enemy combatants and sacrificial victims who also may have sustained injuries in prior conflicts (Scherer 2015a, p. 100). In comparative terms, scholars have used prevalence of traumatic injury in skeletons as an indicator of levels of past violence (Milner 1995, 1999; Milner et al. 2013; Walker 1989). The Maya offer an important cautionary example that violence may, in some contexts, be underrepresented in the skeletal sample; osteological trauma may seem relatively rare at the same time that text, imagery, and archaeology point toward frequent warfare (Scherer and Golden 2014a).

Ritual Practice: Sacrifice and Mortuary Rites

In recent years, bioarchaeologists have increasingly engaged in reconstructions of ritual practice. Key to reconstructing ritual acts pertaining to human bodies is the taphonomic study of human remains in situ and in the laboratory, ideally by the same bioarchaeologist. Bioarchaeological taphonomy is informed by research in forensic anthropology (Haglund and Sorg 1997, 2002; Pokines and Symes 2013). Some bioarchaeologists also draw from the French *l'anthropologie du terrain,* or archaeothanatology as it has come to be known in the English literature, a methodological and conceptual approach spearheaded by Duday (2009). In essence, the study of burial taphonomy requires detailed description of the burial by someone knowledgeable in human anatomy, the process of decomposition, and the natural forces that can affect the burial environment (e.g., water, root activity, rodents). Archaeothanatology is the most detailed of the mortuary taphonomic approaches, yet its practice ideally requires training with Duday as there is no published methodology in English or Spanish beyond a series of compiled and translated lectures (Duday 2009).

Regardless of the approach to mortuary taphonomy, the objective is the same: to reconstruct anthropogenic activities related to the human and nonhuman forces that affected the body from the point of death to the time of archaeological recovery. Detailed field documentation is coupled with complementary bioarchaeological laboratory analyses to produce a detailed life and death history for individual skeletons (or skeletal elements). An additional level of macroscopic and microscopic analysis includes the identification and interpretation of postmortem changes to bone including fragmentation patterns, rodent gnawing, thermal alteration, and parameters of skeletal commingling (e.g., minimum number of individuals, bone representation index). Analyses of individual (or closely related) graves have proven popular in recent years owing to a variety of factors well reviewed by Wrobel (2014c).

Careful taphonomic analysis is essential for the identification of human sacrifice and other acts of ritual violence (Tiesler and Cucina 2007). The Maya offered sacrifice in a variety of contexts, including both children (especially during royal funerary rites) and adults, some of whom were enemies captured in war (Houston and Scherer 2010; Scherer 2015a, pp. 140–150). Although some obvious sacrificial victims have been recovered (Scherer 2015a, p. 210), the range of treatments of the bodies is not fully understood. A few contexts containing the bodies of numerous slain, presumably sacrificial victims, have been identified in the Maya area, including at Yaxuna (Ambrosino et al. 2003), Mayapan (Masson and Peraza Lope 2014, pp. 527–529), the skull pit and related deposits at Colha (Barrett and Scherer 2005; Massey and Steele 1997), the cenote at Chichen Itza (Tiesler and Cucina 2012b), and a series of deposits from the Postclassic period Guatemalan Petén Lakes sites of Ixlu and Zacpetén (Duncan 2005, 2009a, 2011, 2012, 2014; Duncan and Schwarz 2014, 2015). Yet such mass deposits are less common in the Maya area compared to central Mexico and South America (Verano and Chávez Balderas 2014).

Recent analysis of human remains from Midnight Terror Cave in Belize highlights the complexities of interpreting evidence for sacrifice (and violence in general) in archaeological contexts. Kieffer (2015) reports on human remains from at least 118 individuals that were found in 37 isolated surface deposits throughout the cave. At least 16 of those individuals demonstrate perimortem sharp and blunt force trauma that she suggests is evidence that the individuals in the cave were victims of sacrifice. At least two individuals had fused second and third cervical vertebra, which she diagnoses as probable cases of Klippel–Feil syndrome (a rare genetic disease) and suggests these two people "may have been treated differently, excluded from society and ultimately… [the condition] may have led to them to [sic] being chosen for ritual sacrifice" (Kieffer 2015). Prout (2015) calls into question the accuracy of the diagnosis for one of the individuals, points out that the other individual was likely affected by Type II Klippel–Feil syndrome, and suggests that it is unclear if these individuals would have noticeably suffered from a disability that negatively impacted their quality of life. Conversely, Scott (2015) argues that even if these individuals were disabled, it is unlikely they were perceived as "social outcasts," and the very notion that they were selected for sacrifice because of a purported marginal status is questionable.

The interpretational challenges posed by the remains from Midnight Terror Cave highlight an even greater challenge regarding the correct identification of deposits of respected or venerated kin and fellow community members, as opposed to the deposits of sacrificial victims and desecrated enemies (Duncan 2005; Tiesler 2007). The issue is especially problematic in contexts of body deposition outside the "typical" Maya household interment. For example, a Late and Terminal Classic period peak in the number of bodies placed within Tunichil Mucnal Cave, Belize, "indicates that these individuals were sacrificed in association with agricultural fertility rituals" (Awe and Helmke 2007, p. 33). However, combined bioarchaeological, ethnographic, ethnohistoric, epigraphic, and paleodemographic evidence suggests that the Maya used caves both as sites of sacrifice and also as places to deposit friends and family (Cucina and Tiesler 2014; Scott and Brady 2005; Wrobel et al. 2014). The issue is further complicated by abundant evidence for postmortem manipulation of not only the bodies of enemies but also those of one's own community (Fitzsimmons 2011; Hurtado Cen et al. 2007; Scherer 2015a; Scherer et al. 2014; Tiesler 2007). Even violence directed at the living should not always be understood as violation of an enemy. A series of cache vessels containing severed fingers (predominantly distal fingers) and avulsed teeth (exclusively mandibular incisors) at El Zotz, Guatemala, were most likely removed and deposited by voluntary mourners in the wake of a respected king's death (Scherer 2015a, pp. 153–155, 2015b).

The sacrifice of children is well attested in Classic Maya art (Houston and Scherer 2010; Scherer and Houston in press). From a bioarchaeological perspective, evidence for such practices comes not only from traumatic injury to bone but also from unusual demographic patterning in skeletal assemblages. During the Classic period (particularly the Early Classic), the bodies of Maya kings and queens were often buried with the remains of children and adolescents, the latter being the most uncommon age category in most Maya skeletal assemblages (Scherer 2015a, pp. 140–150). It is unlikely that these children conveniently died around the same time as these important individuals, but were instead ritually killed. At El Zotz, six infants and children (from a few months old to 4–5 years old) lay in lidded cache vessels, entombed with an Early Classic period king (perhaps the founder of the dynasty) (Scherer 2015b). Domenici (2013, 2014) reached similar conclusions regarding the Late to Terminal Classic period remains of 11 children who were found in Cueva del Lazo in the Zoque region of Chiapas, on the western margins of the Maya area. The demographic structure of the skeletal assemblage is quite like that of the El Zotz remains, with the children ranging in age from 6 months to 6 years old at the time of death. Despite the general absence of perimortem trauma, the distinct age structure of the deposit points to child sacrifice in the cave.

Taphonomic analysis is also important for the reconstruction of funerary rites. The disposition of the skeleton at the time of recovery reflects a mix of processes including the body's original deposition at time of interment, the forces of decomposition, the clothing and funerary wraps that restricted the body, placement within dirt fill or an open space, burial reentry, and exogenous forces such as burrowing rodents or tree roots. Tiesler and Cucina's (Tiesler 2006; Tiesler and Cucina 2006) work on the remains of Pakal is an excellent example of what can be gained from careful in situ taphonomic analysis. Generally, decomposition in an open-air environment should result in some scattering of bone as the body putrefies, whereas the presence of clothing or burial shrouds can limit disarticulation. They found that based on the specific arrangement of the skeleton in the tomb coupled with other lines of evidence that the Palenque king must have been garbed in a skirt and generally dressed in a fashion similar to the way he is depicted on stone sculpture at Palenque. In similar fashion, the shrouding of bodies, a practice known through imagery and textile fragments from tombs, can be reconstructed by considering the articulation of the joints of the shoulder and hip, and the positioning of the arms and legs (Scherer 2015a, pp. 83–89; Schneider 2008).

Scholars have long recognized archaeological and epigraphic evidence for mortuary reentry (Fitzsimmons 1998, 2009; Stuart 1998), and consideration of burial taphonomy is essential for reconstructing such events in the field. At Xuenkal, Mexico, Tiesler and colleagues (2010) apply an archaeothanatological approach to the study of a minimum of 18 individuals from five burial assemblages within a single structure. They were able to reconstruct a complex history of inhumation, burial reentry, and movement of bones within each of the burials. At El Kinel, my colleagues and I documented a number of burials that were reentered and from which bones were removed (Scherer et al. 2014). Even entire skeletons seem to have been exhumed at El Porvenir and other sites in the Usumacinta River region, perhaps coeval with the abandonment of those settlements (Scherer 2015a, p. 173).

A variety of funerary and nonfunerary contexts contain thermally altered bone. Macro- and microscopic analyses of burnt bone can be used to determine the timing of thermal exposure (near the time of death or long after a skeletonization) as well as the general type of heat and flame to which the body was exposed (Medina Martín and Sánchez Vargas 2007). In a recently excavated deposit at Tikal, Chinchilla et al. (2015) show that two bodies were burned shortly after death in a postsacrificial rite that may have been meant to recall the mythic birth of the sun. At El Zotz I have shown that the bodies of sacrificed children were burned when charcoal or some other smoldering material was placed around the body and perhaps even within their abdominal cavities (Scherer 2015b). The bodies in the mass grave at Mayapan were also burned (Masson and Peraza Lope 2014, pp. 527–529). The contexts and significance of body burning are highly variable and fully explored in a forthcoming edited volume (Tiesler and Scherer in press).

As bioarchaeologists become increasingly adept at reconstructing ancient Maya ritual practice, future research will undoubtedly involve working out some of the complex significance tied to these acts. A number of scholars have interpreted child sacrifice as a form of exchange with (generally fickle) Maya supernaturals (Domenici 2014; Geller 2011b; Scherer and Houston in press). Others have highlighted the mythic undertones of some sacrificial deposits (Chinchilla Mazariegos et al. 2015). The arrangement of bodies within the grave also provides a window into ancient Maya systems of belief. For example, my colleagues and I have shown that orientation of the body reflects particular practices and ideology distinct to the respective kingdoms of Piedras Negras and Yaxchilan, in part linked to the movement of the sun (Golden et al. 2008; Scherer 2015a; Scherer et al. 2014). At Río Bec, Mexico, Pereira (2013, table 1) observed that seated bodies comprised roughly 25% of the skeletons in the sample. This body position is exceedingly rare in the Maya lowlands. From this and other lines of mortuary evidence he concludes that the position may have been intended to signify "centrality, verticality, the link to earth, and the transformations of the dwelling" in contrast to more typical burials that stress "laterality, horizontality, a link to fire and the domestic hearth, and the permanence of the domestic space." Critical to such work is the presence of bioarchaeologists in not only the laboratory but also the field where they can contribute their expertise to the taphonomic study of Maya bones and graves.

Concluding Remarks: Opportunities, Obstacles, and Impacts in Maya Bioarchaeology

Maya bioarchaeology has flourished in the two decades since the publication of *Bones of the Maya*. In contrast to many other parts of the world, bioarchaeologists working in the Maya area have had to grapple with notoriously poor skeletal preservation. Looking ahead, scholars also must contend with diminished sources of funding and the overall shrinking of excavation projects. Scholars who wish to investigate patterns of diet, health, or mobility over the long term require large skeletal series, the sorts produced by multiyear projects, with combined field crews numbering in the dozens, and excavating multiple months out of the year. Although this situation describes landmark projects such as those at Altar de Sacrificios, Altun Ha, Copan, Lamanai, Piedras Negras, and Tikal, it is unlikely that we will ever again see projects of such magnitude due to the changing landscape of funding, the reorganization of research institutions, and a variety of other factors. Today, archaeological projects in the Maya region are organized around specific questions that can be tested with limited budgets and tend to focus on great public works of elite culture (especially in Mexico, Guatemala, and Honduras) that draw funding dollars from private and public sources but often do not include support for major residential excavation that is necessary to produce large burial series.

Yet the growth of bioarchaeology in the Maya area has been inverse to the decline of large-scale archaeological projects. Although the size of field projects has shrunk, the sheer number of field projects has increased over the decades, resulting in a far more diverse burial record, albeit one where individual site sample sizes are much smaller. The result is that bioarchaeologists working with recently excavated materials must develop research questions appropriate to such contexts as demonstrated, for example, in the contributions to *The Bioarchaeology of Space and Place* (Wrobel 2014a). Nevertheless, the large skeletal series excavated in decades past remain available for future study as our research questions and methods evolve. Indeed, one of the pressing needs facing archaeology in the Maya area is a shortage of space to accommodate new collections as well adequate facilities to facilitate research of curated archaeological collections, including human remains.

Within the broader body of research on the Maya from the past two decades, bioarchaeology has had the greatest impact on our understanding of changing health and diet through time, especially as this work relates to questions of the Maya collapse. Yet bioarchaeological research has been unevenly cited. Some scholars working on paleoenvironmental and paleoclimate research regularly consult current bioarchaeological literature, whereas others do not. In recent years, bioarchaeology also has begun to contribute to discussion of Maya ritual practice, especially on questions of violence, sacrifice, and mortuary practice (Tiesler and Cucina 2007). I expect this will be an area of research and interdisciplinary dialogue that will flourish in years to come. Although bioarchaeologists have long been interested in questions of movement and migration, the dialogue between bioarchaeologists and nonbioarchaeologists could be strengthened. Maya economies remain poorly understood, yet as scholars are beginning to probe these issues more deeply, bioarchaeology has the potential to contribute to research on the economies of food production and distribution despite a history of focusing more narrowly on diet.

Research on Maya skeletons has influenced bioarchaeologists working in other parts of the world. The impact is perhaps greatest in the area of dietary and migratory stable isotope research, due to the trailblazing efforts of a handful of scholars whose studies are frequently cited (e.g., White 2005; White et al. 1993, 2000, 2001a, b; White and Schwarcz 1989; Wright 2005a, 2012, 2013a; Wright and Schwarcz 1998, 1999; Wright et al. 2010). Scholars of the Maya are also regular contributors to comparative bioarchaeological edited volumes ranging on topics from health (Márquez and Storey 2007; Storey et al. 2002), social bioarchaeology (Geller 2006), mortuary archaeology (Duncan 2005; Geller 2011b), the head (Geller 2011a), the bioarchaeology of individuals (Geller 2012; Wrobel 2012), identity (Duncan 2009b; White et al. 2009), commingling (Duncan and Schwarz 2014), and violence (Duncan 2012).

Nevertheless, a review of citation patterns suggests that archaeologists and other nonbioarchaeological scholars working outside the Maya area only rarely consult studies of Maya skeletons. I suspect this is less the fault of the particular bioarchaeologists working in the Maya area and more broadly relates to publishing trends in bioarchaeology at large. As Stojanowski and Duncan (2014) observe, bioarchaeologists in general tend to publish in academic sources with a regional focus or in edited volumes that present global bioarchaeological research united around a thematic focus. Historically missing, however, is a broader engagement with the public and with other domains of academia. As they note, “bioarchaeology also has the potential (unrealized thus far) to directly engage policy debates on topics such as violence, gender, health policy, and matters of the body. In addition, bioarchaeology would be better served and protected from external critique by embracing ‘big data’ and reallocating some of its energies toward exploring and solving problems relevant to the broader social sciences” (Stojanowski and Duncan 2014, p. 58).

Writing on bioarchaeology at large, Knüsel (2010, p. 71) comments that “good bioarchaeological research requires the bioarchaeologist to frame questions to suit the archaeological record and with a good grasp of theoretical insights in order for the study to appeal to both anthropologists and archaeologists and to the wider public." I would suggest that much of the recent bioarchaeology of the Maya would meet Knüsel's definition of "good," yet it remains underutilized by a broader audience. Stojanowsky and Duncan (2014) point toward social media as one venue that bioarchaeologists are beginning to employ to reach the greater public. However, bioarchaeologists also need greater engagement with fellow academics, and for bioarchaeologists studying Maya skeletons that includes other scholars of the Maya. In part, this already seems to have begun in recent years. Bioarchaeologists have been recent invitees at public symposia on the Maya at the University of Texas Maya Meetings and the Tulane University Maya Symposium and Workshop, among others. However, more bioarchaeologists need to follow the lead of White (1999) and Cucina (2015a) and organize conferences and edited volumes that are explicitly interdisciplinary in nature. In terms of bioarchaeology at large, we arguably have achieved critical saturation of interregional edited books about bioarchaeology written for other bioarchaeologists. Instead, scholars studying Maya skeletons need to engage academic dialogues that are both interdisciplinary and interregional in nature in order to share with the world the rich and valuable insight that can be gained from studying Maya skeletons.

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