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MESOAMERICAN BIOARCHAEOLOGY: PAST AND FUTURE

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Abstract

Despite a long history of contributions by physical anthropologists to our understanding of the Mesoamerican past, it has only been over the past few decades that a closer relationship has developed between bioarchaeology and archaeology in the region. The next step should be the integration of bioarchaeologists in the planning as well as the execution of projects. In this review of the present status of bioarchaeology in Mesoamerica we examine its contributions to several broad topics, emphasizing its growing theoretical component and the development of new methods like isotopic analysis, and suggest some lines of inquiry for future investigations.

Bioarchaeology has recently been identified as one of the two most important fields contributing to the advancement of Maya archaeology (Marcus 2003), and that argument might also be extended to the rest of Mesoamerica. Broadly defined, bioarchaeology is an interdisciplinary integration of theory and method that uses any kind of organic remains to test hypotheses related to health, growth and demography; ancient activities and physical behaviors; and cultural and physical environments. However, because a review of such broad topical scale is beyond the scope of this article, we have chosen to limit our content to the histories of skeletal analyses (as bioarchaeology is more traditionally defined) in topics of current interest, and we suggest some future research.

With a few exceptions, the study of skeletal remains was mostly relegated to appendices in site reports until about 1980. Data on age, sex, metrics, cranial and dental modifications, and pathology were largely descriptive and generally not used for hypothesis testing. The most notable early work came from: (1) Hooton (1940), who postulated that Maya health may have declined because of overconsumption of maize, causing the collapse; (2) Saul (1972), who published a monograph devoted entirely to skeletal remains, which established him as the father of osteobiography; and (3) Serrano Sánchez and Lagunas Rodríguez (1975), who incorporated contextual data in their analysis of the La Ventilla B skeletons to produce one of the earliest truly bioarchaeological studies in Mesoamerica.

The present Departamento de Antropología Física in Mexico has, in one form or another, been part of the Instituto Nacional de Antropología e Historia (INAH) since 1951, and students of both archaeology and physical anthropology are trained together in the Escuela Nacional de Antropología e Historia (López Alonso et al. 1985). This led to a tighter integration of archaeology and physical anthropology than was the case in the United States. With few exceptions, however, the inclusion of physical anthropology is now also becoming a regular feature of American projects due to the increased public awareness and popularity of the field, improvements in scientific technologies that enable better hypothesis testing, recognition that human remains are an invaluable source of direct information on human behavior, loss of North American material due to the North American Graves Protection and Repatriation Act (NAGPRA), and burgeoning enrollment in graduate programs focused on physical anthropology. Recently, both physical anthropologists and archaeologists have called for bioarchaeology to take a more prominent role in investigations with closer cooperation between the two disciplines in the planning as well as the execution of projects (Gómez Chávez 2003:16; Serrano Sánchez 2003:11; Serrano Sánchez and Terrazas 2003:91; Tiesler Blos 1997, 2007:37).

In the past, some of our colleagues in Latin America have complained, with justification, that their contributions have not always been adequately recognized in the Anglo-American literature. Similarly, work published in American outlets has not always been referenced in Spanish language publications. These failures reflect the difficulties of communicating across languages and national borders. However, recent developments have greatly improved this troubling situation. One is the creation of American and Mexican journals devoted to the study of the region's past (including its bioarchaeology): *Ancient Mesoamerica*, *Arqueología*, and *Latin American Antiquity*. Another is the creation of several regular conference series with accompanying publications that include scholars from both sides of the border: the Mesa Redondas of Monte Albán, Teotihuacan, and Palenque, and the Coloquio Internacional de Antropología Física, published as the *Estudios de Antropología Biológica*. Also, there is the University of Pittsburgh's distribution of publications from Latin American institutions like the Universidad Nacional Autónoma de México (UNAM) and INAH in the United States, and its joint bilingual publication series with INAH. We have tried in this review to reflect the spirit of this expanding communication.

THE BODY

A rich art tradition and a number of early post-Conquest texts offer insights into Mesoamerican views of the body and the variety of

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practices designed to decorate or alter it, like tattooing, scarification, earlobe plug insertion, and hairstyles (Houston et al. 2006; R. Joyce 2000; Rands and Rands 1965; Thompson 1946). Unfortunately, few of these practices leave traces that survive the dissolution of the flesh. Cranial and dental modification (in a ruder era, cranial deformation and dental mutilation) are the most common of these and were the earliest foci of bioarchaeological curiosity (Cáceres 1938; Dingwall 1931; van Rippen 1917). However, in spite of the long-term interest in these features and the potential they have for yielding cultural information, there has been little interpretation done on body modifications.

As with many kinds of artifactual data, the earliest systematic research on body modifications involved classification. For cranial modification, the system of Dembo and Imbelloni (1938) continues to be used most often (see Tiesler Blos 1998). A classification system for dental filing and inlay was first established by Rubín de la Borbolla (1940) and later replaced by Romero's catalogues (Romero and Fastlicht 1951; Romero 1986). New types are still being added (Howie et al. 2009; López Olivares 1997; and Serrano Sánchez and del Ángel E. 1997). Tiesler Blos (2001:48, Figure 4) argues that an additional level of meaning is introduced by the patterning of types in the dentition. The inlay materials also seem significant, but there has been little research on their meanings or on whether particular inlay materials, tooth modification types, or patterns carry the same meaning in all Mesoamerican societies. Also, although ablation does not belong in a system of crown modification, it is still a form of dental modification and there is evidence for it in both art and cached tooth offerings (Pendergast et al. 1968; Saul and Hammond 1974).

The relationship with social meaning and identity expressed by cranial modification is quite different from that expressed by dental modification because of the different stages of life when they are performed. Cranial form must be altered in infancy and so reflects the agency of those performing the practice. By comparison, dental modification was done on permanent teeth and practiced on late adolescents or young adults (but see Peña Gómez 1992; Tiesler Blos 2001:35, 64), and therefore may be a greater reflection of the agency of the individual.

Cranial modification was ubiquitous, practiced by approximately 95% of the people in both southern Mesoamerica (Tiesler Blos 1998:175) and northern Mesoamerica (Cid Beziez and Torres Sanders 1999a:321; Lagunas Rodríguez 1989:Table 2; Pereira 1999:153–168; Serrano Sánchez et al. 2003:103–104), but the preferred shape could vary by time or space (Lagunas Rodríguez 1989: 30, 33; Tiesler Blos 1998). Although some Maya forms of cranial modification were associated at times with gender or rank, there are no consistent patterns in these aspects of style selection across the region or even within specific sites. Particular variants are occasionally associated with single structures (Tiesler Blos 1998: 206–207), perhaps because of familial microtraditions of using a specific apparatus. By contrast, there are also examples of regional conservatism where styles are uniform over time and among residential groups despite evidence of migration within the region (Howie et al. 2009).

Given the very high frequency of cranial modification in Mesoamerica, at least in the Classic and Postclassic periods, it may be more productive to examine the social identities of those who did not have modified crania. Some of these may be individuals who simply represent unsuccessful attempts (Tiesler Blos 1998: 192), but others may have been denied this common practice because they had some special or aberrant status. Since cranial modification was done in the first few years of life, this denial would have been either the decision of the immediate family or a prohibition imposed on the family by some wider community segment. For example, the two unmodified individuals from the Zona Militar structures of Teotihuacan were both young adult males buried as isolated skulls (Cid Beziez and Torres Sanders 1999a).

Dental modification is a more complex phenomenon than cranial modification, with a good deal more variability in its expression. The available data suggest higher frequencies among the Maya than in northern Mesoamerica (Cid Beziez and Torres Sanders 1999b; Civera 1993; González Miranda and Salas Cuesta 1999; Havill et al. 1997; López Olivares 1997; Martínez López et al. 1996; Peña Gomez 1989; Pereira 1999; Williams and White 2006).

The most significant attempt to synthesize the existing dental modification data was made by Tiesler Blos (2001). For the most part, there are no consistent correlations between particular alteration types or patterns and gender or status. Tiesler Blos (2001: 78–79; see also Martínez López et al. 1996:242) notes general elite associations for Romero's pattern E (inlay) and the Ik pattern (upper central incisors filed in the B-4 form, probably a reference to the Sun God). However, even the B-4 type is often accompanied by relatively unrestrained modification of the adjacent teeth (e.g., Massey and Steele 1997:71). This sort of variability, generally the case even within particular sites, suggests that there are few fixed referents for dental alteration types and patterns and that there is, quite likely, a considerable personal component in the choice of design. However, modifications in Postclassic period Maya elites from residential structures at Lamanai, Belize, seem to indicate a separation of identities that could be rooted in lineages or "houses" (Williams and White 2006), some of which might have been established by intraregional immigrants, as suggested by dietary differences and the ceramic petrography (Howie et al. 2009).

Again, it might be fruitful to focus investigation on who does not have it where it is common, and who does where it is not. For example, only two individuals in the Zona Militar structures have altered teeth. Cid Beziez and Torres Sanders (1999b) note that both are men and are represented only by heads. One also lacked cranial modification. As another example, the high levels of dental alteration among the Feathered Serpent Pyramid sacrifices alerted Serrano Sánchez et al. (1997: 306–307) to the likelihood of their foreign origins, since confirmed by oxygen-isotope analysis (White et al. 2002).

Cranial modification and dental alteration were meant to be viewed, though we don't know the precise balance between aesthetic appeal and public message in them. Trephination, on the other hand, has no public aspect. It is restricted largely to the Late Classic period (Xoo phase) in the Valley of Oaxaca, though earlier cases are known from the Mixteca (Christensen and Winter 1997). There are also some possible cases elsewhere in Mesoamerica, but they are scattered and some have been contested (Wilkinson and Winter 1975a).

Martínez López et al. (1996:242) calculate that 3–9% of the Xoo phase burials from Monte Albán had been trephined, noting that the procedure was done on individuals from the lower ranks of society, occurred about evenly in both genders, and was probably therapeutic in intent. In one particularly revealing case, four individuals from adjacent graves in the same residence had all been trephined, with one to five procedures each (Wilkinson and Winter 1975a, 1975b). The repetition and variety of techniques have suggested to some that there was an aspect of medical experimentation to

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the trephinations (Wilkinson and Winter 1975b:23; González Licón and Márquez Morfin 1990:129–130). Some examples do seem to be associated with prior cranial trauma or infection (e.g., Christensen and Winter 1997), but neither therapeutic intervention nor medical curiosity can account for all.

The supra-inion depression has been explained by some as the healed traces of a trephination done by scraping while others maintain that it is an unintended by-product of cranial modification. Lagunas Rodríguez (1989:39, 41, 43–45) and Tiesler Blos (1998:91, 204) believe that most cases result from the apparatus used in cranial modification, particularly of the tabular erect variety, but say that some subadult crania nevertheless seem to show deliberate surgical intervention (e.g., Lagunas Rodríguez 1989:Figures 13–14). If so, the intervention may only have been intended to treat reactions to the modification device. The interaction between genetic/congenital factors, biomechanical forces, and infection in the development of the supra-inion depression in modern children is presently being investigated (Derrick 2009).

THE COMPONENTS OF IDENTITY

Identity is both biological (sex, age) and social (rank or class, ethnic affiliation, occupation). Biological sex and developmental age are the most fundamental aspects of osteological analysis as well as the most enduring and basic elements of identity in that they form the basis of cultural constructions like gender. Occupational activities have been sparsely investigated in Mesoamerica but can sometimes be reconstructed from muscle markings even when no artifactual evidence exists (White et al. 2009).

Age categories, particularly those of childhood, are now starting to receive more attention from Mesoamericanists (Ardren and Hutson 2006). Children are no longer assumed to be simply the passive recipients of cultural transmission, but are now seen as having, and practicing, agency (Joyce 2006:296). There are also some data to suggest that certain subadult age categories were widely recognized in Mesoamerica (Ardren 2006:9; R. Joyce 2000, 2001a, 2006:285–286; Storey 1992a; Storey and McAnany 2006). These include infancy, early childhood (pre-weaning toddlers), and perhaps two or three more that are less clearly defined. The transition from one category to the next may have been triggered by chronological age, biological development (e.g., menstruation), or by particular events or achievements that may have been only loosely correlated with age.

The social meaning of age in relation to gender is well illustrated by a DNA study of sacrificial remains at the Aztec city of Tlatelolco where there is a preference for male children as victims of sacrifice (de la Cruz et al. 2008). Male children under weaning age (approximately 3 to 4 years) appear to have had special currency for the negotiations of the Aztecs with their gods. López Austin (1984) has proposed that the purity required to communicate effectively with the gods was most easily obtained with children (especially those still breast-feeding). Males may have been chosen in order to properly personify male deities (de la Cruz et al. 2008). The recent ability to identify sex in subadult skeletons through DNA analysis is a particularly significant breakthrough in understanding the social meaning of childhood identities.

The shift from childhood to adult status may have come fairly early in Mesoamerica. The presence of some early teens (14–16 years of age) among the soldier sacrifices at Teotihuacan's Feathered Serpent Pyramid shows that, even before the age of 16, males could serve in the military and be sacrificed in that role (Serrano Sánchez et al. 1991). Some of the human trophies worn by the soldiers indicate that the Teotihuacan military considered enemy subjects in that young age bracket to be acceptable kills (Spence, White, Longstaffe, and Law 2004:9). Women may have achieved full status in Teotihuacan society at an even younger age; those sacrificed at the Feathered Serpent Pyramid were as young as 13–15 years (Serrano Sánchez et al. 1991).

In the Maya world there is an especially rich literature on gender studies in which the social, political, and economic status of women is debated in terms of complementary versus hierarchical roles (Ardren 2004; Gustafson and Trevelyan 2002; R. Joyce 1996, 2000; Pyburn 2004). These topics have not been explored as extensively in northern Mesoamerica (but see González Licón and Zamora Sánchez 2008; Brumfiel 1991, 1996; Serra Puche 2001), and unfortunately biological data have not been used very much in this debate (but see Storey 2008). Not only has there has been little attempt to reconstruct women's activities from the skeleton, but mortuary treatment is still the primary means of determining socioeconomic status. Our ability to reconstruct female identities has largely been limited to diet and health studies (see below), but isotopic mobility research is now enabling a better understanding of the political roles played by women in terms of marriage alliance (e.g., Buikstra et al. 2003; Price et al. 2007), and their roles in enculturation (White, Spence, Longstaffe, and Law 2004) and economic activity (Spence, White, Longstaffe, Rattray, and Law 2004). In the ethnic barrios of Teotihuacan the status of women seems to have been particularly enhanced and their roles expanded (Spence et al. 2005).

The first significant contribution to reconstructing social status using biology in Mesoamerican societies was made by Haviland (1967), who found that high status males at Tikal were taller than their contemporaries (but see Danforth 1994). It is generally assumed that social rank differentially affected exposures to environmental and health hazards. Elite status would presumably have allowed access to purer water and a wider variety of foodstuffs, improving health (Coyston et al. 1999; Storey 1999). For conditions such as dental disease and weaning stress elites may have suffered the same difficulties as commoners (Storey 1999). Certain elite practices may even have put them at a disadvantage—for example, the expectation of military service, frequent autosacrificial rituals that opened the door to infection, and perhaps some ritual restraints on food consumption or even the overconsumption of food (artistic representations frequently show obesity among elites [Robiscek 1981]).

In general, studies of social organization have long been limited by sampling designs in which ceremonial sites, and particularly the core areas, were predominantly targeted for excavation. Nonetheless, dietary and dental modification studies have shown us that elite groups had separate identities within sites (White, Pendergast, Longstaffe, and Law 2001; Williams and White 2006) and that there were regional heterarchies of elites (Metcalfe et al. 2009). Post-processual approaches to elites also resulted in individual biographies of important personages (Buikstra et al. 2003; Tiesler Blos and Cucina 2006a), and mobility analyses are enabling us to understand more about the intersite interactions among elites (Wright 2005a).

In the Maya area, the dominance of research questions relating to the collapse has also limited our understanding of changes in social organization over time. More recent research activity in the Preclassic and Postclassic periods is beginning to enable a reconstruction of the broader dynamics of social organization. For

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example, isotopic analysis of human skeletons at the Preclassic period site of Cahal Pech indicates strong social differentiation at this very early time (Powis et al. 1999) while, by contrast, other studies suggest less differentiation during the Postclassic period (Williams et al. 2009).

DIET AND HEALTH

The majority of research on skeletal pathology in the Mesoamerican world is currently related to either nutrition (e.g., Whittington and Reed, eds. 1997) or trauma resulting from conflict and sacrifice (Barrett and Sherer 2005; Nance et al. 2003). Although the existence of a very large number of medical conditions is indicated by descriptions of illness in the codices and the ethnobotanical pharmacopeia (Roys 1931; de la Cruz 1940), other categories of pathology such as metabolic and infectious diseases, tumors, and genetic conditions are notably underrepresented in stand-alone research (but note Jaén et al. 1991). A very early interest in syphilis (Ashmead 1896; Goff 1953) has, however, persisted in Mexico and expanded to treponemal infection in general (Mansilla Lory and Pijoan Aguade 2005; Pijoan Aguade and Salas Cuesta 1991). Congenital pathology has been observed in art (Murdy 1981; Robertson et al. 1974), but only occasionally in bone (Romano Pacheco 1991). Here, however, we will deal only with the relationship between diet and health. Inadequate diets can be manifest in slow growth and development, nonspecific juvenile stress indicators, nutrient deficiencies (particularity iron and vitamin C), nonspecific infectious disease, and demography.

In the 1970s, processual archaeology, with its emphasis on subsistence and adaptation, was the dominant paradigm in American archaeology. This is when we started to see bioarchaeology developing, bringing with it a means of understanding relationships among culture, environment, and biology, which continued in the 1980s and after—for example, the demonstration that Formative period Mesoamericans suffered fewer health problems as a result of plant domestication than those living in other parts of the world where the transition was more abrupt (Hodges 1987, 1989).

Although maize was generally assumed to be the staple crop in Mesoamerica, it was not until human skeletons were analyzed with stable isotopes that we were able to quantify the actual consumption of maize (White and Schwarcz 1989). This biochemical approach has burgeoned because it provides direct evidence for food consumption as opposed to the inferences allowed by pathology, and it enables the investigation of diverse biological and social issues. Although the isotopic evidence indicates that maize was indeed the staple at all sites investigated to date, there is great variability in its consumption across space, time, and social groups (White, Maxwell, Dolphin, Williams, and Longstaffe 2006). Protein sources tended to be more stable over time but varied considerably by region and included terrestrial mammals as well as marine and reef resources. Status was expressed by consumption of foods that were most difficult to obtain or held ideological significance. In some environments this was maize, or maize-fed animals, and in others it was high-trophic-level hunted animals or marine resources (White 1999).

Both the rise and fall of Maya civilization are associated with maize. Iron deficiency has been linked to its overconsumption (El-Najjar 1976), and is manifest throughout Mesoamerica by the skeletal lesions of porotic hyperostosis and cribra orbitalia. Very early in the history of Maya archaeology Hooton (1940) challenged archaeologists to investigate iron deficiency as a reason for the Classic period collapse of the Southern Maya Lowlands after he observed a high frequency of porotic hyperostosis among the skeletons from Chichen Itza's cenote of sacrifice. This idea formed the root of the ecological model for the collapse. The ability to use stable isotope analysis to reconstruct diet in the absence of pathology has been enormously helpful in untangling relationships among maize consumption, environmental change, cultural change, and nutritional deficiency. For example, tests of the ecological model using both isotopic and pathology data do not support it as a pan-Maya explanation of the collapse (Wright 1997a, 1997d; Wright and White 1996).

Lesions consistent with vitamin C deficiency have also been reported (Saul 1972; Kennedy 1983). However, it is particularly difficult to believe that scurvy was caused by a dietary deficiency in an environment so abundant in sources of vitamin C. Iron and vitamin C deficiencies continue to be investigated, especially in the Maya area, but their relationship to one another and with diet and the environment is still unclear. The role of parasites or other nondietary factors in creating these deficiencies needs to be more thoroughly investigated. Certainly in coastal sites where marine resources were consumed in significant quantities, parasites may be implicated (White, Longstaffe, and Schwarcz 2006).

Studies of juvenile stress in terms of growth and development research have constituted another major area of investigation into health (e.g., Peña Reyes and Hernández Espinoza 2008). Since the 1930s (e.g., Steggerda 1932) modern Mesoamerican First Nations populations have been the subject of anthropometric research directed at understanding relationships between genetics and the environment. This area of the world became a major research laboratory for nutritional and developmental studies in the 1970s (Frisancho et al. 1970; Himes and Malina 1975; Johnston et al. 1975; Nickens 1976). The resulting database has a potential for analogy but is underused by bioarchaeologists. Although the effects of stress on sexual dimorphism and body height are still unclear and most likely regionally and temporally variable, it appears that ancient populations were taller than those in later times (Danforth 1994, 1999; Márquez Morfin 2008). Although this seems counterintuitive, the osteometric data likely suggest a high level of adaptation to environments more densely populated than today. Growth and development studies should also be used to contribute to our understanding of the childhood experience.

Another commonly used measure of juvenile stress is enamel defects, whose expression varies by time and place (Danforth 1997; Dolphin 2000; Mansilla Lory and Villegas Alcántara 1995; Storey 1997). Enamel defects cannot tell us the specific cause of stress, but the timing of their formation indicates that they mainly marked the weaning period and that the time of greatest childhood vulnerability was generally between three and four years of age, which has since been verified with stable isotope analysis (White, Pendergast, Longstaffe, and Law 2001; Williams et al. 2005). Storey (1992a, 1997) has noted that privilege did not buffer children from such stress at Copan.

Our understanding of the effect of childhood morbidity on populations has been hindered by challenges to the methodological validity of osteological paleodemography, sampling, and preservation problems (Waldron 1994; Wood et al. 1992). Although there has been a long-standing interest in ancient Mesoamerican demography (e.g., Moll 1941; Thompson 1965), it has focused primarily on the depopulation effects of the Maya collapse and the Spanish conquest (Culbert and Rice 1990; Demarest et al. 2004; Me-Bar and Valdez

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Jr. 2004), and models of change are generally not grounded in the skeletal record (but see Márquez Morfin 2008). Significant methodological and theoretical contributions have been made by Storey (1986, 1992b, 1997, 2007) to expand the applications of paleodemography and the use of the skeletal record in both Mexico and the Maya region—for example, her demonstration at a Teotihuacan apartment compound that large cities depended on immigration to maintain their populations because of high infant mortality rates. This must have had consequences for the cultural homogeneity of the community, rural-urban relations, and the potential for internal conflict. Storey (1992a) was also among the first bioarchaeologists anywhere to tackle the issue of "frailty," which was raised in the *Osteological Paradox* (Wood et al. 1992) as a source of error in the interpretation of ancient health status.

MOBILITY

Reconstructing the movement of people using the material record has been an enduring preoccupation of Mesoamerican archaeology and an area in which we have seen some of the most significant methodological developments using the biological record (Marcus 2003). The identification of mobility from skeletal remains can be based on either biological (genetic, chemical) or cultural (cranial/dental modification) characteristics. Here we focus on biological markers. Environmental characteristics are chemically recorded in the skeleton and can reflect changes in residential experience. Genetic makeup, however, cannot change within the lifetime of an individual. Therefore, these two characteristics may or may not be related. The size of gene pools mapped onto a landscape can vary so the relationship between geographic movement and genetics may not always be clear with the analysis of genetic markers alone.

The investigation of mobility began with the use of genetic (or epigenetic) indicators. Both metric and nonmetric osteological and dental data and a variety of statistical techniques have been employed to trace migrations and the development of populations through biodistance measurements (Christensen 1998; del Ángel E. 2003; Gómez Valdés et al. 2008; Haydenblit 1996; and Jacobi 1997). One of the most recent, and most ambitious, of these has been the attempt by Beekman and Christensen (2003) to trace the movement of Nahua speakers in Mesoamerica.

These methods have also been used to investigate the subdivisions and local movements of people within a society; the differential circulation of genders in a postmarital residence system (Spence 1994), the social/genetic isolation of elites (Wilkinson and Norelli 1981), and the formation of new groups or classes by intrusive outsiders (Jacobi 1997; Vargas 1973). However, there are a variety of potentially confounding factors that must be controlled. These include interobserver error, inadequate samples, the effects of environment on expression of the genetic substrate, the selection of inappropriate traits, founder effects, and others. Many studies, including some of those mentioned above, have not been entirely successful in avoiding these obstacles.

One frequent error is the use of oversimplified constructs, assuming uniformity where there is often diversity. This might not be a major problem if the sample is broad enough to encompass that diversity, but, given the limitations of archaeological excavation, that would rarely be the case. Most biodistance studies take one or two extant skeletal samples to be representative of an entire site. Although a reasonable assumption for small communities, this is unlikely to be true of urban centers, whose populations are genetic mosaics that require extensive and carefully designed sampling.

These concerns are also valid at a smaller scale. Even residences may be socially and genetically diverse. The concept of "house" is particularly appropriate here, especially with reference to the larger households of elites (Gillespie 2000b). They may contain not only close family but also more distant kin, attached specialists, servants or slaves, and perhaps others. At this reduced scale statistical techniques would not be of much use. Bioarchaeological investigations may have to focus on other methods. DNA analysis is one option (e.g., Fournier and Vargas Sanders 2002). Another is the use of what Rösing (1986) has called "private" traits—nonmetric characteristics that are relatively uncommon but that have a more direct genetic base, less encumbered with epigenetic baggage (Jacobi 1997:147). While these can be very informative, their presence in any particular series is fortuitous.

There is another potential source of bias. In most Mesoamerican residential contexts the number of burials present, even in fully excavated structures, is far less than the number of residents who must have died over the course of the occupation. It is suspected that many burials were displaced during structural renovations by later inhabitants (Saul and Saul 1997: 29; Storey 1992b:127–130). Storey's (1992b:134–136) analysis of human bones in nonburial contexts (e.g., middens, construction fill) in the Tlajinga 33 residence almost tripled the number of identified individuals, but this is still likely only one third of the number who must have lived, and died, in the excavated area over the three or four centuries of its use. Furthermore, the demographic profile of the recovered burials differs from that of the displaced material, rendering interpretations based only on the intact burials suspect. The most worrisome specter is that in some societies entire segments of the population may have been channelled into mortuary tracks that have left no trace. At the very least then, bioarchaeologists should be searching out all such displaced bones and incorporating them fully into their analyses.

Recently, biochemical techniques have been enlisted in the investigation of mobility. DNA analysis comes immediately to mind but, at least at present, it is not widely used. It is difficult to extract usable DNA from the poorly preserved bone of Mesoamerica, and reliable interpretations generally require broad genetic sampling in a region (Merriwether et al. 1997). As DNA data banks grow, the technique should become more useful. One of its few successful applications to date involves the complex question of population movement and ethnic continuity in Epiclassic-Early Postclassic period central Mexico (Vargas Sanders and Salazar Campos 1998; Fournier and Vargas Sanders 2002). At a finer scale it has also clarified the nature of the social units occupying residential structures in Epiclassic period southern Hidalgo communities (Fournier and Vargas Sanders 2002:58–59).

Isotopic analyses (strontium and oxygen in particular) are presently more widely used in the investigation of these sorts of questions (Manzanilla et al. 2000; Price et al. 2000, 2008; White et al. 1998) because they act as geographic markers. The oxygen-isotope content of a person's bones and teeth is derived largely from the isotopic composition of the water they drink, which in turn is determined by geographic variables like altitude, temperature, distance from the ocean, etc. There is hope that still other isotopes (e.g., lead, hydrogen and sulphur) will also prove to be useful in this respect.

Because dental enamel does not change after mineralization, the isotopic composition of an adult tooth will retain the geographic

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"signature" of the region that the person lived in, as an infant or child, when that particular tooth was forming. Bones, on the other hand, remodel continually throughout life, and so will reflect any more recent relocation of the individual. Unlike DNA or other genetic markers, chemical analysis can thus track more than one relocation during life.

There are, however, some important caveats to these chemical techniques. The movement has to take place between isotopically distinguishable regions or the relocation will be undetectable. Also, the individual will have to have been resident in the new locality long enough for the remodeling bone to adopt the new isotope levels, which could be seven to 15 or more years in the case of adults (but less in children). It should also be noted that a person sampled before complete bone turnover will produce a misleading value that reflects neither the homeland nor the new residence. Finally, there is the fact that widely separated regions of Mesoamerica may coincidentally produce the same isotopic values. The oxygen-isotope values of Monte Albán, for example, overlap considerably with those of the Pacific slope of Guatemala and north-central Michoacan.

Strontium-isotope analysis suffers from these same limitations. However, the strontium and oxygen isotopes complement each other in important ways, so their use together improves the accuracy of the results (White et al. 2007). The strontium-isotope content of a person's bones and teeth is derived from the strontium-isotope content of the plants that they eat, which in turn derives from the region's bedrock. Therefore, a chemical "triangulation" using both techniques on the same sample provides a finer resolution of the subject's origins and movements, and the use of tissues formed at different life stages enables reconstruction of the timing of movements. By knowing which segments of a population (i.e., gender, social status, etc.) moved at what age, it is also possible to reconstruct motivations for movement (e.g., colonization, conquest, trade, marriage). Dietary isotopes (carbon and nitrogen) have also been used to discriminate between local and foreign individuals (Tykot et al. 1996; White, Pendergast, Longstaffe, and Law 2001) but are less powerful tools.

The ability to discriminate small-scale and even individual movements has been useful for addressing substantive social issues. For example, in Teotihuacan oxygen-isotope analyses have been used to shed light on the use of immigration to maintain population levels (White, Storey, Longstaffe, and Spence 2004), the organization of trade (Spence, White, Longstaffe, Rattray, and Law 2004), the maintenance of ethnicity via the circulation of infants and adults through a central Mexican diaspora network (White, Spence, Longstaffe, and Law 2004) and military organization and behavior (Spence, White, Longstaffe, and Law 2004; White et al. 2002). Also, strontium- and oxygen-isotope analyses of samples from the Maya region have revealed that high-ranking individuals buried in Tikal, Altun Ha, Copan, and Kaminaljuyu were clearly not from the Teotihuacan area, despite some impressive textual and artifactual evidence to the contrary (Buikstra et al. 2003; White et al. 2000; White, Longstaffe, and Law 2001; Wright 2005a).

HUMAN SACRIFICE AND CANNIBALISM

The word "sacrifice" is derived from the Latin *sacer facere*, which means to make sacred and normally implies a surrender to the supernatural of something precious. In terms of human sacrifice, the surrender ranges from body tissues such as blood (Nájera 1987) to body parts such as teeth and fingers (which are found in ritual deposits or caches [Becker 1992; W. Coe 1965; Pendergast et al. 1968; Saul and Hammond 1974]) to the entire body. Here, we focus only on those forms of sacrifice that cause death.

Hooton's (1940) revelation that the victims of sacrifice at the cenote of Chichen Itza were not just young women was an early contribution of physical anthropology to the topic of human sacrifice (see also de Anda Alanís 2007). Nonetheless, Buikstra (2007) notes that interest in Maya ritual violence is not significant until after 1960 and that the bioarchaeological approach has only recently been fully appreciated. The two principal volumes in English on Mesoamerican human sacrifice nicely illustrate this shift. Boone (1984) has 11 authors, none of them physical anthropologists and nearly all of them American. Tiesler Blos and Cucina (2007), both physical anthropologists, include 24 authors, over half of them physical anthropologists and divided about equally between American and Mexican institutions.

The interest in human sacrifice has been inspired by numerous codex and conquistador accounts. Although human sacrifices in Mesoamerica do include a wide variety of practices and appear in many different contexts (Gómez Chávez 1990; López Alonso et al. 2002; Talavera et al. 2001), a variety of unrelated practices, particularly those related to mortuary processing and secondary deposition, have sometimes been mistaken for sacrifice (Gómez Chávez 1990; Spence and Pereira 2007:155; Tiesler Blos 2007). Tiesler Blos (2007:Tables 2.1–2.2) has suggested criteria to distinguish between sacrifice and other practices, and among the various forms of sacrifice. The complexity of her tables is a testament to the difficulty of the task.

Especially rich for ancient Mexican societies relative to Maya ones, the ethnohistoric record has resulted in the assumption that the Maya were more peaceful. There is now, however, ample evidence that the Maya practiced sacrificial rituals of many types on a scale from individual to large groups (Fowler 1984; Massey and Steele 1997; Owen 2005; Tiesler Blos 2003; Tiesler Blos and Cucina 2003, 2006b; Tiesler Blos et al. 2002; Whittington 2003), and that sacrifice had many different ideological and social meanings that can be better understood through the use of multidisciplinarity, modern theory, and more stringent methodological standards (Tiesler Blos and Cucina 2007).

There are numerous ways to classify human sacrifice, among them the scale of the event, the participating segment of the community (Gómez Chávez 1990) and the goal of the ritual (Tiesler Blos 2007:19–20). Most of these can be tied to the identities of the victims. Isotopic analysis can identify their geographic proveniences, although these might not always inform us about their sociopolitical affiliations. Those identities may be acknowledged in the sacrificial ritual and may even play a central role in it—for example, the probable Maya lords of Burial 5 of the Moon Pyramid in Teotihuacan, who were buried in positions and with paraphernalia that marked both their elevated rank and their Maya origins (Sugiyama and López Lújan 2007:132–137). Alternatively, the original identities of the victims may be stripped from them, and they may be buried basically as objects, like trophies, rather than as identifiable social characters in the ritual drama—for example, the decapitated bodies of Burial 6 and the decapitated heads of the later Burial 4 of the Moon Pyramid (Spence and Pereira 2007). The original identities of victims may even be eclipsed by new identities assigned to them for the purpose of the ritual, like the deity impersonator sacrifices of the Aztecs (Berdan 1982).

It may also be useful to make a distinction between ritual killing and human sacrifice (White et al. 2008), reserving sacrifice for those

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events where the goal is primarily to communicate with or influence the supernatural realm. The primary (though perhaps not professed) goal of ritual killing would be to demonstrate power or punish transgression. Although some appeal to the supernatural might be attached to the event, it is secondary; the major effect is temporal. However, sacrifice and ritual killing may not be that easy to distinguish, and indeed the ancient Mesoamericans themselves may have been a bit fuzzy on this point, as witness the large Aztec sacrifices of war captives (Conrad and Demarest 1984).

A number of the finds put forward as examples of human sacrifice occur in residential contexts (Welsh 1988:172; Gómez Chávez 1990). These include the burials of heads, with and without associated cervical vertebrae; other body parts and articulated segments thought to indicate dismemberment; decapitated bodies; multiple primary and secondary burials; burned remains; and various others. These are often taken as evidence that human sacrifice was not only practiced but was practiced in that particular place by the members of that particular residential group. Given that human sacrifice is generally the prerogative of the state, this seems unlikely. Any such find should be carefully scrutinized and alternative explanations explicitly considered—a sort of differential diagnosis. It may be that in some cases the remains were indeed those of a sacrifice but one carried out elsewhere, in a public venue. The remains may then have been given to the residents because the victim was related to them or because they had been responsible for the procurement of the victim. Other possible explanations for these anomalous finds in residential contexts include the ritual deposition of ancestral relics or war trophies; the secondary burial of close kin with a senior kinsperson whom they had preceded in death; the burial of kin killed in combat or executed by the state; the burial of kin who had died elsewhere and whose body (or selected parts of it) was returned home for burial; the overlooked or discarded elements of an exhumed burial; or a burial disturbed or scattered by later work in the residence.

Among the most contentious of these claims of residential sacrifice are the occasional discoveries of clusters of perinatal burials in Teotihuacan apartment compounds. There is no doubt that the later Aztecs practiced child sacrifice—for example, the infamous Offering 48 of the Templo Mayor, which has an MNI (Minimum Number of Individuals) of 42 subadults between the ages of two and seven years (Román Berrelleza 1990; Román Berrelleza and Chávez Balderas 2006; Román Berrelleza and Rodríguez García 1997). Notably, however, the Templo Mayor was not a residence but the main public structure of Tenochtitlan.

The Classic period finds in Teotihuacan occur in the patios of the multifamily residential structures, around and within the patio altars. Up to 18 infants, mostly perinatal, may be present. Some investigators believe these to be sacrifices (Cid Beziez and Torres Sanders 1997; Jarquín Pacheco and Martínez Vargas 1991; Serrano Sánchez and Lagunas Rodríguez 1975). Others (Spence and Gamboa Cabezas 1999; Storey 1992b) suggest that they are the successively deposited bodies of infants who had died natural deaths and were accorded the privilege of burial by altars. Spence and Gamboa Cabezas (1999:188–189) point out the devastating demographic consequences for the social group of an infant sacrifice on such a scale, unless the infants are drawn from a pool far larger than the residence or barrio. If this were the case, we must then explain just how they ended up in one particular residence.

The Spanish chroniclers also made much of the cannibalism that accompanied some sacrificial rituals. Although the work of Pijoan Aguadé (1981, 1985; Pijoan Aguadé and Mansilla Lory 1997) has established the occasional practice of cannibalism in northern Mesoamerica from the Formative period on, a careful reading of indigenous writers indicates that cannibalism may not have been as widespread and acceptable as the sources suggest (Isaac 2005). There has been a long-standing interest among Mexican physical anthropologists in perimortem and postmortem alterations to human bone. Although their main goal was to develop a better understanding of the roots of Aztec conflict, sacrifice, and cannibalism (e.g., Lagunas Rodríguez and Serrano Sánchez 1972; Pijoan Aguadé 1981), their work has benefited bioarchaeologists everywhere. The examination of nonfunerary posthumous body treatments as they might relate to cannibalism among the Maya is much more recent (Medina Martin and Sánchez Vargas 2007; Mock 1994; Tiesler Blos 2003; Tiesler Blos and Cucina 2003), and evidence for cannibalism in these studies is largely inconclusive.

Turner (1983; Turner and Turner 1999:22–24) and White (1992) have developed criteria for the identification of cannibalism in the archaeological record. Because these criteria are based largely on Anasazi sites, which show very thorough processing of the remains and may reflect hunger more than ritual, they are quite stringent. There has also been a certain sensitivity (some might even say timidity) about the topic in the United States because of critics like Arens (1979). Still, some caution is necessary in order to balance the uncritical claims of cannibalism made by some archaeologists such as Coe and Diehl (1980:375–377), who assert that the evidence for Olmec cannibalism, based on six skeletal elements, is "overwhelming." As Medina Martín and Sánchez Vargas (2007: 110–112) demonstrate, a superficially plausible case can collapse under close inspection.

Turner and Turner (1999:415–458) have applied their criteria to several finds in Mexico and conclude that some of them fulfill all expectations while others are either unclear or better explained by other hypotheses. The earliest of these finds is the El Riego phase (ca. 7000–5000 B.C.) double-child burial from the Tehuacan Valley. Fowler and MacNeish (1975:267, 270) suggest that the find may represent cannibalism. Anderson (1967:94), on the other hand, was more cautious in his interpretations. Turner and Turner (1999: 429–433) have reanalyzed the material and accept it as an example of ritual cannibalism. However, the sharp differences in color along some suture lines suggest that the cranium may have been broken and the parts separated before being burned (Anderson 1967:94). At present it seems best to reserve judgement on this find.

SUGGESTIONS FOR FUTURE RESEARCH DIRECTIONS

Geographic baselines and markers for biochemical studies

It appears that individual mobility in Mesoamerican societies was surprisingly high (Wright 2005b). Although isotopic analyses can identify the foreigners in a community, they are still limited by the fact that the same isotopic value may represent more than one location. Therefore, people who appear to be local may actually be from a foreign but similar environment, and we cannot identify with certainty the homelands of those who appear to be foreign. To overcome these limitations we need to establish better regional baselines and develop the use of more isotopic markers (e.g., lead, hydrogen, and sulphur). Although considerable work has been done to understand the distribution of strontium isotopes in Mesoamerica (Hodell et al. 2004; Price et al. 2007) the addition of lead isotopes will refine interpretations. Oxygen, hydrogen and sulphur isotope compositions are more complex and require more mapping.

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The Development of Mesoamerican Standards

We need standards for growth and age assessment that are appropriate for Mesoamerican populations. Márquez Morfin (1985) has noted that the long bone standards developed by Merchant and Ubelaker (1977) from Arikara data tend to underestimate the age of Mesoamerican subadults. However, Storey (1986:546) raises the question of whether these differences reflect the smaller body size of Mesoamerican peoples or more specific health problems. We do have some published Mesoamerican standards and data for stature (Genovés 1966, 1967; del Ángel E. and Cisneros 2004), the timing of health insults that create hypoplasias (Dolphin 2009; Wright 1997d), long bone growth (Danforth et al. 2009; Márquez Morfin 1985; Storey 1992b), and sexual differentiation (Wrobel et al. 2002; Lagunas Rodríguez and Hernández Espinoza 2005:36, Tables 3–4). The question remains of how widely these standards apply beyond the specific populations on which they are based.

Isotopic zooarchaeology

Isotopic analyses of fauna have allowed the reconstruction of ancient environments (e.g., Kennett and Voorhies 1996), but more needs to be done to map out seasonality and environmental change, especially where civilizations may have been impacted. Furthermore, trophic level cascades may have occurred in some of the delicate tropical ecosystems, particularly in areas of high population density, and their effects on ancient populations should be studied. Faunal analysis can also clarify human-animal interactions in the wild-domestic continuum, trade, and ideological practices (e.g., White, Pendergast, Longstaffe, and Law 2001). Dogs have been used in dietary reconstruction (White, Storey, Longstaffe, and Spence 2004), but their potential to act as proxies for humans is largely unrealized.

Differential access to basic resources and health

Mesoamerican societies of the Classic and Postclassic periods were state systems with class divisions. It would be very useful to know just what class meant pragmatically in those societies, particularly in terms of health and access to basic resources like food. We should also be asking whether such access varied even within classes. Health indicators apparently remain more or less level across different segments of the commoner population in the Copan region (Whittington 1999; Whittington and Reed 1997). However, Márquez Morfin and González Licón (2001) compared health indicators in Monte Albán tomb and non-tomb burials, finding significant differences. Recognizing that the contextual distinction simply reflected a social hierarchy within the kin groups that occupied the residences, rather than a real class distinction, they interpreted the differences in terms of status variation in consumption within the residence of maize and animal protein.

The social isolation of emerging elites

One of the major topics in Mesoamerican archaeology is the development of hereditary rank and the question of why one segment of an egalitarian society would have ceded such power to another—or how that other segment managed to wrest it away from them (Clark 2000). An important aspect of this is the degree of social isolation of the emerging elite. Presumably there had initially been regular intermarriage across this developing social barrier, the higher status group being too small to find acceptable spouses and sustain their numbers otherwise. With this stream of incoming spouses there would also come, of course, social obligations, cultural practices (perhaps gender specific), and other baggage. Bioarchaeologists should be able to measure this social (and genetic) interchange through morphological analysis and biodistance studies, and could track the drop-off in its intensity as elites struggled to separate themselves from the commoner population. We should also be able, given the right samples, to identify one elite strategy to accomplish this: intermarriage with developing elites in other communities to extend their networks and to reduce their demographic dependence on the local population. Wilkinson and Norelli (1981) were among the first to attempt this sort of analysis but erred in equating tomb burial in Monte Albán with elite status (see Márquez Morfin and González Licón 2001:81).

Diasporas and migrations

The investigation of migrations and the composition and formation of diasporas can integrate archaeologies of landscape, memory, and childhood. Much of the research on diasporas to date has been done on populations related to Teotihuacan (e.g., Pollard 2000; Spence 2000, 2005), but there were numerous diasporas and migrations in Mesoamerica, some of which can be investigated using existing isotopic baselines (e.g., the Nahua migrations, the movement of Peten Maya into the Puuc region after the collapse, the movement of "Toltecs" into the Northern Lowlands, and the dislocation that occurred as a result of the Spanish conquest).

Morphological and metrical biodistance studies may reveal exotic contributions to local gene pools and even indicate their source (Jacobi 1997). However, we need large samples from both donor and recipient populations. We must also try to identify which segment of the local society was most impacted by newcomers and what role gender played in the interaction.

RESUMEN

A pesar de una larga historia de contribuciones de la antropología física a nuestro entendimiento del pasado mesoamericano, ha sido solamente en las últimas décadas que se ha desarrollado una estrecha relación entre la bioarqueología y la arqueología. El próximo paso sería la inclusión de bioarqueólogos tanto en la planificación como en la ejecución de los proyectos arqueológicos. En esta reseña del estado de la bioarqueología en Mesoamérica intentamos investigar varios temas, incluyendo la presentación y modificación del cuerpo humano, las dimensiones de la identidad social y sus fundamentos biológicos, la salud y la dieta, la movilidad de pueblos e individuos y el sacrificio humano y la antropofagia. Enfatizamos siempre el desarrollo de la teoría y de nuevos métodos de análisis, en particular la aplicación de isótopos en la investigación de la movilidad y la dieta. Al final presentamos algunas sugerencias para las investigaciones bioarqueológicas futuras.

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