AN EPIDEMIOLOGICAL TRANSITION IN THE CHINESE NORTHERN ZONE

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ABSTRACT

ELIZABETH BERGER: An Epidemiological Transition in the Northern Zone
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Bioarchaeological research has greatly contributed to an understanding of the health consequences of the transition to agriculture in prehistory. This paper proposes that a similarly dramatic transition in health accompanied the transition to pastoralism during the Bronze Age in the Chinese Northern Zone. Bioarchaeological data, in combination with other types of data, can be used to test the hypothesis that the advent of pastoralism and agropastoralism in the Northern Zone was accompanied by a reduction in infectious diseases and dietary deficiencies, and an improvement in population health. This work can build on previous work in the region by moving beyond the consideration of human behavior change in its sociopolitical context, to consider it in its ecological context. It will consider humans as one element in complex, multi-scalar systems, and will examine the health consequences for humans when the cultural-natural systems of which they are a part undergo reorganization and transformation.

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INTRODUCTION

Mobile pastoralism has a powerful hold on the imaginations of sedentary peoples. These settled outsiders, from ancient agricultural civilizations to modern industrial societies, ascribe a range of both flattering and unflattering traits to the pastoralists. On the one hand, pastoralists live harsh lives in unforgiving marginal environments; on the other, they are free, indulging a fundamental human wanderlust and conquering as they go. These images have arisen from millennia of interactions between sedentary peoples and mobile pastoralists: the unconquerable Scythians of Herodotus' *Histories*, the Golden Horde ruling Eurasia from the Volga to the Danube, Sami herders coaxing a living from the reindeer herds of the subarctic.

The reality of pastoralism is of course far more complex than these romantic stereotypes allow. It is practiced in a huge variety of ecological settings, from high altitude zones like the Andes and the Himalayas to semi-arid East Africa. Pastoral groups may exploit one dominant herd species such as sheep or cattle, though they often exploit a "complex" or combination of species (Galaty and Johnson, 1990). Many pastoral groups incorporate agriculture into their economic repertoire either habitually (agropastoralism) or when needed, and rely heavily on trade with neighboring groups. Though pastoralism is often associated with mobility, this mobility may take many forms, from full-scale nomadic migration of entire communities to seasonal transhumance of only a few members of a group (Wendrich and Barnard, 2008). Even sedentary commercial ranches like those in the American West are a form of pastoralism (Galaty and Johnson, 1990).

The range of these behaviors offers a dramatic illustration of the plasticity of human biocultural adaptation. Pastoralism is often characterized as an adaptation to ecological conditions, allowing groups to exploit marginal environments in which agriculture could not support a human population (Crawford and Leonard, 2002). However, the adaptive nature of this lifeway can only go so far in explaining its origins. Economic specialization and ethnic identity play a role; pastoral groups often deliberately maintain an identity distinct from their sedentary neighbors (Barth, 1961; Barth 1969; Frachetti, 2008a; Shelach, 2009; Spooner, 1973), of which herd animals and the pastoral lifestyle are potent symbols.

Mobile pastoralists also provide important comparative data for studying human ecology and human-environment interaction. The human and natural systems of which these groups are a part are often non-equilibrial in nature (Crawford and Leonard, 2002), and provide a good case for examining the capacity of complex systems for adaptation and transformation, and humans' capacity for behavioral flexibility, especially when studied over long time cycles and across multiple scales (Gunderson and Holling, 2002; Redman, 2005).

Steppe pastoralism: a case study for epidemiological transitions

Understanding the history of human health and disease is critical to understanding both the trajectory of human history and current problems in public health and epidemiology (McMichael, 2001; Roberts and Manchester, 2007; Rothschild, 2003). Evidence from historical and archaeological sources, as well as biological evidence from human remains, can shed light on the environmental, cultural, behavioral, biological, and evolutionary factors that changed human health in the past, and therefore improve our understanding of these factors in the present.

A useful conceptual framework, which can be applied to both present and past human experience, is that of epidemiological transitions. These are transitions in human health and population structure that accompany dramatic changes in subsistence, technology, or lifeway. Epidemiological transition theory combines an understanding of the multiple forces at work in human population change into a comprehensive approach (Omran, 1971). In one scheme, that of Barrett et al. (1998), the human species has undergone three large epidemiological transitions in the course of our history. The first transition followed the rise of sedentary agriculture, and involved an increase in density-dependent and non-vector parasitic and infectious diseases, which humans encountered by living in larger permanent settlements, disturbing novel habitats, and engaging in closer contact with domesticated animals; a reduction in nutritional quality due to dependence on limited staple crops and overall reduced dietary diversity; reduced stature and life expectancy; worse dental health; and an increase in fertility. The second transition followed the advent of industrial modes of production and broad public health and sanitation measures, which reduced the rate of mortality from infectious diseases but left chronic, non-communicable diseases as the main source of morbidity and mortality. This transition is still considered to be ongoing in many developing countries. Finally, according to the authors, humans are currently experiencing a third epidemiological transition, characterized by the rapid emergence of new infectious diseases, the re-emergence of older diseases once thought to be in decline, the creation of a "global disease ecology" (p. 248), and the diminishing effectiveness of antibiotic therapy.

Each of these transitions accompanied a dramatic change in human behavior and our relationship to our environment: the advent of food production and dense settled life, the rise of industrial pollutants along with public sanitation measures, and the recent rapid expansion into new ecological zones and the dramatic increase in the ease and speed of international travel and trade. Experts in the fields of ecology, medical geography, archaeology, biological anthropology, history, epidemiology, and many others can make critical contributions to the study of these phenomena.

I propose in this paper that the theoretical framework of epidemiological transitions can be applied more broadly, to detect and describe similarly dramatic transitions that occur in smaller, regional contexts. I use as an example archaeological and other evidence that attests to a dramatic transition from agriculture to pastoral and agropastoral production in Inner Asia and the Chinese Northern Zone around the beginning of the Bronze Age (1200-600 BCE). During this transition, the people of the region adopted animal husbandry and mobile or semi-mobile lifeways, eventually developing a complex of behaviors, technology, and material culture very distinct from the sedentary agricultural civilization of China to the south.

Given the comprehensive nature of this change in human behavior, affecting settlement density, diet, and activity patterns, I hypothesize that the people of the Northern Zone underwent an epidemiological transition during this period. In this thesis I will first review the theoretical and empirical background of the epidemiological transitions model. I will then define the study area and period, and review archaeological and bioarchaeological evidence from this region relating to ancient health and subsistence change. Finally, I will suggest a bioarchaeological program of research to test the hypothesis of an epidemiological transition, and suggest a set of results that would support the hypothesis.

THEORETICAL BACKGROUND

Epidemiological transitions

What constitutes an "epidemiological transition"?

As stated above, an epidemiological transition is a change in the health and demographic structure of a population, brought about by a complex interaction between multiple environmental, sociological, and economic factors (Barrett et al., 1998; Omran, 1971). Omran's original scheme of three stages has been criticized as unilinear and teleological, and for not considering the trade-offs in quality of life that accompany reduced mortality and increased longevity in some populations. More recent critiques have also attempted to account for the different experiences of groups according to gender, race, class, and level of development, recognizing that these transitions and stages are not always, or even not usually, global in their scope (Farmer, 1996; Popkin, 1994).

While many scholars have worked to reframe the idea of epidemiological transitions to fit the diverse experiences of contemporary and recent historical populations, Barrett and coworkers (1998) proposed an expansion of this framework backwards in time to include the changes in health observed by biological anthropologists with the origins of agriculture.

It is clear that in the past, more than in the present, dramatic epidemiological, sociological, and demographic changes were regional or local rather than global. McNeill (1989) propose regional infectious disease pools after contact between state-level societies in the 5th century CE, and other regional changes in lifeway before this time also likely had a profound impact on human health. Recent work on the origins of agriculture, for example, has revealed differences between regions in the health consequences of sedentary agriculture, which point to the diversity of the human experience and the regionally specific conditions of this experience (Douglas and Pietrusewsky, 2007; Stock and Pinhasi, 2010).

It is also important to recognize the difference between health and evolutionary fitness. Given that the overall health of many populations deteriorated with the advent of sedentary agriculture, researchers might well ask why the practice persisted and led to population growth. One possible solution lies in the fact that though health declined, fertility increased, meaning that one effect of the transition to agriculture was to increase the reproductive fitness of individuals and the populations to which they belonged (Lambert, 2009).

What evidence attests to epidemiological transitions in prehistory?

The best evidence for epidemiological transitions in prehistory comes from human remains, as they can attest directly to the state of health of individuals in a population. It is rare to find soft tissue from ancient contexts, and so the vast majority of human remains available for bioarchaeological research are skeletonized. It should be borne in mind that these remains can only provide information about diseases that affect the skeleton, and only if the disease process continued long enough to do so. In addition, disease processes often do not leave skeletal lesions distinct enough for differential diagnosis (Wood et al., 1992). For this reason, relative rates of lesions over time or between populations provide a more reliable measure of overall population health than absolute rates (Cohen and Crane-Kramer, 2003).

Some specific signs of relative population health include skeletal evidence of infection, both specific and nonspecific; bone loss and nutritional anemia, especially among women and lower socioeconomic classes; reduced stature, when population continuity is relatively certain; increased rates of dental pathology; and worse children's health, including higher mortality, more dental defects, and impaired bone growth (Barrett et al., 1998; Cohen, 1997; Cohen and Armelagos, 1984; Larsen, 1997; Steckel and Rose, 2002a). While there is a recent trend in bioarchaeological research towards reconstructing individual life histories (Barrett and Blakey, 2011), to answer questions relating to epidemiological transitions researchers must rely on population-level data, including relative rates of the above-mentioned pathological lesions, and the population's demographic structure (including death tables, though there are epistemological limitations to this as well, discussed below) (Ubelaker, 2003). In the case of historical populations, written records of health and disease are also extremely valuable.

Specific skeletal markers of health and disease are discussed in more detail below.

What factors contribute to epidemiological transitions?

Many factors can contribute to an epidemiological transition. If we take the triangle of human ecology as a framework (see Figure 1), we can see that the three primary factors that contribute to human health status—population, habitat, and behavior—may all play a role in an epidemiological transition.

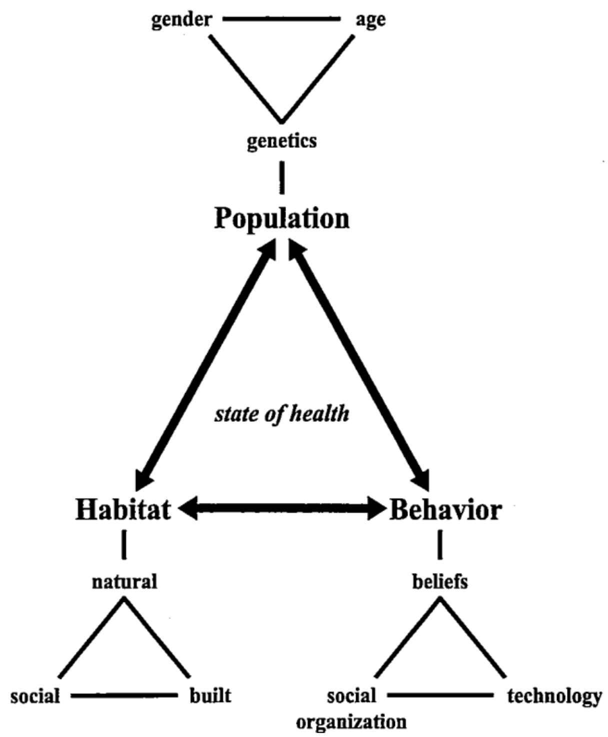

Figure 1 The triangle of human ecology (Meade and Emch, 2010, p. 31)

Take the three epidemiological transitions of Barrett et al. (1998) as examples. In the case of the first epidemiological transition, which occurred at the advent of sedentary agriculture, changes included:

> *Habitat:* a new built environment that included both dense permanent villages where human waste could accumulate, and irrigation canals that held standing water, which increased disease transmission;
>
> *Behavior:* new technology that allowed agriculture to predominate as a subsistence strategy, which led to more nutritional deficiencies and dental pathologies and increased labor demands; and
>
> *Population:* higher birth rates and lower life expectancy, which changed population structure and led to dramatic population expansion.

At the second transition, which has accompanied industrialization, changes included:

Habitat: ever larger and denser settlements, with worse pollution in both urban and rural areas;

Behavior: improved public health measures and medical knowledge, which has reduced the prevalence of infectious diseases; and

Population: longer life expectancy, which increased the prevalence of chronic diseases.

Finally, the latest, or third, transition has included:

Habitat: accelerating encounters with novel environments, leading to human contraction of novel infections;

Behavior: ever easier global travel and commerce, creating a worldwide disease pool, and a breakdown in public health measures, leading to the evolution of antibiotic-resistant pathogens; and

Population: ever-increasing life expectancy and incidence of chronic non-communicable diseases.

I hypothesize that in the case of the transition to pastoralism in the Bronze Age Northern Zone, changes would have included:

Habitat: sparser and less permanent settlements, hampering the spread of communicable diseases;

Behavior: a diet high in animal protein, leading to better nutrition, but more horseback riding and contact with herd animals, increasing the risk of zoonotic infections and traumatic injury; and

Population: demographic flexibility, allowing populations to cope with non-equilibrial environmental conditions (discussed more below) (see Table 1).

Table 1: Correlates of epidemiological transitions with sedentary agriculture and mobile pastoralism

	"First epidemiological transition": sedentary agriculture	Proposed epidemiological transition: mobile pastoralism
Habitat	**Low mobility and high population density:** interpersonal contact, accumulation of waste, contaminated water sources, high incidence of non-vector density-dependent infectious diseases and parasites **Irrigation:** habitat for disease vectors	**High mobility and low population density**: less contamination of water sources, fewer non-vector infectious diseases and parasites
Behavior	**Reliance on starchy staple crop:** low dietary diversity, higher incidence of dietary deficiencies and dental pathologies **Contact with domesticated animals:** some accidental trauma, zoonotic diseases	**Reliance on both animal products and agricultural foods:** greater dietary diversity, high intake of protein, reduced incidence of dietary deficiencies and dental pathologies **High contact with domesticated animals and horseback riding:** higher incidence of trauma, zoonotic diseases
Population	**High birth rate:** population growth, high age-specific mortality especially among women of childbearing age	**Demographic flexibility:** birth rate and outmigration respond to economic and ecological conditions

Some work has already addressed this hypothesis for a few Asian skeletal populations, and suggests these changes did indeed occur (Eng, 2007; Walker and Yablonski, 1997). However, there is much more data yet to be analyzed, and greater sample sizes will allow for more confidence in the conclusions, as well as more nuanced analysis of differences between ecological zones and periods.

Human ecology

Recent developments in the field of ecology have emphasized the importance of principles such as uncertainty, complexity, resilience, and non-equilibrium for understanding natural systems. These principles can not only more accurately describe such systems and suggest better management practices, but can also be applied to data from the past to better understand the evolution of human-environment interactions and their influence on the course of human biological and cultural history. Resilience theory in particular provides a helpful way to understand dramatic reorganizations of complex systems, including those of which humans are a part (Redman, 2005).

As defined in the ecological literature, resilience is the ability of a system to absorb changes or disturbances and still retain its identity, i.e. its defining properties (Gunderson and Holling, 2002; Holling, 1973; Moran, 2008). Paradoxically, certain non-equilibrial systems, which cycle between periods of stability and transformation, may exhibit the greatest resilience (Redman, 2005; Gunderson and Holling, 2002). Systems exhibiting this tendency to transform are termed complex adaptive systems, and recent work aims to understand them in terms of multiple scales, spatial variants, system memory, complexity, and episodic change. In this model, when a disturbance is too great, a system will reorganize and exhibit new properties.

Complex adaptive systems and resilience theory are particularly helpful for understanding marginal environments such as semi-arid grasslands or high mountain zones, in which many pastoral and agropastoral modes of subsistence have developed (Crawford and Leonard, 2002; Goldstein and Beall, 2002; Gray et al., 2002; Gunderson and Holling, 2002; Holling, 1973; Moran, 2008). They can describe the yearly fluctuation of conditions in these environments more accurately than older ecological models based on equilibrium. They are also helpful for understanding human-environment systems on a longer time scale: a system reorganization may be a good way to understand subsistence change in the Northern

Zone, when social and ecological conditions shifted enough to disturb the agricultural system of the late Neolithic and provoke the transformation to pastoralism.

Archaeological and paleoenvironmental data are important for the study of human ecology because of the deep time perspective they provide (Redman, 2005). It is widely agreed that multidisciplinary, long-term studies are needed to understand the dynamics of human populations and their adaptive mechanisms (Little, 2002), and archaeological and bioarchaeological research are therefore valuable for these research programs. In the spirit of multidisciplinarity, research into the human ecology of the past may include data and expertise drawn from the fields of paleoenvironmental studies, historical archaeology, landscape archaeology, geoarchaeology, zooarchaeology, paleobotany, and bioarchaeology.

It is also important to recognize that typological, binary, or linear models cannot accurately describe the complexity and stochasticity of human cultural evolution and adaptation, including the emergence of pastoralism (Barker, 2000; Barker and Gilbertson, 2000; Salzman, 2004; Wendrich and Barnard, 2008). In other words, the progression from nomadic foraging to sedentary agriculture to industrialism is by no means universal; even in the places where this progression did take place, it proceeded at different paces and in response to different factors. Mobile pastoralism did not arise as a step “backwards” from sedentary agriculture, nor did Northern Zone pastoralists become “stuck” at an earlier stage of cultural evolution as their Chinese neighbors advanced to complex state-level societies. Their pastoral lifeway should rather be investigated as a response, presumably adaptive, to local cultural and ecological factors. Only by treating the data from this period and region independently of typological models, and attempting to understand this way of life on its own terms, can we adequately account for its complexity (Bernbeck, 2008).

Pastoralism

As described in the opening of this thesis, there are very few universals among pastoralist societies (Dyson-Hudson and Dyson-Hudson, 1980) or among mobile groups (Spooner, 1973). Many pastoralist groups practice some form of mobility (nomadism or transhumance), though properly defined these are separate dimensions of a lifeway, one referring to subsistence strategy and one to degree of movement (Barfield, 1993; Cribb, 1991). The most basic definition of pastoralism is a way of life that relies heavily on products of domesticated animals for subsistence, which may include meat, milk, and blood (Cribb, 1991). In this paper, agropastoralism will be used to refer to subsistence strategies in which domesticated herd animals figure prominently, but in which agriculture is also regularly practiced.

The literature on living mobile pastoralist groups demonstrates the wide variety of adaptations that fall under the heading of pastoralism. Many pastoralist groups have adopted the practice as a way of exploiting marginal environments and buffering against risk (Abdi, 2003), fulfilling the role of specialists within larger complex societies and regional or even global economies, and often entering into both trade and hostile relations with neighboring settled populations (Wendrich and Barnard, 2008; Galaty and Johnson, 1990). This dual economic and conflict relationship came to define the interaction between Northern Zone pastoralists and settled Chinese civilization early in their development, and has persisted into the modern era (Di Cosmo, 2002; Crawford and Leonard, 2002; Shelach, 1999, 2009).

In addition, many pastoral groups exhibit cyclical and flexible behavior, periodically turning to agricultural pursuits when economic and ecological conditions permit, once again undermining the concept of stable cultural types or homeostatic human-environment systems

(Chang, 2008; Salzman, 1980). Finally, the formation of ethnic or ethnic-like identity also plays a role in the development and maintenance of mobile and/or pastoralist practices. Such identities are defined by economic niche or other aspects of a pastoralist society, and are often also defined in direct opposition to neighboring settled peoples (Barth, 1961, 1969; Frachetti, 2008a; Shelach, 2009; Spooner, 1973).

Work by biological anthropologists and others has clarified some of the biological consequences of adopting a pastoralist lifestyle. In general, pastoral societies exhibit only small differences in energy expenditure between the sexes (Leonard et al., 2002). Also, among the Turkana, who rely on a relatively extreme form of mobile pastoralism, researchers have found low overall energy intake, high protein consumption, high fertility rates, moderate rates of infant mortality, slow growth in childhood but attainment of stature comparable to other populations, seasonal fluctuation in body weight, and possible immunosuppression in children due to seasonal food shortages (Little, 2002). Of course, we cannot expect to find exactly these patterns in ancient Northern Zone populations, as the economic, social, and ecological conditions were very different from those of African study populations. Additionally, in many contemporary and recent historical populations health status depends mostly on the larger political context of which the pastoralists are a part, and on the level of disruption of the local ecosystem and its retention of resilience (Eng, 2007; Gray et al., 2002).

In addition to looking for direct evidence of an epidemiological transition (i.e. changes in human health), it will also be helpful to look for the precipitating factors of the transition, that is, the specific dimensions of early Northern Zone pastoralism and the way in which they developed over time. It is important to emphasize again in the current context that typological thinking, though sometimes a useful heuristic device, will likely be counterproductive (Salzman, 2004; Shelach, 2009; Wendrich and Barnard, 2008). Schema that define pastoralist societies in terms of level of mobility, type of mobility, environment, animals reared, etc. can be useful for interregional comparisons, but the spatial and temporal differences that are relevant for the Northern Zone subsistence transition are still too poorly understood and likely too complex to be clarified by attempts at typologizing. This also holds true for attempts to define bounded ethnic groups for the purposes of comparison: rather than search for boundaries, scholars may gain more insight by focusing on agent-centered approaches and allowing for the dynamic nature of lifeway and group identity (Frachetti, 2008b; Smith, 2008). Given these goals, it will be most fruitful to compare individual representative sites from within the Northern Zone.

Of most interest as causative factors of epidemiological transitions are specific, quantitative changes such as changes in diet (e.g. consumption of animal protein), changes in the intensity or nature of exploitation of animal resources, settlement density, and intergroup interactions relating to trade and warfare. These variables can be investigated through bioarchaeological and archaeological methods, without recourse to typology or discrete categories. In other words, the goal of the research should not be to assign each site or cemetery population to an ethnic group or to a “type” of pastoralism, but to investigate each one in terms of a series of relevant variables, and then to identify patterns in these data.

THE STUDY REGION

Definitions

Period

According to archaeological evidence, the Neolithic farming communities of the Northern Zone became pastoralists and agropastoralists over a period of about 600 years, spanning the end of the Neolithic and the beginning of the Bronze Age (1200-600 CE) (Shelach, 2009). By about 100 BCE, the cultural and political distinction between China and the Northern Zone was firmly established, and is evidenced in Chinese historical writings of the time. These include proto-ethnographic accounts of the differences between the Chinese people and their Northern Zone neighbors, who are described as milk-drinking nomads (Di Cosmo, 2002).

Region

The relevant area for this study is the zone of contact between the Chinese civilization and the steppe immediately to the north. Confining the area of study to this zone is a somewhat artificial distinction, as the changes taking place in the Northern Zone (or *beifang* 北方 in Chinese) reflect a way of life that was emerging across the larger region of Inner Asia (Di Cosmo, 2002). However, this process was probably not identical across the region, and so it is logical to begin the research with a sub-region of Inner Asia—in this case, the Northern Zone.

I recognize that the label of "Northern Zone" privileges the Chinese perspective. However, it is the most cohesive label for the region, and acknowledges that one of the region's defining characteristics is its proximity to but distinctiveness from Chinese civilization. In addition, I recognize that calling the Yellow River valley civilization of this time period "China" is problematic, as the concept of a unified Chinese civilization did not emerge until later. However, using this single term to refer to what is today central China does reflect that a common way of life, eventually encompassing language, material culture, and political organization, was emerging in the Chinese heartland at this time.

This part of Inner Asia can usefully be divided into sub-regions, defined by geographic features and climatic conditions. In one scheme, these include: north China and, from east to west, Manchuria, Mongolia (including Inner Mongolia), and Xinjiang (Barfield, 1989). In another scheme, they include, again from east to west: Manchuria, the Chifeng region (in Inner Mongolia), the Ordos region, and the Gansu corridor (Shelach, 2009). For the purposes of this research, I propose the use of three sub-regions: Manchuria, Inner Mongolia, and Xinjiang (after Eng, 2007, derived from Barfield, 1989) (Figure 2). Any investigation of the subsistence transition should keep these general divisions in mind, to acknowledge that ecological and other conditions were not constant, and that the transition is unlikely to have proceeded in the same way or at the same speed across the entire Northern Zone. Indeed, archaeological evidence points to this lack of homogeneity.

Figure 2 Three sub-regions of the Northern Zone: Manchuria, Inner Mongolia, Xinjiang (shown with modern-day geopolitical borders) (Eng, 2007, p. 19).

Evidence for a subsistence transition in the early Bronze Age Northern Zone

Before the first millennium BCE, in much of northeast Asia, including the Northern Zone and what would later become China, populations relied predominantly on agricultural production for their subsistence. Social stratification and even stratified settlement systems had developed in much of the region (Shelach, 2009).

By the end of the first millennium BCE, a dramatic contrast had emerged between the societies centered on China's Yellow River valley and those of the Northern Zone. An increasingly stratified settlement system and political structure continued to develop in the Chinese heartland, reliant on intensive irrigation agriculture (McNeill, 1989; Shelach, 2009). Meanwhile, in the Northern Zone, a very distinct way of life had emerged, relying on mobile or semi-mobile animal husbandry, usually supplemented by agriculture. The economic base in this region was more diverse, and the social structure was less stratified, though a high degree of political centralization would eventually develop here (Shelach, 2009).

What emerged in this period is the famous dichotomy of "the steppe and the sown." Though it is a crude distinction and a simplification of both the Northern Zone and Chinese societies, it has been an enduring trope in East Asian history, culture, and political relations throughout the centuries since the Bronze Age (Lattimore, 1940; Shelach, 2009; Di Cosmo, 2002). (See Table 2 below for the chronology of both regions during this period.)

Table 2: Chronology of China and peoples of the Northern Zone (Eng, 2007 p. 10). Names of Northern Zone peoples are archaeological cultures or names used by Chinese historians.

Time Frame	China	Northern Zone Peoples
~8th to 3rd millennium BC	Neolithic, pre-dynastic cultures, e.g., Peiligang, Yangshao, Dawenkou, Longshan	Xinglongwa, Zhaobaogou, Hongshan, Laohushan, Xiajiadian
3rd to 2nd millennium BC	Xia (Erlitou? ca.2050-1650 BC) Shang (ca.1650-1100 BC)	Xunyu, Guifang
11th to 2nd centuries BC	Zhou (ca.1100-256 BC) Spring and Autumn (722-481 BC) Warring States (403-221 BC)	Rong, Di, Linhu, Loufan, Eastern Hu, Xiongnu
2nd century BC to 2nd century AD	Qin (221-207 BC) Han (206BC-220 AD) Western Han (206 BC-8 AD) Xin (8-23 AD) Eastern Han (25-220 AD)	Xiongnu, Wusun, Yuezhi, Wuhuan, Xianbei

This transition is evidenced by data from material culture, especially artistic styles and artifacts associated with horse riding that are common across the region, and by animal remains, which are often excavated from mortuary contexts (Barfield, 1989; Di Cosmo, 2002; Shelach, 2009). In addition, preliminary evidence suggests that the settlement structure of the Northern Zone changed dramatically in this period: the one systematic regional survey so far conducted (in the Chifeng area of Inner Mongolia) showed that the three-tiered settlement system that had emerged in the Neolithic, along with the permanent stone architecture of the largest settlements, disappeared with the advent of pastoralism, to be replaced by smaller and less permanent settlements (Chifeng, 2003; Linduff et al., 2002). The relative number of animal remains at various sites suggests that the transition was more dramatic in the western part of the Northern Zone (Xinjiang) and perhaps less dramatic or more gradual in the eastern part (Manchuria and eastern Inner Mongolia).

A study of different lines of evidence from the Gumugou cemetery in Xinjiang (Zhang and Zhu, 2011) attests to the pastoralist subsistence strategy of the population at around 1800 BCE. This is at the early end of the period during which archaeological evidence shows the transition to have occurred farther east, again illustrating the heterogeneity of the transition across the Northern Zone. Nitrogen stable isotope analysis of human bones from the site revealed humans to have a $\delta^{15}N$ concentration of approximately 13 ‰—15 ‰, in the expected range for carnivores, indicating a high level of consumption of meat and dairy. Based on animal remains, bone objects, and felt and leather grave goods, the researchers concluded that the people at Gumugou consumed significant quantities of mutton and beef, supplemented by hunted meat. The isotope analysis also revealed a higher proportion of C_3 than C_4 plants[1], which, in combination with paleobotanical remains recovered at the site, led the researchers to conclude that the predominant grain consumed by the population at Gumugou was wheat, and that the agricultural component of their diet was less in quantity and diversity than that of the population at the nearby contemporaneous Xiaohe cemetery. The authors call for further analysis of human remains from different sites and periods within this area to clarify the Bronze Age human diet.

Finally, written records from China, the earliest relevant examples of which date from the first century BCE (Sima Qian's *Shi Ji* 史记, or the *Records of the Grand Historian,* composed during the Western Han Dynasty), provide descriptions (albeit prejudiced) of the nomadic herding society of the Northern Zone (Di Cosmo, 2002), which had fully emerged by this time.

This transition is unusual among large subsistence shifts in prehistory, allowing for an interesting test case for the broader applicability of the epidemiological transitions model,

[1] The average concentration of $\delta^{13}C$ in individuals at the site was between −18.39‰ and −17.85‰, which, when adjusted for the +5‰ enrichment between the diet and human bone collagen, is in the range for C_3 plants (−23‰ to −30‰) (the range for C_4 plants is −8‰ to −14‰) (Zhang and Zhu, 2011).

specifically to describe additional, region-specific epidemiological transitions. Complicating the investigation is the fact that this transition was a complex and gradual phenomenon. Rather than the abrupt or catastrophic change envisioned by some scholars, it appears to have occurred gradually, over several centuries at least, and occurred at different speeds and to different degrees in different ecological zones (Shelach 1999, 2009). In addition, most populations in the region developed mixed economies that did not depend exclusively on mobile pastoralism. This does not negate the possibility of an epidemiological transition, but suggests that finding appropriate study populations may be a challenge.

Explanations for a subsistence transition in the early Bronze Age Northern Zone

Several different explanations are offered in the literature for the origins of pastoralism in the Northern Zone. The primary hypotheses are, first, a replacement of the region's population with one that practiced pastoralism, and second, a climatic shift that forced the population to adopt animal husbandry as a buffer against environmental uncertainty, or to supplement insufficient agricultural foods (Shelach, 2009). Researchers point out that material culture associated with daily tasks did not change dramatically during this period, rendering unlikely the scenario of large-scale population replacement. Additionally, one study has found that worldwide, the cultural trait of pastoralism is correlated with the genetic relatedness of modern populations—in other words, pastoralism tends to be practiced by genetically related groups, suggesting they inherited the practice from common ancestral groups; however, there is no additional effect from geographic proximity, suggesting that pastoralism has not often been transmitted horizontally between neighboring populations (Holden and Mace, 2002). These lines of evidence appear somewhat contradictory, but taken together they seem to suggest that indigenous processes played a major role in the development of pastoralism in the Northern Zone.

As for the second, climatic, explanation, paleoclimate data do not support this hypothesis: though the climate of this region did become slightly cooler and drier in this period, the shift was not dramatic enough to preclude the practice of agriculture. A lower temperature may have offset the effect of lower rainfall, and the region may even have been moister than today, though irrigation agriculture is still practiced in the region today (Shelach, 2009). The variability of rainfall between years would also have been an important climatological factor in human subsistence behavior. However, archaeological evidence points to the continued practice of agriculture as a "supplemental activity" even after the advent of mounted pastoralism in the region, continuously to the present day (Di Cosmo, 1994 p. 1094). Therefore, the shift towards pastoralism was probably not solely a reaction to climatic pressures. Rather, a combination of climatic, economic, and social factors was probably responsible for the greater adoption of animal husbandry in this period. These factors may include the formation of ethnic-like identities[2] and the self-definition of groups in opposition to their agriculturalist neighbors, opportunities for trade and economic specialization (Cribb, 1991; Lee and Bates, 1974; Rosen, 2003; Shelach, 2009), and possibly the introduction of certain technologies and practices from other Inner Asian societies (Di Cosmo, 2002) .

If the transition was necessitated by environmental stressors, I would expect to see evidence of dietary and/or physiological stress in populations near the beginning of the

[2] This term is used by Shelach (2009) to distinguish his favored approach (ascribing identities to ancient people based on an examination of their biological and cultural remains) from that used by some archaeologists working in Eurasia (the assignment of ethnonyms found in historical texts to specific archaeological cultures).

transition, and an improvement in diet and health once the transition was underway, or a at least a change in health problems after the transition. On the other hand, if the transition was part of broader social changes such as the formation of ethnic or ethnic-like identities, humans' dietary changes should accompany changes in material culture (such as grave goods and bodily decorations) that indicate identity formation (Shelach, 2009).

The transition was likely due to a combination of these factors, and the bioarchaeological data may be helpful in determining the relative importance of each of them in the various sub-regions of the Northern Zone. Whatever the causative factors that led to the transition, the resultant changes in subsistence, settlement, and activity patterns likely precipitated dramatic changes in human health.

METHODS FOR FUTURE RESEARCH ON AN EPIDEMIOLOGICAL TRANSITION IN THE BRONZE AGE NORTHERN ZONE

What types of data are needed to test for this epidemiological transition?

While human remains recovered in archaeological excavations within China are often assessed for age and sex, and studied for ethnic or racial affiliation, relatively little collection of paleopathological data has so far been attempted with the human remains from the Northern Zone. There is a large body of excavated material potentially available for study, which will be crucial in investigating the possibility of an epidemiological transition accompanying the Bronze Age subsistence transition. These remains will also be important in illuminating the speed of the transition through dietary reconstruction, and for testing different hypotheses for the cause of the transition (Shelach 1999, 2009).

As discussed above, in studies of mortuary populations, relative rates of pathological lesions are more reliable than absolute rates as indications of population health. Also, in order to test the hypothesis of an additional epidemiological transition in the Northern Zone, the health status of the population both before and after the Bronze Age subsistence transition must be understood. Therefore, it is important to gather data from different time periods, and also to be able to conduct interregional comparisons between populations practicing different subsistence strategies in the same period.

An ideal sample would include pre-agricultural populations and post-agricultural populations from the Northern Zone, to test for the presence of the first epidemiological transition with the beginnings of agriculture; pastoralist and agropastoralist populations from each of the three sub-regions discussed above (Manchuria, Inner Mongolia, and Xinjiang) to investigate the effects of ecological variation on the transition; and Bronze Age populations from the Chinese area to the south, to compare the health of a contemporaneous population practicing a very different subsistence strategy under a different system of social and political organization.

Of course, an ideal sample may not be currently available. As excavations across the Northern Zone continue under the auspices of the Chinese Academy of Social Sciences, provincial archaeological institutes, and university departments, more skeletal samples will become available. For now, the research can begin with the available specimens. For example, if good comparative samples of pre-agricultural and post-agricultural populations from the Northern Zone are not available, data from the start of millet agriculture in the Yellow River Valley (to the south), which are already being collected (Pechenkina et al., 2002), may be an analogous case for studying the first epidemiological transition in north Asia, as a baseline for the proposed additional transition in the Northern Zone.

Research into the human past is usually best approached as an interdisciplinary effort, and this applies also to the study of epidemiological transitions. To that end, while bioarchaeological data is the most direct evidence, it should be tested and correlated with archaeological, environmental, zooarchaeological, paleobotanical, and other data (Shelach, 1999; Ubelaker, 2003).

Bioarchaeological evidence

As human remains provide the most direct record of the ancient disease experience (Ubelaker, 2003), bioarchaeological data is the primary source of evidence for epidemiological transitions in prehistory. It is important to combine multiple bioarchaeological methods, including both quantitative and qualitative data where possible—for example, using both the presence of plant and animal remains (qualitative) and bone chemistry analysis (quantitative) in dietary reconstruction (Sanford, 1993). Paleodemographic and paleopathological data are both important, and are described in more detail below.

Non-bioarchaeological evidence

Paleoenvironmental data will help to evaluate whether the subsistence changes recorded for the early Bronze Age in the Northern Zone were necessitated by climate change. Reviews of the published data so far suggest that this was not the case (Shelach, 2009), but it is still important to look for evidence of possible environmental factors that may have influenced human behavior, caused stress, or impacted human health and demography.

Archaeological evidence—the physical remains of human settlements and cultural practices—has so far been the main source of evidence for the subsistence transition in this region. These data may include material culture such as art and personal decorations; mortuary practices; technology relating to subsistence; trade goods as evidence of interregional contact; and the size, type, and distribution of human settlements. The art of this period is evidence of the importance attached by the people to horses and other animals, and bronze horse-riding accoutrements are evidence of increasing mobility (Shelach, 2009). Mortuary practices and personal decorations in graves show a shift in ethnic-like identity that defined the Northern Zone populations in opposition to their southern neighbors. Finally, settlement data, though more is certainly needed from across the Northern Zone, so far suggests that there was a profound shift during this period, toward less permanent and more dispersed settlements, which is consistent with pastoral and agropastoral practices (Chifeng, 2003; Shelach 1999, 2009).

Aside from dietary reconstruction carried out on human bones themselves, paleobotanical and zooarchaeological remains are the most important source of data for dietary reconstruction. So far, very little paleobotanical research has been conducted in this region, but it will be important in future research to determine the continuing role of agriculture in the Northern Zone and the plant components of the human diet. Most of the zooarchaeological remains so far recovered from this region were found in mortuary contexts, in the role of grave goods or sacrifices, and so may not reflect actual consumption patterns. However, they probably suggest the increasing importance of domesticated animals during this period, especially sheep/goats and horses (Shelach, 2009).

Mashkour (2003) has reported some success in determining nitrogen and oxygen stable isotopic signatures of vertical seasonal transhumance in the tooth enamel of sheep and goats culled from the herds of modern-day Iranian pastoralists. The ratios of oxygen and nitrogen stable isotopes in the animals' diet are affected by temperature and plant types, which are in turn determined by the ecological zones through which the animals moved during the period in which their tooth enamel was forming. This project has clearly valuable potential applications for dating the beginnings of mobile or transhumant pastoralism in a given area, and for inferring seasonal mobility of a group of people, at least in contexts of vertical transhumance (seasonal movement between lower and higher altitudes).

Background of bioarchaeological methodology

Bioarchaeology of the transition to agriculture

Previous bioarchaeological research on human subsistence and health transitions has focused primarily on the consequences of the transition to agriculture in different regions of the world (Lambert, 2000; Larsen, 1997; Steckel and Rose, 2002a; Stock and Pinhasi, 2010), constituting the first epidemiological transition. As described above, this transition often entailed increased fertility but an overall decline in health. Thus, shorter stature, higher prevalence of dental caries, more nutritional deficiencies, and a higher burden of infectious diseases characterize many early agricultural societies (Cohen and Armelagos, 1984; Larsen, 1995; Steckel and Rose, 2002a). This research provides a precedent and an established methodology for the study of the human health consequences of other large prehistoric subsistence shifts.

The first epidemiological transition has been documented in archaeological populations for most regions in the world in which agriculture arose in prehistory. This includes Egypt (Starling and Stock, 2007), South America (Ubelaker and Newson, 2002), Mesoamerica (Norr, 1984), North China (Pechenkina et al., 2002, 2007), Southwest Asia (Rathbun, 1984), and others. However, complexity and local variation are frequently apparent. For example, research in Southeast Asia suggests that the negative health consequences observed in populations of early cultivators of maize, wheat, and millet are not always evident in early cultivators of rice (Dommett and Tayles, 2007; Douglas and Pietrusewsky, 2007; Krigbaum, 2007). This may be due to several factors, including the high nutritive value and low cariogenicity of rice, that rice cultivation in Southeast Asia was often accompanied by continuing foraging and fishing, and that it was adopted relatively gradually; or perhaps this merely indicates that wet rice agriculture led to a different suite of health problems that bioarchaeologists have yet to identify, for example increased parasite loads from the presence of standing water in rice paddies. The complex interaction of factors in these transitions means that there is significant regional variation in human biological reactions to subsistence change (Stock and Pinhasi, 2010), again emphasizing the need for studying epidemiological transitions as region-specific and diverse phenomena.

While there are still calls by researchers in the field for greater standardization of methods and training (Ortner, 1992; Steckel and Rose, 2002b; Ubelaker, 2003), the *Standards for Data Collection from Human Skeletal Remains* by Buikstra and Ubelaker (1994) is widely used. These standards were adopted for the Global History of Health

Project, which aims to collect paleopathological data from around the world to facilitate large interregional and diachronic studies of the history of human health (Steckel and Rose, 2002b; Steckel et al., 2004). As this set of standards is the most widely use and agreed-upon in the field, and as comparative data is important in the study of human health history, it should be adopted in the proposed research. In addition, the methodology used in the research must be published in detail to allow for comparative inter- and intra-regional analysis (Ubelaker, 2003).

One further advantage of bioarchaeological methodology is the focus on a biocultural approach. This approach is emphasized in many branches of biological anthropology today, and aims to put biological data about human life within its cultural context and vice versa (Larsen, 1997; Steckel and Rose, 2002b). This integrated perspective can more fully account for the wide range of human adaptation and behavior, and for changes in human populations such as health transitions.

It is important in this research to acknowledge, and address where possible, the limitations inherent in using mortuary populations to reconstruct the health and demography of the living populations to which they belonged. These limitations are often referred to as the “osteological paradox” (Cohen, 1997; Wood et al., 1992). These limitations include the failure of certain diseases to leave any evidence on dry human bone; the tendency of certain diseases only to leave evidence after long infection, indicating that individuals displaying disease lesions may in fact have been the stronger ones, able to withstand the infection for longer; and the effect of “demographic nonstationarity” (Wood et al., 1992 p. 344) on the age composition of a mortuary population. While these issues are difficult to address, especially in cases of incomplete excavation of cemeteries, they do not negate all bioarchaeological findings. They suggest that rates of diseases, trauma, and other pathologies are most reliable when reported as relative rates, allowing comparisons between populations or through time, and suggest that reconstruction of absolute rates of pathology in living populations are not usually possible from mortuary remains (Cohen and Crane-Kramer, 2003). These concerns also make it imperative to seek out other lines of evidence to support conclusions drawn from bioarchaeological data.

Bioarchaeology of pastoralism

Examples in the literature of bioarchaeological work being carried out on pastoralist populations are somewhat limited, especially compared to the extensive work conducted on agricultural populations; however, these studies have so far produced very interesting results.

One project has investigated stable isotope ratios in human populations from historic and Neolithic periods in Kenya, Tanzania, and South Africa (Ambrose, 1986; Ambrose and Deniro, 1986). The researchers found that carbon and nitrogen isotopes could reliably be used to distinguish pastoral from agricultural populations, and could even distinguish pastoralists dependent on different animals and agriculturalists dependent on different crops.[3] However, variation between and within habitats that cannot be explained with current data indicates the need for more work on physiological and micro-environmental influences on bone chemistry. This work also emphasizes how important it is to have a baseline of animal carnivores and herbivores for quantitative analysis of human diet.

[3] For example, among the historical populations investigated, pastoralist populations had $\delta^{15}N$ values of 10.4‰ to 15.2‰, while agriculturalist populations had averages values between 7.7‰ and 10.4‰. An agriculturalist population dependent on C_4 plants had average $\delta^{13}C$ values of –6.4‰, while populations dependent on both C_3 and C_4 plants had values between –10.6‰ and –12.7‰ (Ambrose, 1986; Ambrose and Deniro, 1986).

Bocherens et al. (2006) investigated stable carbon and nitrogen isotopes from Iron Age and Historical periods in Turkmenistan, and found that the mixed diet of the earlier period persisted into the later[4]. The authors state that milk and meat consumption should produce the same signature in bones, as milk contains the same isotopic signature as the bulk proteins. They also demonstrated the agreement of zooarchaeological (qualitative) and isotopic (quantitative) data for dietary reconstruction in this area. Similarly, Murphy (2011) analyzed human remains from Iron Age sites in Botswana. Archaeological evidence had attested to the presence of herd animals and not domesticated plants, but the stable isotope data indicated a mixed diet including C_4 plants as a major protein source[5], as well as intriguing inter- and intra-site variation in human diet.

Walker and Yablonski (1997) reported a change in the health of pastoralists in the south Aral Sea area of Central Asia in the first millennium BCE. The pastoralists in the study originally exhibited excellent health, which the authors attribute to a high-protein diet and to mobility, which allowed the pastoralists to avoid the high burden of infectious diseases experienced by sedentary populations. However, after around 200 BCE, when the pastoralists became less mobile and increased their interaction with the sedentary agriculturalists, their health declined, a change measurable in rates of porotic hyperostosis (see below for discussion of this condition).

Some recent work has been done on the paleopathology and diet of Inner Asian pastoralists. Eng (2007) compared the health of pastoralists, agropastoralists, and sedentary agriculturalists in the Northern Zone. The study covered a long time span, including periods

[4] Two individuals from the Iron Age and one from a historical period were analyzed. They all exhibited low $\delta^{13}C$ value (~ –20‰) consistent with consumption of C_3 plant foods, and high $\delta^{15}N$ values (~14‰) similar to specimens of dog and wild carnivores tested from the area (Bocherens et al., 2006).

[5] Individuals from the two study sites had $\delta^{13}C$ values of –8.93‰ and –7.70‰, respectively, which is within the range expected from consumption of C_4 plants such as sorghum and millet (Murphy, 2011).

well after the origins of pastoralism, and aimed to examine the effect of political relations on population health. The study produced complex but very interesting preliminary results for health in the Northern Zone (see Table 3 below). Eng found overall better health in pastoralist populations, including lower levels of generalized stress, nutritional deficiencies, dental pathologies, and infectious disease lesions in bone, along with greater stature. By most measures, the agropastoralist populations showed a health status intermediate between that of the pastoralists and the agriculturalists. Some of these findings were not at the level of statistical significance, indicating the need for further data collection to evaluate their validity. Also, her agropastoralist sample came from a single large cemetery site, and her samples of agriculturalists and pastoralists were pooled samples from sites of different time periods. Even given the sampling limitations, however, this research indicates what findings might be expected from future research on pastoral and agropastoral populations in the Northern Zone.

Table 3 Rates of pathological lesions in adults by economic group in Eng (2007, p. 138). AMTL=antemortem tooth loss; TMJ=temoromandibular joint; DJD degenerative joint disease; EH=enamel hypoplasias; PH=porotic hyperostosis; CO=cribra orbitalia; fx=fracture

	Nomadic Pastoral		Agropastoral		Agricultural	
	Cases	%	Cases	%	Cases	%
AMTL	93 / 194	48%	173 / 350	49%	7 / 24	29%
Carious	60 / 220	27%	192 / 341	56%	6 / 23	26%
TMJ DJD	30 / 183	16%	48 / 336	14%	8 / 23	35%
EH	19 / 193	10%	33 / 309	11%	5 / 21	24%
Tib osteoperi	4 / 129	3%	18 / 310	6%	0 / 16	0%
PH	4 / 198	2%	3 / 332	1%	0 / 22	0%
CO	22 / 190	12%	20 / 306	7%	1 / 22	5%
Limb fx	12 / 182	7%	22 / 353	6%	4 / 24	17%
Cranial fx	22 / 204	11%	6 / 336	2%	2 / 21	10%
Nasal fx	5 / 134	4%	2 / 138	1%	1 / 20	5%
Shoulder DJD	28 / 105	27%	56 / 190	29%	3 / 11	27%
Elbow DJD	37 / 112	33%	66 / 216	31%	4 / 13	31%
Hip DJD	33 / 184	18%	37 / 309	12%	8 / 31	26%

Work is beginning on quantitative dietary reconstruction in this region through stable isotope analysis. A study of a small sample of pastoralists and associated caprid (sheep/goat) remains from three Late Bronze Age and Early Iron Age sites in Xinjiang (Eng et al., 2009) showed a slight change in dietary composition over time, indicating human consumption of lower trophic level animals at the later two sites[6]. The results also suggest that the people at these sites and their animals consumed mostly C_3 plants (though the authors do not specify, this was most likely wheat). The authors compared their results to published isotope data from Chinese Neolithic sites, at which the population relied mostly on millet (a C_4 plant).

Another recent paper from China (Zhang et al., 2010) examined the isotopic composition of human bones from the Neolithic (pre-pastoralist) Miaozigou site in Inner Mongolia. Based this data, in addition to tools and wild animal bones found at the site, the authors concluded that C_4 plants, most likely millet, made up the bulk of the diet of this population, though hunting, gathering, and fishing were also important in their economy[7].

The work proposed in this paper will expand on the work of Eng (2007) and the other studies mentioned above by first, increasing the amount of paleopathological data available for analysis, allowing for more robust conclusions; and second, moving beyond the consideration of human behavior change in its sociopolitical context, to consider it in its ecological context. It will consider humans as one element in complex, multi-scalar systems, and will look at the health consequences for humans when the cultural-natural systems of which they are a part undergo reorganization and transformation.

[6] The average $\delta^{15}N$ concentration in the Late Bronze Age site studied was 15.36‰, while the concentration at the two Early Iron Age sites was 13.00‰ and 12.69‰, respectively (Eng et al., 2009).

[7] The average $\delta^{13}C$ concentration of individuals at the site was –7.19‰, within the range of consumption of C_4 plants (or animals fed on C_4 plants). Individuals from the site also had an average $\delta^{15}N$ concentration of 9.23‰, which is consistent with an omnivorous diet (Zhang et al., 2010).

Bioarchaeological methodology

As described above, to assess the hypothesis of a regional epidemiological transition in the Bronze Age Northern Zone, standard measures of paleopathology as outlined in *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker, 1994) and the Global History of Health Project (Steckel et al., 2004) should be employed, in order to facilitate cross-regional and diachronic comparisons. Below are predictions for what might be observed in skeletal populations from this time period with regards to different types of bioarchaeological data.

Nutritional deficiencies and metabolic disruption

Specific nutritional deficiencies, general nutritional deprivation, and other metabolic disruptions such as fever and infection with intestinal parasites may all leave visible evidence in the human skeleton. Such evidence include hypoplastic lesions (in cases of general metabolic disruptions, iron deficiency anemia, and scurvy); growth disruption in teeth or bones, including linear enamel hypoplasias or other defects in teeth, and radiopaque "Harris lines" in bones; and undermineralization or malformation of bones (in cases of rickets and osteomalacia) (Larsen, 1997; Ortner, 2003). Differential diagnosis of these pathologies is often very difficult, but even without knowing their specific etiologies, the presence of the signs described above can serve as general indicators of stress and dietary deficiencies.

Low-protein or other nutritionally poor diets can impact growth attainment as well (Larsen, 1997). By comparing long bone length to dental age researchers can determine periods of slowed growth in childhood, and by comparing the stature of populations across periods (in cases of population continuity), it is possible to identify periods of relative deprivation and stress. To a lesser extent, terminal stature may also be influence by other stressors, most notably infectious disease load.

Porotic hyperostosis and cribra orbitalia are usually taken as signs of iron deficiency anemia in an individual (Larsen, 1997). Iron deficiency can arise from a dietary deficiency of bioavailable iron or, as some researchers believe, from intestinal parasites or other intestinal infection. In fact, the latter may be a more common cause of iron deficiency anemia than dietary deficiency (Kent, 1986; Larsen and Sering, 2000). However, Walker et al. (2009) suggest that iron deficiency anemia is unlikely to be the cause of the marrow hypertrophy seen in porotic hyperostosis, suggesting instead that these conditions are caused by hemolytic or megaloblastic anemia, and that cribra orbitalia has a more complex etiology, often including nutritional deficiencies such as scurvy.

I would expect the occurrence of these pathologies to be lower in pastoralist communities than in agriculturalist ones. Though diet can only be inferred indirectly without dietary reconstruction by chemical methods, it can be reasonably assumed that pastoralists' consumption of meat and dairy products provided a high-protein diet, as well as a diet rich in bioavailable iron (Larsen and Sering, 2000). Pastoralists would also be expected to have a lower rate of intestinal parasitic diseases, given their more dispersed settlement pattern and therefore presumably less contaminated water sources. It is also possible, however, that some parasite species contracted by eating or handling undercooked meat would have a greater presence in these populations.

Infectious diseases

As with metabolic diseases, infectious lesions on bone are difficult to diagnose differentially. Many infectious diseases also do not leave visible evidence on dry skeletal remains, because the infected individual dies before these can develop, or because the lesions heal over time (Larsen, 1997; Ortner, 2003). Nonetheless, some chronic infectious diseases leave characteristic distributions of lesions on the skeleton. Specific infectious diseases discernible in human skeletal remains include tuberculosis, leprosy, and treponemal infections such as syphilis (Roberts and Manchester, 2007).

Nonspecific infections of bone (periostitis and osteomyelitis) are also important indicators of the health of a population, as they may reflect poor nutritional status, a high burden of other infectious diseases, or trauma. Rates of nonspecific infection are often taken as indications of the overall health of a population. For example, an increased rate of nonspecific infection has been documented in populations from the Woodland to the Mississippian periods in the Eastern Woodlands of North American, coinciding with greater reliance on maize agriculture and congregation of the population into larger settlements (Larsen, 1997).

Many human diseases may have originated as zoonotic infections (Barrett et al., 1998; Roberts and Manchester, 2007). For this reason, it may be expected that some novel infections, or perhaps a higher rate of infections acquired from domesticated animals (such as brucellosis and some forms of tuberculosis), may have made their way into human populations after the advent of pastoralism in the Northern Zone. For example, evidence from North America suggests that rates of tuberculosis increased at the start of sedentism, as a result of closer association with domesticated animals (although human infection by the bacterium *Micobacterium tuberculosis* probably predates animal domestication, some *Micobacterium* species primarily infect non-human animals and only secondarily infect humans, so that contact with animals is required for infection) (Roberts and Manchester, 2007). One would therefore expect the prevalence of tuberculosis to increase in pastoral populations, given their greater contact with herd animals.

Despite the risk of zoonotic infection, pastoralists probably experienced an overall decline in the rate of infectious diseases, especially density-dependent and water-borne diseases, due to the decrease in settlement size and attendant decrease in unsanitary conditions and water supply contamination. Pastoralists also likely had to contend with fewer soil-borne fungal infections (mycoses), though agropastoralists would still have been at risk for these.

Intestinal parasites have a large impact in human health in many populations around the world. They are difficult to study in ancient populations, as they do not directly impact the hard tissues of the body. Some researchers have proposed using rates of porotic hyperostosis, as evidence of iron deficiency anemia, as a sign of infection with intestinal parasites (Cohen and Crane-Kramer, 2003; Larsen and Sering, 2000). Where available, coprolites can also be used to test for the presence of parasites in a population. Both theoretical predictions and comparative ethnographic research suggest that nomadic foragers have fewer parasites and lower rates of anemia than sedentary farmers (Cohen and Crane-Kramer, 2003), and I would expect this to hold true for early pastoralists in the Northern Zone.

Dental pathology

Dental pathological lesions of interest to bioarchaeologists include carious lesions, periodontal disease, and tooth loss; other non-pathological dental variations, including calculus and tooth wear, are also of interest. All these pathologies have been linked to agricultural diets, since many agricultural staple foods (such as maize) tend to be cariogenic, and grinding tools used in food preparation can leave debris in food that causes wear and injury to teeth (Cohen and Armelagos,1984; Larsen, 1997). However, the relationship between dental pathology and diet is not a straightforward one, as individual genetics, hygiene practices, composition of the oral microfauna, and parafunctional use of teeth can all influence rates of dental pathologies in a population (Eshed et al., 2006).

Compared to previous agricultural populations in the region, I would expect pastoralists to exhibit lower rates of carious lesions, as their diet likely contained less starchy material than millet agriculturalists', though this can only be confirmed with dietary reconstruction. Dental wear may still have resulted from parafunctional uses of teeth such as leather working, but periodontal disease and antemortem tooth loss have been found to be lower in populations with diets high in animal protein (Larsen, 1997).

Eng (2007) found that highest rate of carious lesions among adults in the Northern Zone occurred among her agropastoralist samples, whose rates were statistically significantly higher than that of either the pastoralists or agriculturalists[8]. (Her samples span a long time period, from the Neolithic to the "Middle Imperial" or 13th and 14th centuries CE). She proposes that the similarity of the agriculturalists' rates to the pastoralists' may be due to

[8] The percentages of individuals with carious lesions in Eng's samples were: agriculturalist, 26%; nomadic pastoralist, 27%; and agropastoralist, 56% (Eng, 2007).

limited sample size, but points out that the pastoralist population definitely had a lower rate of caries than the agropastoral population, as per expectations.

Degenerative joint disease

Degenerative joint disease (DJD), including osteoarthritis and osteophytosis, though multifactorial in origin, is primarily a response to mechanical loading and physical activity (Larsen, 1997). There is a great deal of variation through time and across populations and climates in rates of DJD, and much of this variation has been attributed to changes in activity patterns based on labor needs and subsistence strategies. In several populations, the shift from mobile foraging to sedentary agriculture was accompanied by a reduction in rates of DJD, because of reduced labor demands. However, the introduction of horseback riding to a population can lead to an increase in prevalence of the “rider’s complex,” a pattern of DJD in the spinal column and pelvis that results from regular horseback riding (Larsen, 1997). Therefore, I would expect to see higher rates of DJD in pastoral populations as compared to agriculturalists, particularly in joints associated with horseback riding.

Eng (2007) found a complex picture relating to DJD, which varied in the four major joints examined (shoulder, elbow, hip, knee) according to factors such as proximity to the Chinese state, subsistence mode, period, and sex. She attributes some of these findings to sampling errors, though some may be attributable to sociopolitical factors such as rates of horseback riding, intensity of craft production by women, and labor and military service requirements for men imposed by the Chinese state.

Trauma

Trauma can result either from interpersonal violence or from accidents relating to lifestyle, activity patterns, and terrain. Eng (2007) found the greatest number of signs of interpersonal violence (cranial and facial trauma and bladed weapon wounds) in pre-imperial nomadic pastoralists from the "Outer zone" (farther from the influence of the Chinese state)[9], which she attributes to the conflict over pastures in the dry northwest, and the lack of centralized control and curbing of violence between groups. Fractures in the pastoralist sample conformed to clinical expectations of falls from horseback, and were most common in adult males. However, she found a higher rate of fractures overall in agricultural populations, perhaps also the result of handling domesticated animals.

I would expect the rates of trauma to increase after the rise of pastoralism as compared to earlier agriculturalist groups, as a result of frequent horseback riding and greater contact with domesticated herd animals. The well-known study by Berger and Trinkaus (1995) found that patterns of trauma in Neanderthals matched modern rodeo riders more closely than any other recent or archaeological sample in the study, presumably because both populations were in frequent close contact with large animals. Though the interaction of pastoralists with their herd animals was probably not so violent, horseback riding and herding most likely provided ample opportunities for injury.

[9] Among males in this group, 16% had cranial trauma and 8% had nasal fractures, as compared to another pre-imperial nomadic pastoralist sample from the "Inner zone" (closer to Chinese influence), which exhibited no cases of either. However, females from the Inner zone exhibit a much high rate of cranial trauma (28%) than the Outer zone females (4%), which may be evidence of raiding rather than warfare, or may indicate domestic violence (Eng, 2007).

The main differences in interpersonal violence in the northern zone found by Eng (2007) were dependent on the level of influence of imperial China[10]. Future data may reveal differences in interpersonal violence between pre-pastoralist and pastoralist groups in this region. If interpersonal violence increased around the start of pastoralism, it may be evidence of increased conflict over resources and may point to the validity of the model of environmentally stress-induced subsistence change and shortage of resources at the advent of Northern Zone pastoralism.

Paleodemographic data

The demographic structure of an ancient population is difficult to reconstruct from mortuary remains. Even if a cemetery population can be taken as a representative sample of a site's overall mortuary population, the relationship between the demography of the living and the demography of the dead is not straightforward.

Eshed et al. (2004) point out that the mean age at death of a population may be a reflection of fertility rather than mortality, as a growing population with a pyramidal age structure will have a lower mean age at death even if age-specific mortality remains the same (Ubelaker, 2003). To determine the effect of the transition to pastoralism on population structure, therefore, it is important to have comparative data from before and after the transition, and to consider the possibility of population growth or decline as an explanation for observed differences in life expectancy.

[10] Adult males had no cases of cranial or nasal fractures during the Pre-imperial period (Neolithic and Bronze Age, 4th to mid-1st millennia BCE), 3% had cranial and 3% nasal fractures during the Early Imperial period (Iron Age, mid-1st millennium BCE to mid-1st millennium CE), and 10% had nasal fractures though none had cranial fractures in the Middle Imperial period (Yuan Dynasty, 12th to 14th centuries CE) (Eng, 2007).

Studies of living pastoralist populations also present a complex picture of fertility rates. Much work has shown a lower level of fertility in nomadic populations than in neighboring sedentary ones (Kobyliansky and Hershkovitz, 2002; Leslie et al. 1988). However, work on nomadic Turkana groups in Africa has shown that, contrary to the findings of studies of other nomadic populations, the Turkana have a higher level of fertility than neighboring sedentary population (Leslie et al., 1988). The work also found a strong seasonal trend in birth rates, and has demonstrated the importance of demographic plasticity through outmigration and reduced fertility for population survival in drought conditions (Gray et al., 2002; Leslie et al., 1988; Little, 2002). Neupert (1999) describes the wide fluctuation of birth rates among Mongolian pastoralists in the Republic of Mongolia during the 20th century, going from a low rate in the first half of the century due to economic and political stressors, to a boom in growth that peaked at a birth rate of over 7 children per woman at mid-century, followed by a slow decline to 2.5 births per woman as of 1993.

Given the complexity of this picture, and the methodological challenges of paleodemographic research, it is necessary to recognize the difficulty of reconstructing demographic change for the period in question for this research. However, demographic transitions are often important correlates of epidemiological transitions, and it is therefore important to attempt this reconstruction. Death tables, representing the demographic structure of a mortuary population, can provide evidence of disease or adverse health that is not represented by visible skeletal changes (Ubelaker, 2003). Changes in mortality and fertility offer crucial clues about the impact of subsistence transitions on human health and demography. As more data on skeletal populations from the region become available, the model of population change can be refined.

One would also expect differences in the impact of the subsistence transition on different segments of the population. For example, social factors such as division of labor, which influences activity pattern and diet, can create marked difference in health between men and women (Larsen, 1997). Eshed et al. (2004) found no reduction in age at death for males after the advent of agriculture in the southern Levant, but a clear reduction for females, which they attribute to higher maternal mortality resulting from higher birth rates. Differential access to resources or different foodways can of course also result in health differences between social strata (Smith, 2008). The heterogeneity of health within a population must be included in any complete account of an epidemiological transition.

Stable isotope and trace element analysis

In testing for the presence of an epidemiological transition in the Northern Zone, one of the most important research goals is dietary reconstruction. This is particularly important for determining differences in pastoral and agropastoral practices between sub-regions within the Northern Zone, and how these differences impacted human health.

The most important distinction for this study is the rate of consumption of animal products (meat and dairy), for which it is necessary to assess the trophic level of humans in the environment. The reconstruction of ancient diet by analysis of ratios of stable isotopes of nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) in archaeological bone is well-established (Ambrose and Deniro, 1986; DeNiro and Epstein, 1978, 1981; Hutchinson et al., 2000; Katzenburg and Saunders, 2008; Pate, 1994; Schoeninger and Moore, 1992). With baseline data on plant and animal stable isotopes from the same region, it should be possible to determine the amount of animal versus plant material in the human diet. It should also be possible, using carbon stable isotope values, to determine whether the plant component of the human diet at this time was primarily composed of a C_4 plant such as millet, or a C_3 plant such as wheat (Hutchinson et al., 2000).

While stable isotope analysis is a "nearly direct record of diet", it is important to consider this quantitative evidence in conjunction with qualitative data (Larsen, 1997 p. 300). This includes primarily animal remains: though most faunal remains collected in excavations in the Northern Zone have been from mortuary contexts and so may not be representative of the human diet, they will still be useful in determining what species were present and whether they were hunted or domesticated animals. Dietary reconstruction should also incorporate botanical remains, where available (though these have only been collected for a few sites so far). Work by Zhang and Zhu (2011) and Bocherens et al. (2006), described above, successfully combine faunal, botanical, and archaeological remains with isotope data from human remains for dietary reconstruction.

Paleopathology data can also contribute indirectly to dietary reconstruction: as discussed above, agricultural populations tend to have higher rates of dental caries from eating high-carbohydrate diets, have more dental wear from eating grains ground with stone, and suffer more nutritional deficiencies from a lack of diversity in the diet (Pechenkina et al., 2002; Steckel and Rose, 2002b).

Analyses of certain trace elements, such as strontium, can also clarify patterns of human migration (Larsen, 1997). However, this research requires a thorough understanding of regional differences in trace element compositions of water sources. This technique is also mostly useful for assessing migration between regions, and will not be as useful for assessing circular and seasonal patterns of migration. While not necessary to test for an epidemiological transition, the results of trace element analysis, if conducted eventually, would be interesting in clarifying the late prehistory of this region.

CONCLUSION

The research proposed in this paper has significance for a scholarly understanding of human biocultural adaptation. It can help clarify the consequences of a major human dietary shift, by testing for the presence of an epidemiological transition, and for how dramatic this transition may have been—whether, as I suspect is the case, the subsistence transition from farming to pastoralism reversed some of the deleterious effects of the rise of agriculture, or whether, as another large shift in lifeway, it also may have had deleterious consequences of its own.

It will provide a valuable comparative case for existing studies of subsistence and health transitions all over the world. Such comparative research is critical for understanding the history of human health and environmental interaction (Ubelaker, 2003). Its value for comparative research will be enhanced by the use of a standardized method for data collection as outlined in the Global History of Health Project standards (Steckel et al., 2004). It will also use multiple lines of evidence, including paleopathological, zooarchaeological, paleobotanical, archaeological, and paleoclimatological data, for independent verification of findings.

Data from the period of 1200 to 600 BCE, during which the pastoral and agropastoral practices of the Northern Zone took shape, should be compared to earlier and later phases of cultural development in the region, as relative rates of pathology and health measures are more reliable than absolute rates in archaeological populations. Where possible, comparisons between sub-regions within the Northern Zone and with neighboring agriculturalist populations will help clarify the relationship between subsistence, health, and local climatic and political conditions.

A final potential issue with the proposed research is one of definitions. At what point can an epidemiological transition be said to have occurred? Is there a threshold at which a health transition can be said to be on this level of significance? Along the lines of the discussion above, I would caution against such categorical thinking. The premise of this paper is that epidemiological transitions are complex and heterogeneous. There is a degree of subjectivity in determining whether data constitute evidence of an epidemiological transition or not. I would argue that the epidemiological transition model is a valuable heuristic device that can help researchers in biological anthropology, archaeology, ecology, and medical geography pinpoint substantial shifts in human behavior and health, and better understand the parameters of behavior change and adaptation that continue to influence our lives.

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