In: Human Remains and Museum Practice, edited by Jack Lohman and Katherine Goodnow, pp. 60-70. Berghahn Books, New York.

CHAPTER 7

The Scientific Value of Human Remains in Studying the Global History of Health

Richard Steckel, Clark Spencer Larsen, Paul Sciulli & Phillip Walker

At some level, virtually all researchers are aware of the significant processes of biocultural evolution that gave rise to modern societies over the past 10,000 years. We know that many modern problems have roots reaching deep into the human past, and that current conditions were often created by complex interdependent processes that unfolded over very long periods of time. As a result, the research of many social and medical scientists would benefit greatly from access to a very long-term historical perspective on fundamental issues relating to health and the human condition.[1] Working with numerous collaborators, we have designed a project to create that perspective for an important dimension of the quality of life, chronic morbidity as measured from skeletons. Project researchers will combine the skeletal data with contextual information about sites where people lived for use in reinterpreting the causes and consequences of changing health along the historical path leading to modern societies.

The diversity of human experience, and the corresponding variation in our health, have been enormous since the late Paleolithic era. These profound changes are highlighted by four pivotal transitions in the last ten millennia of human history: (1) the shift from foraging to farming, (2) the rise of cities and complex polities, (3) European expansion and colonization, and (4) industrialization. Each of these global transitions had an enormous impact on health and the human condition. With the rise of farming, the human population became larger and more sedentary, which resulted in crowding and the creation of conditions conducive to the spread and maintenance of infectious diseases.[2] During and following the transition to farming, pathogenic organisms causing highly contagious diseases evolved significantly. The diversity of foods eaten also diminished, eventually resulting in the modern worldwide dependence on a handful of super-crops (maize, wheat, rice) that lack specific nutrients essential for growth and development.[3] Many believe that with the rise of cities, health deteriorated further as a result of crowding, inadequate sanitation, growing inequality, and conflict.[4] Although colonization offered new opportunities for the rapidly growing European population, it also led to the devastating spread of new pathogens to formerly isolated populations in areas such as in North and South America.[5] The spread of measles, smallpox, and other acute infectious diseases resulted in huge population losses throughout the world, not just in the western hemisphere. Finally, the industrial age often brought new health costs, and many workers faced diets inadequate to sustain them in their hard work and heightened exposure to diseases spread at crowded places of work and living.[6]

Physical anthropologists and archaeologists are best equipped to provide the evidence necessary to measure very long-term health changes. Over the past several decades, they have excavated thousands of sites and studied hundreds of thousands of skeletons and their contexts. Because of its biological basis in the physiological processes of growth, development, and acclimatization to environmental change, the information about interactions with past environments encoded in these human remains provides a valuable comparative basis for evaluating interpretations of the past based on artifacts, documents, and other sources.[7]

These basic sources of information on the lives and living conditions of our ancestors are often accessible, but for various historical, political, and logistic reasons have not been assembled into a truly comprehensive, detailed and coherent mosaic adequately depicting the evolution of health. Our effort will create such a resource for basic health indicators readily obtainable from human skeletal remains. While it builds upon a small project completed for the western hemisphere,[8] the immediate focus is Europe and the Mediterranean and the long-term goal is a global project.

Skeletal measures of health

Human skeletal and dental tissues are highly sensitive to the environment. They provide a storehouse of information on health from conception through adulthood that can be combined with estimates of age and sex to provide detailed individual health histories, and merged to form a valuable picture of community health.[9] For this investigation, we have developed and tested laptop-based software to collect the following commonly accepted general health indicators for each skeleton:

Adult height

Substantial evidence from the study of modern populations reveals that impoverished environments (ie, poor diets, heavy disease loads, and hard work) suppress growth in childhood and, if chronic and severe, substantially reduce final adult stature.[10] A large historical literature based on anthropometric records explores the relationship between height and economic wellbeing.[11] We will greatly expand this research by using established procedures to estimate stature from long bone lengths.[12]

Enamel hypoplasias

Hypoplasias are lines or pits of enamel deficiency commonly found in the teeth (especially incisors and canines) of people whose childhood was biologically stressful. They are caused by disruption to the cells (ameloblasts) that form the enamel. The disruption is usually environmental, due to poor nutrition, infectious disease, or a combination thereof. Although non-specific, hypoplasias

---

1 Coatsworth, J H, (1996), 'Welfare', in *The American Historical Review 101*, pp1–12; Cordain, L, (1999), 'Cereal Grains: Humanity's double-edged sword', in *World Review of Nutrition and Dietetics 84*: pp19–73; Eaton, S B, and Eaton, III SB, (1997), 'Paleolithic nutrition revisited: A twelve-year retrospective on its nature and implications', in *European Journal of Clinical Nutrition 51*, 207–16; Eaton, S B, Konner, M, and Shostak, M, (1988), 'Stone agers in the fast lane: Chronic degenerative diseases in evolutionary perspective', in *The American Journal of Medicine 84:* 739–49; Popkin, B M, (1998), 'The nutrition transition and its health implications in lower-income countries', in *Public Health Nutrition 1*, pp5–21

2 Cohen, M N, (1989), *Health and the Rise of Civilization*, Yale University Press, New Haven; Cohen, M N, and Armelagos, G J, (1984), *Paleopathology at the Origins of Agriculture*, Academic Press, New York; Larsen, C S, (1995), 'Biological changes in human populations with agriculture' *Annual Review of Anthropology 24*, pp185–213; Smith, B D, (1995), *The Emergence of Agriculture* Scientific American Library, New York

3 Cordain, L, (1999) *op cit*

4 Cartwright, F F, (1972), *Disease and History*, Crowell, New York; Cohen, M N, (1989) *op cit*

5 Cook, N D, (1998), *Born to Die: Disease and new world conquest 1492–1650*, Cambridge University Press, New York; Crosby, A W, (1972), *The Columbian Exchange: Biological and cultural consequences of 1492*, Greenwood Publishing, Westport, Connecticut; Kiple, K F, and Beck, S V, (eds), (1997), *Biological Consequences of the European Expansion 1450–1800*, Ashgate, Aldershot, Hampshire, Great Britain/ Variorum, Brookfield, Vermont, USA; Larsen, C S, (1994), 'In the wake of Columbus: Native population biology in the post-contact Americas', in *Yearbook of Physical Anthropology 37* pp109–54; Merbs, C F, (1992), 'New world of infectious disease' in *Yearbook of Physical Anthropology 35* pp3–42; Verano, J W, and Ubelaker, Douglas H, (eds), (1992), *Disease and Demography in the Americas*, Smithsonian Institution Press, Washington

6 Steckel, R H, and Floud, R, (eds), (1997), *Health and Welfare during Industrialization*, University of Chicago Press, Chicago, Illinois

7 Walker, P L, (2000), 'Bioarchaeological ethics: a historical perspective on the value of human remains', in Katzenberg, M A, and Saunders, S R, (eds), *Biological Anthropology of the Human Skeleton*, Wiley, New York, pp 3–39

8 Steckel, R H, and Rose, J C, (eds), (2002), *The Backbone of History: Health and nutrition in the western hemisphere*, Cambridge University Press, New York

9 Larsen, C S, (1997), *Bioarchaeology: Interpreting behavior from the human skeleton*, Cambridge University Press, New York

10 Eveleth, P B, and Tanner, J M, (1990), *Worldwide Variation in Human Growth*, Cambridge University Press, Cambridge

11 Floud, R, Wachter, K, and Gregory, A, (1990), *Height, Health and History: Nutritional status in the United Kingdom 1750–1980*, Cambridge University Press, Cambridge; Komlos, J, (1989), *Nutrition and Economic Development in the Eighteenth-century Habsburg Monarchy: An anthropometric history*, Princeton University Press, Princeton; Steckel, R H, (1995), 'Stature and the standard of living', in *Journal of Economic Literature*, December 33, pp1903–40; Steckel, R H, and Floud, R, (eds), (1997) *op cit*

12 Krogman, W M, and Iscan, M Y, (1986), *The Human Skeleton in Forensic Medicine*, C C Thomas, Springfield, Illinois; Sciulli, P W, Mahaney, M C, and Schneider, K N, (1990), 'Stature estimation in prehistoric Native Americans of Ohio', in *American Journal of Physical Anthropology 83*, pp275–80

have proven enormously informative about physiological stress in childhood in archaeological settings.[13]

Evidence of iron deficiency anaemia

Iron is essential for many body functions, such as oxygen transport to the body's tissues. In circumstances where iron is deficient – owing to nutritional deprivation, low bodyweight, chronic diarrhea, parasite infection, and other factors – the body attempts to compensate by increasing red blood cell production.[14] The skeletal manifestations of childhood anaemia appear in those areas where red blood cell production occurs, such as in the flat bones of the cranium. The associated pathological conditions are sieve-like lesions called porotic hyperostosis and cribra orbitalia for the cranial vault and eye orbits respectively. In infancy and childhood, iron deficiency anaemia is associated with impaired growth and delays in behavioural and cognitive development. In adulthood, the condition is associated with limited work capacity and physical activity.[15] We are aware that not all examples of porotic hyperostosis and cribra orbitalia are indicators of anaemia.[16]

Trauma

Fractures, weapon wounds and other skeletal injuries provide a record of accidents or violence. Accidents such as ankle fractures reflect difficulty of terrain and the hazards of specific occupations. Injuries caused by violence, such as weapon wounds or parry fractures of the forearm, provide a barometer of domestic strife, social unrest and warfare.[17]

Infectious disease

Skeletal lesions of infectious origin, which commonly appear on the major long bones, have been documented worldwide. Most of these lesions are found as plaque-like deposits from periosteal inflammation, swollen shafts, and irregular elevations on bone surfaces.[18] Most are nonspecific (the circumstances causing the infection cannot be determined) but they often originate with *Staphylococcus* or *Streptococcus* organisms. These lesions in archaeological skeletons have proven very informative about patterns and levels of community health.[19]

Dental health

Dental health is an important indicator both of oral and of general health. The most accessible dental health indices in archaeological skeletons are carious lesions and ante mortem tooth loss.[20] The former result from a disease process characterized by the focal demineralization of dental hard tissues by organic acids produced by bacterial fermentation of dietary carbohydrates, especially sugars. In the modern era, the introduction and general availability of refined sugar caused a huge increase in dental decay. In the more distant past, the adoption of agriculture led to a general decline in dental health, especially from the introduction of maize. The agricultural shift and the later use of increasingly refined foods have resulted in an increase in periodontal disease, caries, and tooth loss. The patterns of tooth decay and linkages with dietary and lifestyle changes have been studied in the western hemisphere but few have examined the timing and scope of regional differences elsewhere.

Degenerative joint disease

Degenerative joint disease (DJD) is frequently observed in archaeological skeletal remains. The condition commonly results from mechanical wear and tear on the joints of the skeleton due to physical activity.[21] Generally speaking, populations engaged in physically demanding activities have more skeletal manifestations of the disease (especially build-up of bone along joint margins and deterioration of bone on articular joint surfaces) than populations that are relatively sedentary. Studies of DJD have been valuable in documenting levels and patterns of activity in past populations.[22]

Robusticity

Skeletal robusticity refers to the general size and morphology of skeletal elements.[23] It is well known that bones are highly sensitive to mechanical stimuli, especially with regard to the ability of bones to adjust their size and shape in response to external forces. For example, foragers tend to be highly mobile, leading to elongated or oval femoral midsections, whereas farmers are more sedentary and have circular midsections.[24] These and other morphological differences reveal much about habitual patterns of physical activity and behavioural change over time.[25]

Specific infections

Tuberculosis, leprosy, scurvy, rickets, and treponemal infections (for example syphilis) are examples of diseases that often leave significant evidence on the skeleton.[26] As these were major European diseases over past millennia, we will record their presence or absence.

Age and sex

The human skeleton exhibits many different age-related changes.[27] Juvenile age-at-death is best estimated from dental development. The extent of long bone epiphysis fusion is also a valuable age indicator for older juveniles. Adult age-at-death is typically determined based on assessments of data on a variety of age-related changes. Pubic symphyseal development is one of the more reliable age indicators for people between 18 and 50. Although they show considerable individual variation, cranial suture closure patterns can also prove useful for aging older adults. Tooth wear exhibits a regular increase with increasing age.

Data collection

In June of 2001, we organized a planning meeting at Ohio State University to inventory skeletal remains, discuss coding procedures, and consider administrative matters. The 16 physical anthropologists who attended from Europe reported personal access to over 130,000 skeletons at museums where they worked or conducted research. Their names and affiliations are given in Table 1.

This inventory is described in Table 2 and has since grown by involving additional collaborators who bring the total to more than one million skeletons located in 23 countries: Austria, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Iceland, Lithuania, Netherlands, Norway, Poland, Portugal, Republic of Ireland, Romania, Russia, Spain, Sweden, Switzerland, Turkey, Ukraine, and the United Kingdom. Moreover, as publicity efforts have unfolded over the past year, we foresee expansion to additional collaborators and countries. The project has received seed funding and some financial support for data collection from the National Science Foundation (grants SES-0138129 and BCS-0527658), but we are seeking additional assistance.

The collections included in Table 2 are chronologically diverse and encompass a broad spectrum of ecological and socioeconomic conditions across more than 650 localities. While we have not gathered detailed information on all these collections, we can make some

13 Goodman, A H, and Rose, J C, (1991), 'Dental enamel hypoplasias as indicators of nutritional status', in Kelley, M A, and Larsen, C S, (eds), *Advances in Dental Anthropology*, Wiley-Liss, New York, pp279–93; Hillson, S, (1996), *Dental Anthropology*, Cambridge University Press, Cambridge

14 Walker, P L, (1986), 'Porotic hyperostosis in a marine-dependent California Indian population', in *American Journal of Physical Anthropology 69*, pp345–54

15 Scrimshaw, N S, (1991), 'Iron deficiency', in *Scientific American 265*, pp46–52

16 Schultz, M, (1982), 'Krankheit und Umwelt des vor-und frühgeschichtlichen Menschen', in Wendt, H, and Loacker, N, (eds), *Kindlers Enzyklopädie der Mensch*, Kindler Verlag, Zürich, pp259–312; Schultz, M, (1993), 'The initial stages of systematic bone disease', in Grupe, G, and Garland, A N, (eds), *Histology of Ancient Human Bone: Methods and diagnosis; proceedings of the palaeohistology workshop held from 3–5 October 1990 at Gottingen, Berlin*, Springer-Verlag, New York, pp185–203

17 Martin, D L, and Frayer, D W, (eds), (1997), *Troubled Times: Violence and warfare in the past* Gordon and Breach, Australia; Walker, P L, (1989), 'Cranial injuries as evidence of violence in prehistoric southern California', in *American Journal of Physical Anthropology 80*, 313–23; Walker, P L, (2001), 'A bioarchaeological perspective on the history of violence', in *Annual Review of Anthropology 30*, pp573–96

18 Ortner, D J, and Putschar, W G J, (1985), *Identification of Pathological Conditions in Human Skeletal Remains*, Smithsonian Institution Press, City of Washington

19 Larsen, C S, (1997) *op cit*; Ortner, D J, and Putschar, W G J, (1985) *op cit*

20 *Ibid*

21 Hough, A J, and Sokoloff, L, (1989), 'Pathology of osteoarthritis', in McCarty, D J, and Koopman, W J, (eds), *Arthritis and Allied Conditions*, Lea & Febiger, Philadelphia, pp1571–94

22 Larsen, C S, (1997) *op cit*

23 Ruff, C B, (2000), 'Biomechanical analyses of archaeological human skeletons', in Katzenberg, M A, and Saunders, S R, (eds), *Biological Anthropology of the Human Skeleton*, Wiley, New York, pp71–102

24 *Ibid*

25 Bridges, P S, (1995), 'Skeletal biology and behavior in ancient humans' in *Evolutionary Anthropology 4* pp112–20; Larsen, C S, (1997) *op cit*; Ruff, C B, Walker, A, Larsen, C S, and Trinkaus, E, (1993), 'Postcranial robusticity in homo I: temporal trends and mechanical interpretation' in *American Journal of Physical Anthropology 91* pp21–53

26 Larsen, C S, (1997) *op cit*; White, T D, (2000), *Human Osteology*, Academic Press, San Diego

27 Bass, W M, (1995), *Human Osteology: A laboratory and field manual*, Missouri Archaeological Society, Columbia, Missouri; Konigsberg, L W, and Hens, S M, (1998), 'Use of ordinal categorical variables in skeletal assessment of sex from the cranium', in *American Journal of Physical Anthropology 107*, pp97–112; Stewart, T D, (1979), *Essentials of Forensic Anthropology, Especially as Developed in the United States*, Thomas, Springfield, Illinois; Ubelaker, D H, (1989), *Human Skeletal Remains: Excavation, analysis, interpretation*, Taraxacum, Washington; White, T D, (2000) *op cit*

Table 1: European participants at the first organizational conference

NAME	COUNTRY	DEPARTMENT	AFFILIATION
Pia Bennike	Denmark	Biological Anthropology	Panum Institute
Joël Blondiaux	France		Centre d'Etudes Paleopathologiques du Nord
Miguel C Botella	Spain	Facultad de Medicina	University of Granada
Yuri K Chistov	Russia	Physical Anthropology	Museum of Anthropology & Ethnography
Alfredo Coppa	Italy	Antropologia	La Sapienza University of Rome
Eugénia Cunha	Portugal	Antropologia	Universidade de Coimbra
Ebba During	Sweden	Archaeology	Stockholm University
Per Holck	Norway	Anatomical Institute	University of Oslo
Rimas Jankauskas	Lithuania	Anatomy, Histology and Anthropology	Vilnius University
Antonia Marcsik	Hungary	Anthropology	University of Szeged
George Maat	Netherlands	Anatomy	University of Leiden
Anastasia Papathanasiou	Greece		Greek Ministry of Culture
Inna Potiekhina	Ukraine	Institute of Archaeology	National Academy of Sciences
Charlotte Roberts	United Kingdom	Archaeology	University of Durham
Michael Schultz	Germany	Zentrum Anatomie	University of Göttingen
Maria Teschler-Nicola	Austria	Archaeology, Biology and Anthropology	Natural History Museum, Vienna

Table 2: Distribution of skeletons by region and historical period

	Scandinavia	Western Europe	Southern Europe	Central Europe	Eastern Europe	TOTAL	%
Post-medieval	1,476	7,829	360	0	4,729	14,394	10.9
Late medieval	14,025	24,344	2,240	229	2,354	43,192	32.8
Early medieval	4,201	20,174	1,740	2,623	9,330	38,068	28.9
Roman	0	8,657	2,125	591	1,399	12,772	9.7
Iron Age	12	514	5,111	500	2,462	8,599	6.5
Bronze Age	81	48	4,063	4,258	1,842	10,292	7.8
Neolithic	540	279	1,922	635	370	3,746	2.8
Mesolithic	90	0	121	0	288	499	0.4
TOTAL	20,425	61,845	17,682	8,836	22,774	131,562	99.8
%	15.5	47.0	13.4	6.7	17.3	99.9	

general statements. Although their numbers are relatively small in comparison to later periods, the inventory includes many of the key collections that document the transition from hunting and gathering to agriculture in Europe. The rise of cities and complex polities and the effects of European expansion, colonization, and industrialization are especially well documented, with nearly 120,000 individuals available from sites used during the last two millennia. Materials from the medieval period onward are especially abundant, and when combined with the greater historical documentation of this era, these sources provide considerable potential for a refined analysis of the possible causes and consequences of health changes.

As learned from the western hemisphere project, diversity in the database is an important asset for study of determinants of health. We will achieve this through stratified sampling by categories that were found relevant in that project: time period, settlement size, geographic location, subsistence pathways, technology, elevation, vegetation and topography. Our project participantswhoknowthecollectionswithineachcountry will prioritize recommendations, considering trade-offs relevant to cost-effectiveness of data collection efforts. Their suggestions will then enter our calculus for achieving diversity in environmental characteristics of the sample.

Graduate students will use laptops to collect the skeletal data under the supervision of senior researchers as part of their thesis or dissertation. They will keep a personal journal of cases that indicates the date, time and museum code number of each. In addition they may use, but the codebook does not require, photography to illustrate lesions for later analysis, which accommodates researchers who have interests not easily condensed into metric information or who utilize variables for which categorization is best done after examining a large number of cases. The personal journal helps researches to keep track of the disposition of cases and related information (such as photos), thereby preventing duplicates in the database.

Time since death

^{14}C, the heavy (radioactive) unstable isotope of carbon, is created in the atmosphere when cosmic radiation bombards ^{14}N atoms. The ^{14}C, along with ^{12}C, is ingested by plants as they metabolize $C0_2$ during photosynthesis. Animals (including humans) acquire the ^{14}C and ^{12}C in the same proportion as the plants they are eating. Once the organism dies, the ^{14}C atoms begin to decay. The ratio of the ^{14}C to ^{12}C identifies the age of the bone, or any other organic material. The dating method is used frequently in Europe for collections without historical documentation or chronologically diagnostic artifacts.

Dietary reconstruction

Much can be learned about diets by examining chemical isotopes extracted from small samples of bone for a few individuals who lived at each site. Isotopes of carbon and nitrogen can identify consumption of key domesticates, marine foods (fish and shellfish), and meat.[28]

Assessing environmental context

Economics, physical anthropology, archaeology, history, climate history, and geography are mature fields of study that are poorly integrated even though all involve or can involve study of the past. Among these, the closest links are traditionally found between physical anthropology and archaeology, which involve the study of artifacts such as pottery, tools, weapons, and coins, and their relationships to places of residence, work, travel, and so forth. Increasingly, archaeology is used to inform history, particularly in settings that lack written documentation. Climate history sometimes overlaps with research in traditional history, but most graduate history programs consider the field a minor specialty.[29] Geography in the form of geographic information system (GIS) databases and techniques is important in archaeology and its presence is increasingly felt in physical anthropology and history.[30] This project is unusual in the high degree to which

---

[28] Larsen, C S, (1997) *op cit*

[29] Lamb, H H, (1995), *Climate, History and the Modern World*, Routledge, New York; Rotberg, R I, and Rabb, T K, (1981), *Climate and History: Studies in interdisciplinary history*, Princeton University Press, Princeton; Wefer, G, (2002), *Climate Development and History of the North Atlantic Realm*, Springer, Berlin

knowledge from all of these fields is combined in the study of health.

Supplementing GIS is a considerable archaeological record for all eight of the major temporal periods covered in this project (Mesolithic, Neolithic, Bronze Age, Iron Age, Roman, Early medieval, Late medieval, Post-medieval). The historical record becomes substantially useful in the medieval period. Three key themes emerge from these records, namely (1) adoption and increased focus on farming as a means of acquiring food; (2) population expansion and movement; and (3) increase in social inequality. Especially critical for interpreting health is the impact of farming, which originally derived from the Middle East, and spread east to west.[31] A range of domesticated plants was cultivated, but wheat, barley, millet, and rye were key foods, fuelling local economies. Around five millennia ago, farming within Europe was acquired last in Scandinavia and Britain.[32] Agriculture laid the essential economic foundation for the appearance of villages, some of which eventually grew into cities. Analysis of burials from the Neolithic onward shows growing stratification and associated inequality.[33]

Climatologists have devised numerous ways to measure climate and its variability in the past from sources such as ice cores, tree rings, marine sediments, and pollen analysis.[34] Thompson et al discuss sudden adverse climate events such as occurred approximately 5,200 years ago, when Otzi the Ice Man froze in the Austrian Alps. Direct quantitative measures for some climate variables, such as temperature, are quite recent relative to the chronological span of this project, but models have been developed to estimate many of them. The issue is whether the output of these models is sufficiently accurate to warrant use as explanatory variables. Our climate advisor (Lonnie Thompson) indicates that, at a minimum, categorical variables can be estimated for temperature and precipitation. Tree rings and lake sediments, which extend back as much as 11,000 years for some parts of Europe, are proxies for annual variability in weather.

Coding data on the environmental context

It is a challenging but manageable task to construct consistent and useful measures of the environment in which people lived over the millennia. Our collaborators from Europe and the Mediterranean will be invaluable in providing expertise for this activity.

Settlement size: This aspect of life will be measured on a categorical scale in efforts directed by key personnel in archaeology (Phillip Walker) and history (John Brooke). Following procedures used in the western hemisphere project, and in consultation with the lead researcher for each site and other scholars consulted as needed, they will assign each site into mobile (hunter-gatherer), settled but dispersed, village, small town, or city.

Technology and material culture: Given the diverse evidence on technology, material culture and other aspects of life in the distant past that archaeologists have assembled, the field has developed a methodology for categorizing information[35] that indicates the material standard of living. The technology is an indirect measure of material living, which indicates types of products that could be produced and the scale on which they may have been distributed. We will utilize this methodology to classify technology and material culture into categories of tools, power sources, and housing. With regard to tools, five categories are readily known from archaeological and historical sources: stone, copper, bronze, iron, and steel. Over the past ten millennia (up to the late 19th century) societies have used five major sources of power: human, draft animal, water, wind, and steam. Archaeologists can readily classify housing into two types, temporary and permanent, and within the latter by type of construction: stone versus wood foundations and whether floors and walls were finished or unfinished.

Interregional trade: Archaeologists know that only very simple and inevitably rough classifications are available for this category. As with the material culture, we will use the transportation technology as an indirect measure that crudely indicates the cost of transporting products. Our categories are: backpack; wheeled carts; draft animals; lake or river boat; coastal vessel; ocean vessel (reliably able to travel beyond the sight of land). We can also obtain some notion of the types of products that were traded and the distances over which they were delivered in the prehistoric past. Unfortunately, archaeological evidence on products is heavily skewed toward those of high value in relation to weight such as stone used for tools, shells, beads and so forth. However, some shipping containers survive which indicate the types of products, such as grain, wine or oil, that were exchanged in trade. The recoverable record is far more elaborate for the historical era with shipping manifests indicating the types and amounts of products that were transported. Trade may have acted as a double-edged sword for health by increasing the quantity and diversity of products for consumption while also exposing populations to new pathogens.

Literacy: Numerous modern studies point to the relevance of education for health, and for lack of information on years of schooling, historical studies often use literacy as a crude proxy. At first glance it may seem to be an almost impossible challenge to estimate literacy rates over the millennia. But for most of the time span in this study, we are confident of the result: zero. In fact among historical populations up to the era of relatively cheap printing that began in the late 1400s, literacy rates were undoubtedly low as evident from the few people who had access to writing instruments and materials or possessed private libraries. In ancient Greece and Rome – environments in which literacy rates were probably highest before the 15th century – there is little evidence for a publishing industry, and the share literate was low among women and among the unskilled,[36] implying quite low levels overall. Because professionals and some artisans possessed the skill in the ancient (and later) world, contextual information about the burial sites is important in making approximate assessments. The share literate rose with the Protestant reformation, which obliged the faithful to read the Bible. From the 16th century onwards we can estimate literacy rates from signatures on marriage registers, and by the late 1700s some governments in Europe published data on the subject. With contextual information we expect to classify literacy rates (r) into 6 groups: zero and quantiles that range from $0 < r \leq 20$ on up to $80 < r$.

Socio-economic inequality: We rely on several indicators of inequality, beginning with the presence or absence of monumental architecture, which would have required enormous physical effort of workers within a stratified society. Second, we will measure the frequency of housing styles, whether communal such as long houses or private, that could have enclosed and protected private property. Third, we will assess the presence or absence of slave labour. Fourth, there is a well-developed methodology for using material artifacts to assess social status,[37] from which we will design a template or set of standards. Note that we will prepare a relative scale within the sample of 120 localities based on benchmarks created from several examples within each category, drawing from sites and localities that have exceptionally good contextual information. Ultimately, it is a judgment call to assign a particular site to a category, but it will be an informed judgment made before any data on health are examined for the locality. Moreover, all relevant information collected for each site, such as descriptions of artifacts and historical documents

---

30 Aldenderfer, M S, and Maschner, H D G, (1996), *Anthropology, Space, and Geographic Information Systems*, Oxford University Press, New York; Lock, G R, and Stancic, Z, (1995), *Archaeology and Geographical Information Systems: A European perspective*, Taylor & Francis, London

31 Milisauskas, S, (2002), 'Early Neolithic: The first farmers in Europe, 7000–5500/5000 BC' in Milisauskas, S, (ed), (2002), *European Prehistory: A survey*, Kluwer Academic/Plenum Publishers, New York, pp143–92; Sherratt, A, (1980), 'Early Agricultural Communities in Europe' in *Encyclopedia of Archaeology*, Cambridge University Press, Cambridge, pp144–51

32 Richards, M P, Price, T D, and Koch, E, (2003a), 'Mesolithic and Neolithic subsistence in Denmark: New stable isotope data', in *Current Anthropology, Special Issue: Divergences and commonalities within taxonomic and political orders 44*, pp288–95; Richards, M P, Schulting, R J, and Hedges, R E M, (2003b), 'Archaeology: Sharp shift in diet at onset of Neolithic' in *Nature 425*, p366

33 Milisauskas, S, and Kruk, J, (2002), 'Late Neolithic: Crises, collapse, new ideologies, and economies 3500/3000–2200/2000 BC' in Milisauskas, S, (ed) *op cit* pp247–69

34 Baillie, M G L, and Brown, D M, (2002), 'Oak dendrochronology: Some recent archaeological developments from an Irish perspective' in *Antiquity 76* pp497–505; Bradley, R S, (1999), *Paleoclimatology: Reconstructing climates of the quaternary*, Harpcourt Academic Press, San Diego, California; Frenzel, B, Pfister, C, and Gläser, B, (1992), *European Climate Reconstructed from Documentary Data: Methods and results*, G Fischer, Stuttgart; Magny, M, Guiot, J, and Schoellammer, P, (2001), 'Quantitative reconstruction of younger dryas to mid-Holocene paleoclimates at le Locle, Swiss Jura, using pollen and lake-level data' in *Quaternary Research 56*, pp170–80; Thompson, L G, Mosley-Thompson, E, Brecher, H, Davis, M, Leon, B, Les, D, Lin, P-N, Mashiotta, T, and Mountain, K, (2004), *Abrupt Holocene Climate Change in the Tropics*, Ohio State University, Columbus, Ohio

35 Abrams, E M, (1994), *How the Maya Built their World: Energetics and ancient architecture*, University of Texas Press, Austin; Chang, K C, (1968), *Settlement Archaeology*, National Press Books, Palo Alto; Fagan, B M, (2003), *Archaeology: A brief introduction*, Prentice Hall, Upper Saddle River, New Jersey; Feinman, G M, and Nicholas, L M, (2004), *Archaeological Perspectives on Political Economies*, University of Utah Press, Salt Lake City; Whallon, R, and Brown, J A, (1982), *Essays on Archaeological Typology*, Center for American Archeology, Press Evanston, Illinois

36 Beard, M, (1991), 'Literacy in the Roman world', in *Journal of Roman Archaeology*, Ann Arbor, Michigan; Harris, W V, (1989), *Ancient Literacy*, Harvard University Press, Cambridge, Massachusetts

37 Chapman, R, Kinnes, I, and Randsborg, K, (1981), (eds), *The Archaeology of Death*, Cambridge University Press, Cambridge; McGuire, R H, and Paynter, R, (1991), *The Archaeology of Inequality*, B Blackwell, Cambridge, Massachusetts

upon which judgments are based, will be available for inspection, comment or recalibration according to any scheme future researchers may wish to construct.

Climate: Under the guidance of the project climate specialist, a post-doctoral student in climate history will assemble evidence for each locality in the project. Climate will be constructed as a categorical variable for two components (temperature and precipitation) of five parts. Variability in climate will be represented by the annual variance in tree-ring width and from pollen in lake sediments at or near the locality. We will also construct a dummy variable for a sudden, catastrophic natural event (earthquake, volcano, rapid change in climate and so forth).

Analysis

For over a century scholars have debated the impact of the natural environment on social performance. They have observed that tropical countries languished in economic development and suffered high mortality rates relative to countries located in temperate zones. These casual observations became more clearly delineated with the arrival of national income accounts, vital registration systems and indirect demographic estimation techniques of the post-World War II era.

One line of explanation emphasizes the natural environment. A century ago scholars believed that the stultifying heat and humidity of the tropics sapped people's physical and creative energy while bathing them in parasites and pathogens. Among geographers, Ellsworth Huntington[38] vigorously pursued the connection between the natural environment and human activity. By the 1950s and 1960s, economists and other social scientists were abandoning geographic explanations in favour of human interventions such as technological change, human capital (both education and health) and institutions for understanding social performance. These ideas ascended when economic history emerged as a sub-discipline and its followers have largely viewed economic growth through these lenses.[39]

Recently, economists have renewed the debate over the natural environment's contribution to social performance. Several papers with collaborators demonstrate connections between GDP per capita and life expectancy with geographic or ecological variables such as climate, disease ecology and distance from the coast.[40] While acknowledging its relevance, other researchers[41] have claimed that geography operates predominantly through choice of institutions. In painting with a broad brush to interpret human performance around the globe and over the millennia, Jared Diamond[42] endorses climate and geography as important prime movers of economic and demographic success. Steckel and Rose[43] found that skeletal health was not systematically related to climate, conceding that it may have been poorly measured, but report that other aspects of the physical environment were important, including topography, elevation, vegetation, and subsistence pathways. It remains to be seen whether these variables, debated by scholars for relevance in both the modern and historical eras, were important for health in Europe and the Mediterranean over the past ten millennia.

Although study of the evidence will begin with exploratory data analysis, we will be testing specific hypotheses that arise from the literature about environmental effects on health. First we will summarize chronic morbidity at each site using a new methodological tool called the health index.[44] Then, we will test hypotheses by estimating the regression model:

$$HI = \beta_0 + \beta_1 P + \beta_2 C + \beta_3 S + \varepsilon$$

where HI denotes the health index for a particular site or locality, P is a vector of characteristics of the physical environment in which they lived, C is a vector of climate characteristics of the localities, S is a vector of measures of the social environment within the locality, and ε is an error term. P incorporates measures used by advocates in current debates, including (a) distance of the locality from the coast; (b) elevation; (c) vegetation; and (d) topography. C includes categorical variables for two attributes of climate (temperature and precipitation) and a measure of annual variability of climate within that zone. In testing the null hypotheses about the impact of the physical environment, it is important to control for social factors known to affect health. In our procedures, S is composed of categorical variables for settlement size, the material standard of living, technologies in use, interregional trade, literacy, the degree of socio-economic inequality for the burials at the locality, and food-group components in the diet. We will estimate the model, and test corresponding hypotheses, for each of the eight components of the health index, discussed above in the section on skeletal measures of health.

The two major research elements of the larger project – description and exploratory data analysis, plus results from tests of specific hypotheses about environmental influences on health – will be combined in an edited volume. Among our collaborators, experts in each area will take the lead in preparing individual chapters, and the graduate students who collected the skeletal data and helped in preparing the environmental context are expected to become research partners and co-authors. In preliminary conversations, editors from Cambridge University Press have expressed an interest in publishing such a book, as they did for the western hemisphere project. Upon publication, all data collected in the project will be released to the general public.

The book will begin with an introduction that sets forth the issues at stake and then provide a brief summary of how the book will address them. The next two sections will review the literature on health-ecology relationships in the present and the past. We will prepare a large chapter on data and methods for a general audience such that any college graduate well trained in the social sciences could grasp the approach. We will keep technical terms to a minimum and explain concepts involved in skeletal lesions, biochemical analysis, GIS and so forth. To help readers understand the meaning of the health index in archaeological contexts, which were generally harsh by modern standards, we will use information in health interview surveys from developed and developing countries to estimate the health index. Comparisons will help the audience calibrate or scale morbidity in the distant past relative to modern times.

Broader impacts

Astronomy has been greatly invigorated by newly deployed telescopes, which allow observers to peer deep into space, gathering light emitted from vast distances and recording events early in the history of the universe. In a similar but smaller way, skeletons and related artifacts can be powerful for the medical and social sciences, allowing observers to measure and analyze important aspects of health deep into human history, before the dawn of civilization. Neither astronomy nor bioarchaeology is an experimental science; both operate within the confines of observational evidence from which the intellectually curious can nevertheless learn much about astronomical or human origins and evolution.

This project offers a new and exciting way of collecting and analyzing large data sets in anthropology, climate history and GIS and using them for research in the social and medical sciences to build an understanding of the very-long-term history of human health. One long-term benefit will be a substantial heritage of human capital or expertise, which will lay the foundation for a new approach to studying health, in the form of training for physical anthropologists in broader questions and methods of the social sciences; education of many social and medical scientists in methods of physical anthropology and the uses of skeletal data; and ties among an international network of scholars committed to studying the global evolution of health.

The project will create numerous research opportunities beyond that of the immediate effort on ecology and health, which we will pursue first among the

[38] Huntington, E, (1945), *Mainsprings of Civilization*, J Wiley, New York

[39] See, for example, Landes, D S, (1969), *The Unbound Prometheus: Technological change and industrial development in western Europe from 1750 to the present*, Cambridge University Press, Cambridge; Mokyr, J, (1990), *The Lever of Riches: Technological creativity and economic progress*, Oxford University Press, New York

[40] Gallup, J L, and Sachs, J D, (2001), 'The economic burden of malaria', in *The American Journal of Tropical Medicine and Hygiene 64*, pp85–96; Mellinger, A D, Sachs, J D, and Gallup, J L, (2000), 'Climate, coastal proximity, and development' in Clark, G L, Feldman, M P, and Gertler, M S, (eds), *The Oxford Handbook of Economic Geography*, Oxford University Press, New York, p169; Sachs, J D, (2001), *Tropical Underdevelopment*, National Bureau of Economic Research working paper No 8119, Cambridge, Massachusetts

[41] Acemoglu, D, Johnson, S, and Robinson, J A, (2001), 'The colonial origins of comparative development: an empirical investigation', in *American Economic Review 91*, pp1369–1401; Easterly, W R, and Levine, R, (2002), *Tropics, Germs, and Crops: How endowments influence economic development*, National Bureau of Economic Research working paper No 9106, Cambridge, Massachusetts; Rodrik, D, Subramanian, A, and Trebbi, F, (2002), *Institutions Rule: The primacy of institutions over geography and integration in economic development*, National Bureau of Economic Research working paper No 9305, Cambridge, Massachsetts

[42] Diamond, J M, (1997), *Guns, Germs, and Steel: The fates of human societies*, W W Norton, New York

[43] Steckel, R H, and Rose, J C, (2002b), 'Patterns of health in the western hemisphere', in Steckel, R H, and Rose, J C, (eds), *The Backbone of History: health and nutrition in the western hemisphere*, Cambridge University Press, New York pp563–79

[44] Steckel, R H, Sciulli, P W, and Rose, J C, (2002), 'A health index from skeletal remains', in Steckel, R H, and Rose, J C, (eds), *ibid*, pp61–93

possibilities because we feel the results will be fundamental to progress on the other topics. We plan to pursue these extensions as this particular project winds down, including: (1) long-term trends in patterns of trauma and violence; (2) social inequality and health; (3) early childhood biological stress and adult health; (4) the health of women and children; (5) health during the rise and fall of civilizations; (6) degenerative joint disease and work; (7) analysis of population genetics and migration patterns using ancient DNA, and (8) use of DNA from specific pathogens to study the co-evolution of humans and pathogenic organisms.