4. HEALTH, ADAPTATION, AND MALADAPTATION IN PAST SOCIETIES

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Introduction

The analysis of health in past societies has too frequently been undertaken in a vacuum. Many paleopathological studies have been undertaken with little concern for either the cause or effect of health problems. Too infrequently have efforts been made to attempt to understand the relationship between health and adaptation, and equally infrequent are analyses of the causes of ill health that focus beyond the immediate environment. Paleopathologists are guilty of "quitting early" (Harris, 1988), before the implications of signs of health and illness have been fully understood.

Paleopathological analyses, nevertheless, have great potential for elucidating past adaptive struggles, and their links to the present human condition. Individual measures of health derived from skeletal remains, ranging from mild growth retardation to mortality, can be viewed as signs of the struggle to adapt. The pattern of individual indications of health and disease provides a basis from which one can infer the adaptive and functional costs of illness in areas such as reproduction, resistance to disease, sociability, work capacity, and learning. The pattern of disease in groups can be used to reconstruct differential access to resources and exposure to stress.

In the following paper I wish to provide some sense of the potential of palaeopathology, and some sense of the challenge of not quitting early. I begin by introducing a model for studying health and disease in relationship to adaptation in past societies. After the model is briefly explained, the functional significance of growth stunting, one measure of health status, is explored. This discussion is based on studies of the functional consequences of short stature in contemporary populations and is meant to illustrate the type of inferences that can be derived from measurements of bones and teeth. I end by suggesting directions for future research and by placing the study of health and adaptation in the larger theoretical debate over the validity of processual approaches in archaeology.

A Model of Health, Nutrition, and Adaptation in Past Scocieties

This adaptivist model was originally presented in 1982 (Huss-Ashmore *et al.*, 1982) and has been recently revised (Goodman and Armelagos, 1989) (Figure 4.2). The purpose of this model is not to codify links between component in the adaptive process, or to suggest that all adaptive dynamics can be traced through the model. Rather, the purpose of the model is to provide a mechanism for systematically examining and reflecting on the adaptive process and the centrality of health to this process.

The model starts with a consideration of "environmental constraints" to adaptation (Figure 4.2). These are typically divided between limiting resources and stressors. The most important limiting resources are likely to be basic ones: food, water, shelter. Stressors may be related to climatic extremes, such as excesses of heat and cold, or low partial pressure of oxygen. All of these climatic and physical stressors are important because they may have an effect on resistance to disease. Other environmental stressors, such as parasites and predators, have more obvious and direct affects on health and longevity.

There are a number of different ways that environmentally initiated constraints and stressor can be adapted to. Culture, through its technological, social and ideological systems, mediates the process of extracting resources from the environment. Cultural systems are generally effective in buffering environmental constraints and stressors, or removing the individuals in a society from contact with the stressor.

There are numerous examples of effective cultural buffering of stressors and limiting resources. Shelter and clothing are generally well suited as buffers against extremes of cold and heat. An interesting example of how shelter can aid adaptation is presented by May (1960) who relates how peasants in the hilly region of North Vietnam have customarily built their houses on stilts, about eight to ten feet above the ground. This is just above the flight ceiling of Anopheles minimus, a very fierce malaria vector. The adaptive significance of building houses on stilts became even clearer when overpopulation developed in the more fertile delta regions and groups from the delta began to migrate to the hills. The delta peoples were accustomed to building their houses on the ground. Subsequently, they found themselves to be within range of the malaria vector and they suffered frequently from malaria. Consequently, the delta peoples have been discouraged from relocating and attribute their health problems to the evil spirits in the hills (May, 1960).

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As a general example, the adoption of agriculture is an economic adjustment that embodies a number of changes in the ability of a culture to buffer stresses. The energetic efficiency of agriculture and the amount of food produced per unit area is greater than that of hunting and gathering. Thus, on the face of it, agriculture can provide a buffer against malnutrition, perhaps the most persistent and significant stressor faced by paleolithic hunter-gatherers (McKeown, 1988). However, one nearly invariable demographic effect of agricultural intensification is greater population density. Unfortunately, the increased population density and other ecological and demographic changes that are often secondary to agricultural intensification had unexpected consequences for health, such as improving conditions for the spread of infectious diseases. Furthermore, in West Africa it is likely that clearing of forest for agricultural production brought humans into close contact with mosquitoes, thus leading to the spread of malaria in that area (Livingstone, 1958).

The important point in the above is that the dynamic cultural system, which I have just briefly noted, operates in two ways: as a buffering system and as a producer of new stressors and constraints. As cultures change the nature of environmental adaptation changes. Improved adjustment to one environmental condition is frequently only made by increasing exposure to another condition. Compromised adaptations are frequent; they are the rule. As well, cultures and their adaptations vary in how well different segments of the population are buffered from stressors (Goodman and Armelagos, 1989).

The environmental constraints that are not well buffered by the cultural system, along with the newly produced cultural stressors, reach and contact the individuals in the society. From this point on, the degree to which these constraints are adapted to depends on the individual's level of host resistance. Resistance can be related to one's genetic, developmental, and physiological status. If a stressor is persistent and life threatening over millennia then a genetic resistance might develop. This appears to have been the case almost uniquely in West Africa where the frequency of the S hemoglobin allele, which leads to sickle cell trait, increased genetic resistance to malaria (Livingstone, 1958). More often, however, stresses are not so persistent and a genetic "solution" is never developed. In these cases some degree of resistance and adaptation may derive from shorter term developmental or physiological changes (Thomas *et al.*, 1979).

Unfortunately, chronic stressors and limiting resources often overburden developmental and physiological systems. Thus, while such systems are initially able to meet environmental challenges, the persistence of the conditions often results in a decreased health and nutritional status, which will be further lowered by exposure to new stressors. Individuals who have poor nutrition, for example, are less resistant to infectious diseases, and infectious disease further lowers nutritional status (Martorell, 1980; Allen, 1984; Mata *et al.*, 1971).

The severity and duration of the stress response may be viewed as a function of the degree of cultural and environmental constraints and stressors, balanced against the adequacy of the cultural buffering system and individual resistance resources. Fortunately for the paleopathologist, the stress response, sterotypic physiological changes resulting from the struggle to adjust, is frequently manifest in relatively permanent skeletal changes. While some stressors, if rapid and system specific, may not leave any evidence of a skeletal response (Ortner, 1990), many stressor do leave scars on skeletal elements. Because bone and teeth are limited in their response repertoire, one can read that a struggle to adapt has occurred, although less in known of the stressor that was the cause of the struggle.

Health and adaptation have significance that extends beyond the individuals to the population and society. As we have outlined in the model, stresses effect populations and groups by decreasing work capacity, decreasing fertility, increasing morbidity and mortality, and causing secondary disruptions to the social, political, and economic structure of a community (Allen, 1984). In turn, these cultural and population level changes cycle back to cause further changes in the environment and cultural system.

The evolution of this model from the early to late 1980s reflects an expansion in thinking about the role of health and its significance in human adaptation. In the earlier model, the end result of a failed struggle to adapt was the death of the individual (Huss-Ashmore *et al.*, 1982). In the revised model a further step was added to demonstrate how the individually based indicators of stress, the paleopathological data, might be used to make inferences at the population level (Goodman and Armelagos, 1989). As well, the feedback arrows were added to illustrate how the stressors could have a further cyclical effect on environmental and cultural systems.

It is a challenge to paleopathologists to go beyond the individual to examine how patterns of disease and disruption have significance for families, larger social groups, and cultures. Similarly, it is a challenge to go beyond concerns with proximate causes of illness (contact with infectious pathogens, insufficient diets) to examination of the broader and underlying social, economic, and political factors which determine who comes into contact with stressors and whose resources are most limited. It is proposed that it is only in this way that paleopathology will provide insights into adaptation in the past. It is only a superficial paradox, however, that the inferences upon which these insights need to be based need to come at least in part from studies of contemporary groups.

Nutrition, Disease, and Function: The Significance of Small Body Size

Simple and uncomplicated anthropometric measurements are a powerful means for assessing a population's adaptation to environmental conditions. Except for a very limited number of ethnic groups such as Nilotic Africans, there is surprisingly little variation in mean height among different ethnic groups that can be attributed to genetic differences (Dietz, 1983; Graitcer and Gentry, 1981; Habicht *et al.*, 1974). Thus, it is now accepted procedure for nutritional scientist to compare heights in different groups against a universal standard (Habicht *et al.*, 1974). Because of the universality of the growth pattern at the group level, it is possible to compare the prevalence of stunting in groups, defined in various ways such as the percent of individuals below the 5th or 10th percentile, below negative two standard deviations (near the 2nd percentile), or below 80% or 90% of the mean of the standard. One should, for example, expect about 5% of individuals to be below the fifth percentile height-for-age due to random processes. If the observed percent is significantly greater than 5% then one can usually infer an environmental cause. In this way, the pattern of stress among and within groups can be readily compared. In the analysis of the prevalence of stunting, nutritionists and international health researchers have a powerful tool for targeting populations at risk.

While the general procedure for evaluating stunting has never been seriously challenged, in 1980 the economist David Sekler challenged a number of fundamental assumptions about the *meaning and consequences* of short stature in developing countries. Sekler proposed that most individuals that are short in stature in developing countries are short because they have *adapted* to marginal food availability (Sekler, 1980, 1982). Sekler asserted that the body adjusts to chronically low nutrient availability by reducing its growth. In this way it is able to regain physiological equilibrium. Sekler further suggests that this readjustment occurs without adaptive cost. These individuals are essentially "small but healthy" (Sekler, 1980:225). In fact, small individuals may be better adapted than larger individuals to an environment in which food scarcity is a chronic problem.

Sekler's "small but healthy" hypothesis has attracted a great deal of attention and engendered much debate among policy makers, nutritionists, anthropologists and others concerned with the international dimension of malnutrition. The main question concerns whether or not these individuals are, indeed, small but healthy. If Sekler is correct in his proposition then it follows that there are few functional inferences that can be made based on anthropometric data and we need not worry so much about the mild-to-moderately malnourished.

Contrary to the "small but healthy" hypothesis, Martorell, in an early review of the literature on growth, nutritional status and infectious disease, found that poor growth status is almost invariably associated with increased disease in developing countries (Martorell, 1980; also see Tompkins, 1988). Although this relationship appears to be somewhat attenuated in developed countries, the picture of nearly all past societies is more akin to the situation in contemporary developing than developed countries. The relationship between undernutrition and disease in developing countries is so strong that it is difficult in many cases to ascertain the cause of poor growth status (Martorell, 1989). Growth status seems to be a sign of the cumulative stress experienced by an individual, of which poor diet and disease are likely to be of main importance. A review of the literature clearly shows that the primary proximate causes of short stature are undernutrition and disease. To then affirm that short stature is adaptive implies a sanctioning of the presence of the conditions leading to short stature (Martorell, 1989), which might ultimately be traced back to poverty and inequality in access to resources (McKeown, 1988).

In addition to increased morbidity, poor growth status is associated with a number of other functional consequences. Chavez and Martinez (1982) have systematically addressed the functional cost of undernutrition and small body size in children from Tezonteopan, Mexico. Their long term nutritional supplementation study began in the 1960s. Pregnant mothers and their infants were divided into two groups of which one received daily nutritional supplementation and the other group did not. These authors found that the better nourished children cry less and talk at an earlier age. The amount of activity is highly reduced in the shorter children. The shorter and non-supplemented children displayed less exploratory behaviour (Chavez and Martinez, 1982). This study shows that growth competes with activity a limited nutrient supply. When growth is compromised activity is not spared. Rather, the reverse seems to be true. Poor growth suggests that activity has also been affected. There are functional cost in terms of decreased activity and learning that are signalled by growth stunting (Figure 4.1).

It is also clear from a number of studies that poor growth is related to an increased risk of mortality, the ultimate indicator of adaptive failure (see Alam *et al*, 1989; Chen *et al.*, 1980; Lerberghe, 1988; Smedman *et al*, 1987). Alam and co-workers (1989) for example, have recently found that children in the area of Teknaf, Bangladesh with small arm circumferences suffer a twelve-fold increased probability of dying compared to children with more adequate arm circumferences. Lerberghe (1988) sums up his recent review of the relationship between childhood stunting and mortality in stating: "If both stunting and mortality are different outcomes ... of a succession of stresses on children's health, then the measure of the height of children in a community is an even more valuable tool for evaluation." (1988:259). He then goes on to say: "...the measurement of the prevalence of stunted children then becomes an operationally fairly feasible, be it indirect, measurement of poverty related disease frequency ... The prevalence of stunted children in a community appears to be a good overall indicator of the health status of a community of children..." (1988:259).

Martorell cogently summarizes the problem with the small but healthy hypothesis by asserting the following four points. First, individuals, children and adults, in developing countries are short due to chronically poor diets and frequent infection during development. To consider stunting to be adaptive is to insinuate that its causes are desirable. Second, growth retardation, "rather than an innocuous response to environmental stimuli, is a warning signal of increased risk of morbidity and mortality." (Martorell, 1989:15). Third, the conditions which cause stunting also affect other functions such as cognition and work capacity. Finally, stunted girls who grow up short are at increased risk of delivering growth retarded infants with a greater chance of dying (Martorell, 1989:15).

In considering how Sekler could have made such a nearsighted interpretation of the adaptive consequences of stunting, Pelto and Pelto (1989) suggest that Sekler fell victim to what they identify as the "quitting early" problem (also see Harris, 1988). They propose that many social scientists are guilty of frequently quitting early, before they have evaluated all effects, and especially the long-term causes and consequences of "adaptations." Sekler is clearly guilty of quitting early. Further, the claim of a "no-cost adaptation" (Beaton, 1989) suggests too much of an approval of the status quo.

What are the implications of the study of stunting and the disproving of the "small but healthy" hypothesis for studies of adaptation and health in past societies? The implications that can be drawn from data on the prevalence of stunting in contemporary populations suggests that similar data might also be a powerful indicator of group adjustment in prehistoric societies. We and others have noted some of the difficulties in studying growth patterns from skeletal remains (Goodman *et al.*, 1984; Larsen, 1987). Some of these problems include fragmentary and small sample sizes and an inability to precisely age individuals. On the other hand, long bone lengths can be accurately measured and compared to a modern standard (Maresh, 1955). Inferences can be made from the simple prevalence of subadults and adult who fall, for example, two standard deviations or greater below the mean. On balance, the number of clear and powerful inferences that can be gained from an analysis of growth status far outweighs the technical difficulties (Martin *et al.*, 1990). Examined in the context of the model (Figure 4.2) and the data on the cause and consequences of stunting in contemporary populations, growth data can be used to make strong inferences about group level adaptation.

The more general implication that can be derived from the "small but healthy" debate is that many paleopathologists also quit too soon. We quit before systemically analyzing the implications of individual disease patterns on the group and society. In a contemporary context, Chavez and Martinez (1982) have shown that moderately malnourished children may be sick as much as half the time during their childhood. It is difficult to comprehend the burden this level of illness must place on a mother in a developing community (Leatherman, 1987), and there is no reason to suggest that this burden of illness was any less in most past societies. Too often we ignore questions about the burden of illness on the functional and adaptive capacities of individual and groups.

Ortner (1990) has voiced one interesting challenge to not quitting early. His concern is that we think carefully about the meaning of infectious lesions on bone. Ortner suggests that these lesions should not be interpreted as a sign of stress, but rather as signs of rallying from insults, indicating an adaptive response to infection. Just as the raising of the question was important for nutritionists who rallied to consider the validity of the "small but healthy" hypothesis, the raising of the question concerning the adaptive significance of skeletal indications of disease is an important call to paleopathologist to think through their data. I suggest further that Ortner's challenge has to go even further to not just thinking through the individual response to the insult, but the systemic effect that the struggle to adapt to an infectious disease might have on a family and larger social groups.

A number of research initiatives can strengthen to a greater extent inferences on the functional and adaptive consequences of our indications of health. In some cases it might be important to know the consequences of an indication of stress in a contemporary context. An example of this concerns enamel hypoplastic defects. In order to make clearer inferences about the meaning of enamel hypoplasias, we need to better know the sensitivity and specificity of this indicator to bouts of malnutrition and infection (Goodman and Rose, 1990).

In other cases the underlying cause as well as the functional consequences of a stressor are known. For example, it is clear that most cases of porotic hyperostosis are secondary to iron deficiency, and the effects of iron deficiency on function are increasingly known from contemporary studies (Chwang *et al.*, 1988; Dallman, 1987; Pollitt, 1987). In this case, research is needed on the precise relationship between the skeletal indicators of iron deficiency and biochemical indicators. How chronic and severe a deficiency is indicated by iron deficiency? Although similar knowledge "gaps" are found for most paleopathological measures, I remain optimistic about the ability of well directed research efforts to fill these gaps.

Conclusions and Recommendations for Future Research

There are three fundamental points that I hope to have underscored in this discussion of our ability to understand health and its relationship to adaptation in past societies. The most general and theoretical point concerns the synergetic and interactive relationship between health and adaptation. Health is a function of the organism's ability to adjust to environmental constraints and stressors. It is the result of the adaptive process. Poor health constrains adaptation. It is a condition that needs to be alleviated or adjusted to. In this sense, health, classically defined in terms of morbidity and mortality, is a measure of the success of adaptation.

Under favourable conditions, adaptation is manifest in good health, and health furthers one's ability to adjust to stressful conditions. Such conditions can increase one's adaptive flexibility and ability to endure other stressors and constraints. Conversely, the inability to adapt is apparent in poor health, which in turn decreases one's ability to adapt to further insults. Stressful environmental conditions promote health problems, which constrain adaptation by, among other things, lowering resistance to disease, lowering work and productive capacity, lowering interest in and ability to engage in social and discretionary activities, interfering with learning and cognitive functioning, decreasing fertility and fecundity, and interfering with nutrient intake and utilization (Allen, 1984; Buzina *et al.*, 1989). The process by which health is related to environment and adaptation is nothing less than intrinsic, interactive, and cyclical.

The second fundamental point is that health is a measurable entity in studies of contemporary as well as past societies. Readily available measures of health status, such as rates of infant mortality and stunting, are routinely used to gauge and compare the general level of health of contemporary groups (Goodman *et al.*, 1988). While health status, as well as stress and nutritional status, is a behavioral phenomena that can not be directly measured in past societies, there are numerous commonly employed and increasingly refined methods for reconstructing health, stress, and nutritional statuses from bones and teeth (see for examples the following reviews: Buikstra and Cook, 1980; Goodman *et al.*, 1984; Gilbert and Mielke (eds.), 1985; Larsen, 1987). Some of these measurements, such as those involving mortality and growth rates, are particularly robust in their ability to generate adaptive inferences because there are equivalent and commonly used contemporary measures (Goodman *et al.*, 1988).

While taphonomic processes render it impossible to reconstruct fully all dimensions of health experienced by an individual or a group -- either in the past or currently -- I submit, optimistically but not without empirical and scientific justification, that many techniques are now available that can provide an accurate appraisal of a number of dimensions of health in past populations. The information derived from these techniques, coupled with an understanding of the adaptive and functional significance of the measures of health, can provide key insights into the dynamics of adaptation in past societies.

Thirdly, studies of health in past societies can provide unique insights into the dynamics of past societies and the evolution of the human condition. Unfortunately, many paleopathologists have quit too soon, before the significance of health has been fully explored.

In concluding I wish to make reference to the theoretical underpinning of the model and perspective outlined above in relationship to recent theoretical challenges in archaeology. It is somewhat paradoxical that the research paradigm which is highly processualist in nature is proposed at a time when archaeology seems to be moving away from a processualist paradigm (for example see Hodder, 1986). This paradox may be explainable by the fact that one of the processualist paradigm's greatest failings, lack of concern for individual and culturally specific dynamics, is far less applicable to biological phenomena. The biological impact and consequences of health are more nearly universal than social processes. Therefore, contemporary analogies about the cause and effect of health are quite consistent and can be used to make assumptions about cause and effect in the past. Further, an examination of health can and should be seen not as isolated local-level phenomena, but as a result of the openness of local systems with other systems. In fact, the modern ethnographic data suggest that poor health is invariably tracked back to poverty, which is itself due to regional and interregional processes. The fault of the new archaeology of over emphasis on local ecological processes need not be shared by a processualist view of health and adaptation. Thus, it is not paradoxical that when some social archaeologists are about to discard processes, middle range theory, and ethnographic analogy, bioanthropologists may discover the usefulness of these methodological and theoretical underpinnings. The study of health in past societies needs to be placed in an evolutionary and ecological context, linking it to studies of contemporary groups. In this way we will better understand ideas about progress, the dynamics of past societies, and the evolution of the human condition.

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Figure 4.1 A peasant family from Tezonteopan, Mexico. The two older girls are enrolled in the study of Chavez and Martinez (1982). The one with the white t-shirt with the rose (Rosa) is nineteen and was not nutritionally supplemented. The other sister is fifteen years old and has been given nutritional supplements since birth. The five inch height difference between these same sex sibling is typical of the differences between the supplemented and non-supplemented children. In addition to the height differences, Chavez and Martinez (1982) have found profound differences in activity levels, sociability, and resistance to disease.

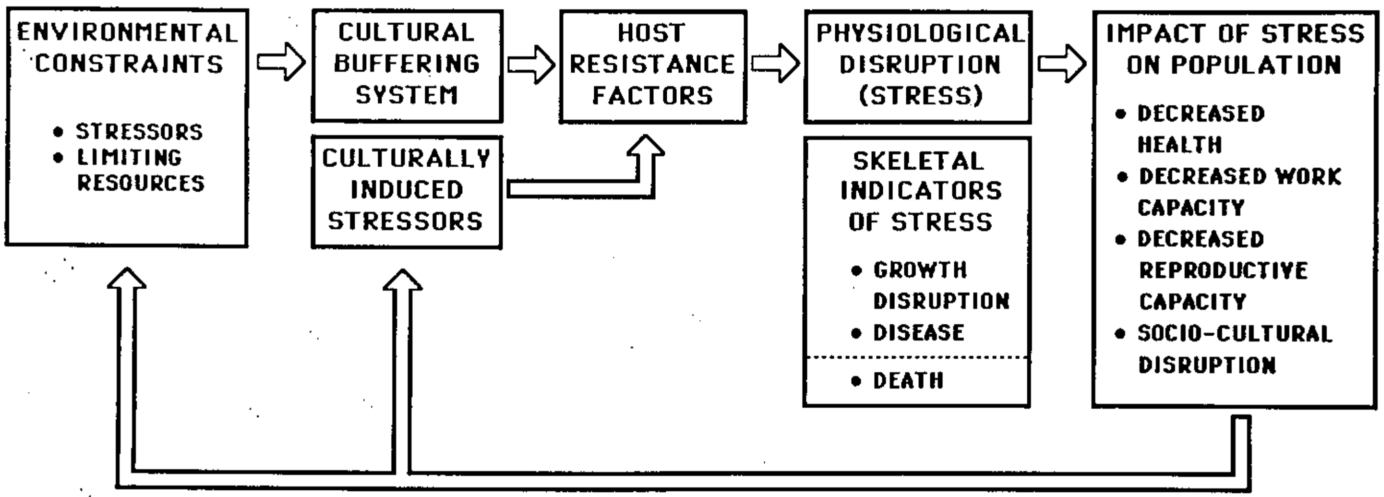

Figure 4.2 A general model for studying the relationship between health, stress, and adaptation in skeletal populations (from Goodman and Armelagos, 1989).