An Ecology of High-Altitude Infancy

A Biocultural Perspective

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1 Introduction

Reproduction is a fundamental problem for all organisms. Animal species exhibit a dazzling array of strategies to produce offspring, which often require large inputs of energy and are associated with major risks to their survival. Among mammals, females incur more direct costs of reproduction insofar as they carry (literally) the burden of embryonic and fetal growth and nourishment of the young through lactation. Thus the health of a female mammal directly affects reproductive outcome, both in terms of her fertility and the survival or death of her offspring. Human females experience these costs as a function of their mammalian heritage, but the variety of environments they inhabit generates substantial differences in the reproductive risks that women face. Their abilities to reduce these risks are important determinants of individual and population differences in maternal and child health and survival.

Given the centrality of reproduction to the lives of organisms, including humans, it is useful to know what constitute the optimal conditions for reproduction. Certainly, adequate nutrition, absence of infection, monitoring, and judicious intervention are among the factors that enhance pregnancy outcome. In biomedicine, complex technologies are routinely used to increase the odds of conception and a healthy newborn. In-vitro fertilization, fetal genetic screening, and cesarean sections are now routine procedures, and ever more complicated procedures such as fetal surgery are on the horizon. But these are primarily, though not exclusively, practices found in wealthy countries, where today most women have relatively few births, later in life, and "invest" each of them with intense meaning and resources. Conditions for reproduction for populations in much of the world are at stark variance from those in wealthy countries; many women experience dramatic constraints on their ability to create or gain access to the conditions necessary for optimal fetal development and infant/child survival. Impoverished living conditions, social inequalities, heavy physical workloads, infectious disease, and nutritional deficiencies all compromise a process that is inherently fraught with demands on a woman's resources.

Anthropologists are interested in reproduction insofar as it represents a universal aspect of the human experience and also because the myriad ways in which different cultural and ecological contexts shape the reproductive process contribute to cross-cultural variation. All societies attempt to control reproduction and its outcome in some way, be it simply through the universal institution of marriage, which restricts access to and timing of what constitutes locally appropriate reproduction; complex prescriptions or proscriptions (prohibitions) for behavior (especially diet) during pregnancy; or child-rearing practices that enhance the well-being of some offspring at the expense of others. These social mandates occur within the parameters of ecological contexts and basic human reproductive biology, which shape the outer limits of reproductive possibilities. Collectively these factors contribute to a tremendous range of reproductive experiences in human populations. Salient aspects of this variation in the reproductive process include women's health, both before and during pregnancy; the health or survival of their offspring; and the personal and cultural meanings of reproduction. These factors ultimately have long-term effects on a population, by shaping its age distribution and growth rate, which in turn impact the environment in which the population lives.

The case to be considered here is reproduction under a unique constellation of natural ecological and sociocultural conditions (what can be termed "socioecology") that constitute a set of challenges to successful, healthy reproduction. The geographic locale is a little-known region called Ladakh, which in the past constituted an independent kingdom in the remote Himalaya, and which is now a district in the hotly contested state of Jammu-Kashmir in India. It forms the western end of the trans-Himalayan (Tibetan) plateau on the northern side of the great Himalaya range. Ladakh is a high-altitude desert area where the average altitude of human habitation is over 3000 meters. It is in the rain shadow of the Himalaya, which effectively blocks the summer monsoon rain clouds that amass to the south, resulting in average annual rainfall of only 10 to 15 centimeters (Mani 1981). In the winter, bitterly cold winds blow across the steppes of northern and central Asia into the region. Ecologically and culturally, Ladakh has many affinities with the better-known regions of Tibet and Tibetan areas of Nepal – similar languages, Buddhist religious practices and beliefs, marriage and family structures, diet and subsistence agricultural practices, among others, all link peoples in this broad Himalayan band. This blend of culture and ecology impacts the reproductive process in this region, but it does so differentially; individuals and populations living here vary in meaningful ways that may lead to dramatically different reproductive outcomes.

Based on studies in other high-altitude areas of the world, especially the Andes of South America, there is reason to believe that the ecological stresses of high-altitude life impinge on human biology and reproduction. High-altitude areas (defined as >2500 m) are characterized by numerous stresses, including cold, ultraviolet (UV) radiation, harsh terrain, and probably most important, hypoxia, the decreased partial pressure of oxygen that occurs at higher elevations (Pawson and Jest 1978). With increasing altitude, oxygen density decreases steadily so that at 3000 meters (10,000 ft), the partial pressure of oxygen is less than 70% of sea-level pressure. Above 5000 meters, oxygen pressure is sufficiently low that permanent human settlements cannot be maintained. Oxygen plays a key role in physiological functioning across animals, including cellular respiration and growth, so it comes as no surprise that humans should be profoundly affected by a high-altitude context. Shortness of breath, rapid heart rate, and in worst-case scenarios, headache, nausea, fluid buildup in the lungs or cerebrum, or even death are among the responses an individual may have to hypoxia (Frisancho 1993).

One of the interesting features of the hypoxic conditions of high altitude is that unlike other ecological features such as temperature that are easily buffered by material innovations (e.g., clothes, shelters), the experience of hypoxia cannot be modified by technologies on a population level. Certainly there are now technological solutions, such as the use of oxygen tanks by high-altitude climbers, but these never evolved in an indigenous high-altitude setting, and are, for all practical purposes, unsustainable in a large population. At the same time, however, an individual's biological resources may alter the experience of hypoxia, and these resources are shaped by culture-specific behaviors and social organizations that influence nutritional status or a genetic inheritance that allows for more efficient oxygen utilization, among others (Leonard 1989; Moore et al. 1998).

With regard to the effects of hypoxia on reproduction, women traveling to high-altitude areas have anecdotally reported disruptions in menstrual activity. During the colonial period, the Spanish noted a very high rate of reproductive failure among their populations trying to establish a permanent presence in the city of Potosi, at 4000 meters in the Andes. No Spanish child was born who survived childhood until fifty-three years after the city was founded; most died at birth or within a short time after birth (de la Calancha 1639, quoted in Clegg 1978). As a result, Spanish women often descended to lower altitudes for pregnancy and birth and remained there until the child was at least one year old. At the same time, the Spanish noted that the indigenous population did not seem to experience these problems. A similar situation has been described in

contemporary Tibet, which has been colonized by increasing numbers of Han Chinese from low altitudes over the past few decades (Moore et al. 2001a). So, residence at high altitude is widely associated with significant reproductive problems among migrants to high altitude. Migrant women recognize these risks and often descend to lower altitudes for pregnancy and for some time after birth.

A proximate mechanism that mediates the relationship between hypoxia and birth outcome has been identified. Numerous studies from New World mountainous areas have demonstrated that the average birthweight of newborns decreases as altitude increases, indicating a possible link between oxygen shortage and reduced delivery of essential nutrients to the fetus (Beall 1976; Grahn and Kratchman 1963; Haas 1980; Haas et al. 1977; Haas et al. 1980; Lichty et al. 1957; McClung 1969; Unger et al. 1988; Yip 1987). Oxygen deprivation in utero could result in impaired fetal growth and compromised birth outcomes, which, in turn, may contribute to high early mortality, although some authors have suggested that they do not (Beall 1981; Wilcox 1993). The negative effect of hypoxia on fetal growth is particularly severe among newcomers to high altitude but is evident to a lesser extent among indigenous populations. Thus, a population's history in a high-altitude environment appears to affect their reproductive success and the relative severity of its impact, suggesting evidence of adaptive processes at work among longer-term inhabitants (Haas 1980; Moore et al. 1998). Furthermore, diversity in cultural behavior, social organization, and other local ecological conditions is likely to contribute to variation in the effects of mountain life on reproduction.

Reproduction in Ladakh occurs in an ecological matrix characterized by hypoxia and dramatic seasonal differences in temperature that constrain subsistence. Most Ladakhis practice subsistence agriculture based on various strains of barley, wheat, legumes, potatoes, and a variety of other root vegetables, and many families keep some animals for dairy products and help in plowing and threshing. Agricultural production is labor- and seasonally intensive as there is no mechanization, and both men and women work hard at agricultural tasks, especially between April and October (Osmaston 1994). Women in Ladakh experience substantial energy burdens as they contribute to agricultural production for their households, and these energetic demands are exacerbated by the hypoxic conditions under which they must work. Aerobic work in a hypoxic environment is exceptionally arduous, even for people who are well acclimatized, and it places high demands on energy-producing, oxygen-dependent metabolic pathways in a context where oxygen is not abundant (Kashiwazaki et al. 1995; Leonard et al. 1995). A Ladakhi woman's

reproductive status often has little effect on her work patterns; most pregnant women labor throughout their pregnancies. Thus their energetic resources and oxygen transport systems experience double and triple demands during this stage. On the other hand, there are widely articulated cultural ideologies suggesting that pregnant women should not work hard, and indeed should be particularly well provided with extra highly valued foods such as meats and dairy products. The extent to which women may lay claim to these benefits depends on the availability of resources and the level of demand for their labor within their household. Both are influenced by season and household dynamics, among other factors.

Ladakhi women, particularly Buddhist women, enjoy relatively high social status compared to women in other parts of Hindu or Muslim South Asia, and women's status is generally thought to be correlated with positive health indices (Thaddeus and Maine 1994). Women freely engage in interactions with unrelated men and are active vendors in the vegetable bazaar in the main town. They engage in valued productive work and control the distribution of food in the household and the profits and produce from large household gardens. Moreover, Ladakh is one of the few places where polyandry was traditionally practiced, and some authors have idealized this marital form as an institution that fosters the empowerment of Ladakhi women (Norberg-Hodge 1991; Rizvi 1983).

There are thus reasons to believe that aspects of Ladakhi social and cultural life highly value the productive and reproductive capacities of women, and that this valuation might translate into benefits to reproductive health and well-being. However, it is difficult to get an accurate sense of health parameters in Ladakh because of the lack of systematic data reporting. Nutritional research done suggests that Ladakhis subsist on an adequate base of calories and protein (Attenborough et al. 1994; Osmaston 1994; Palriwala 1988), while there are scattered references to some vitamin and mineral deficiencies (Attenborough et al. 1994; Meyer 1981; Stobdan 1990). There are two village studies indicating that infant and child mortality rates are high (Attenborough 1994; Elford 1994). Maternal health and health differentials between males and females have not been examined, so existing sources do not tell us much about the reproductive health situation. It is important to note, however, that high rates of infant and child mortality represent a loss of maternal biological resources and a need for higher fertility, which requires further resources, already strained by workload demands.

The research presented in this book documents that reproductive health is compromised among a large sample ($n = 168$) of mothers and infants in eastern Ladakh. Most babies were very small at birth; the

median (and mean) birthweight (2764 g) was only slightly over the World Health Organization cutoff for infants at increased risk of mortality (<2500 g). Indeed, these small infants in the sample had very poor survival prospects. But the pattern of mortality was quite distinctive; while infant mortality rates were on the order of 20%, deaths in the first month of life accounted for over 75% of deaths in the first year of life. After the first critical month, mortality rates declined to relatively low levels. Birthweight was a very strong predictor of mortality in the first month of life, and this implies that the determinants of birthweight are at the roots of high mortality. Since birthweight is largely a function of maternal characteristics, constraints on women's health status are profoundly implicated in the analysis of these very high rates of early infant death. I suggest that this dismal reproductive health situation results from the competing demands of production and reproduction, a situation not unique to Ladakh, but a problem common to subsistence societies throughout the world. Each woman experiences this conflict somewhat differently as a function of different natural and socioecologies. In the Ladakhi context, women's engagement in subsistence work interacts with the demands placed on them by reproduction and the metabolic constraints of hypoxia.

A focus on reproductive health can give us important insights into numerous aspects of Ladakhi social and cultural life and ecology as well as into the lived experience of women and children. Women's health is closely tied to that of their offspring, especially early in life, and thus has implications for infant survival. Infant mortality rates, in combination with fertility rates, determine the age structure and growth rate of the Ladakhi population; demographic processes are crucial aspects of Ladakhi subsistence under what are generally quite marginal and stressful ecological conditions. Expectations about the likelihood of success or failure of the reproductive process condition emotional responses to pregnancy, birth, fetal loss, or infant death. Child-care patterns are affected by maternal workloads and also by expectations about the roles and status of women and children in Ladakhi society. Common reproductive health issues also make their way into local healing traditions. Ladakh is home to numerous medical traditions, ranging from shamanism to Tibetan medicine, to the more recent importation of allopathy (Western or biomedicine). In sum, while this study focuses on a very narrow window of time in a woman's reproductive life and in a child's life, it provides insights into multiple aspects of life in contemporary Ladakh. The reproductive process is, somewhat obviously, the foundation of a population's existence.

A Biocultural Perspective on Health

An ideal approach to reproductive health in Ladakh is a biocultural theoretical perspective, a uniquely anthropological form of inquiry that considers a full range of biological and sociocultural factors to be related to health outcomes. Health status is usually described by biological indices of individuals (e.g., growth, immune responsiveness, blood pressure, hormone status), and the trends in these indices in a population (rates of diseases, average growth profiles, etc.). These biological data are then considered as outcomes of interactions between individuals and their environments. In other words, the body is in a dynamic relationship with the environment and reflects the stresses and resources in that environment, both in the past (over the course of the lifetime of an individual, or over generations) and in the present. Such a perspective draws heavily on evolutionary theory, which views biological and behavioral outcomes in relation to these environmental characteristics and emphasizes the ways that organisms respond to them to enhance their survival and reproduction. Such traits (be they biological or behavioral) are defined as "adaptive."

Biocultural perspectives have their origins in the human adaptability studies by biological anthropologists in the 1960s and 1970s that were designed to broaden understanding of human biological variation under a variety of ecological conditions. This body of research uncovered both genetic adaptations to different environmental contexts and evidence for adaptability (also known as plasticity), the physiological alterations generated by exposure to particular environmental stresses over the course of an individual's life cycle (Harrison 1997). Since an individual's ability to respond adequately to a stressor impacts his or her biological function, it was inevitable that many adaptability studies began to consider the health implications of human-environment interactions, and that the concept of adaptability became a core concept in the emerging field of medical anthropology in the 1970s. Anthropologists using the concept of adaptability have increasingly realized that biological responses to environmental stresses are mediated in significant ways by behavior, which for humans is often culturally patterned and socially situated. Cultural traditions, technologies, and social conditions can both exacerbate or ameliorate natural ecological stresses. Hence the emergence of a biocultural paradigm within human adaptability studies and medical anthropology.

Although traditionally the biocultural approach has been linked to evolutionary analyses emphasizing functional adaptation to the natural environment, more recently some have argued that a change of emphasis

is required to understand how the body is affected by contemporary social environments, especially those characterized by poverty (Goodman and Leatherman 1998b). The important environmental stresses facing many human populations are seen to be of largely social – as opposed to natural – origin, and derive from the intersection of global and local political economies that more often than not produce conditions that severely threaten health. Human adaptive capacities may be inadequate to respond to the multiple stresses deriving from poverty, and hence the focus shifts away from adaptation, to identifying and describing the *stresses* in the environment, the ways that the body responds to such stresses, and the short- and long-term consequences of these responses for both the body and the social group (Goodman and Leatherman 1998b; Thomas 1998).

This shift in focus is an important complement to analyses of adaptive outcomes and provides additional power to the biocultural paradigm. It is crucial to identify the sources of stressors in an environment, their historical roots, and the means by which they are sustained. At the same time, the links between stressors and biological outcomes need to be specified. In some contexts, adaptive outcomes are evident; in others, stressors may be so severe or numerous that the body's adaptive capacity is overwhelmed, with negative health consequences. This synthetic approach should provide insight into the complex determinants of a population's health status, and to do so demands investigation into history, ecological, social and cultural dynamics, and biology. Figure 1.1 provides an abstract of this biocultural model, demonstrating the ways that inequalities and other constraints on access to resources require biological and behavioral responses that ultimately impact human biology and health.

Four core concepts of the biocultural enterprise frame this study of reproductive health in Ladakh: the population/the body, environment, health, and adaptation. They are described below.[1]

The Population and the Body

Anthropologists are generally concerned with humans as members of specific populations. Individuals arrange themselves in myriad ways for different purposes, and the researcher's interests and local contingencies usually determine the group to be studied. A group is most often bounded by geographical space, and its members share a loosely defined "culture." It may be a household, clan, community, or nation-state. It can also be considered a gene pool if most reproduction occurs within the group. Thus a population can be both biologically described (by common

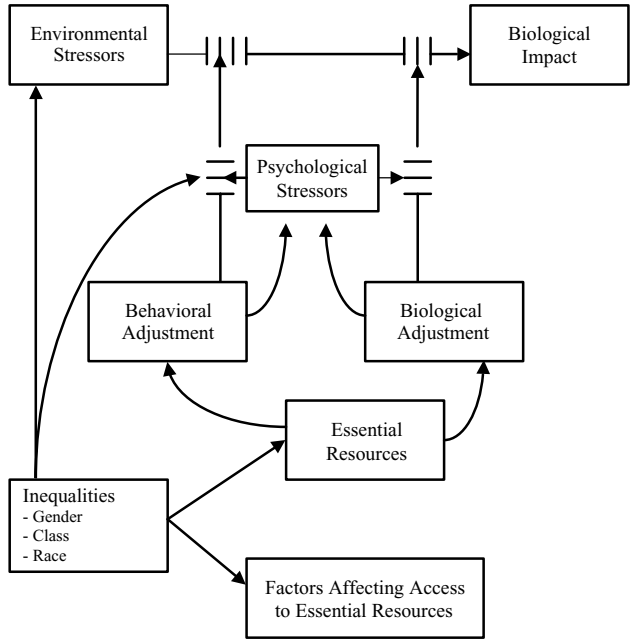

Figure 1.1. Biocultural adaptive dynamics (Redrawn with permission from Thomas, R. 1998. The evolution of human adaptability paradigms: Toward a biology of poverty. In Goodman, Alan H., and Leatherman, Thomas L. (eds.), *Building a New Biocultural Synthesis: Political-Economic Perspectives on Human Biology*. Ann Arbor: University of Michigan Press.).

descent and relatedness) as well as socially defined. Populations can be large or small, although larger units tend to exhibit more heterogeneity in biology and behavior than do small groups. In general, we are interested in the frequency of physiological or behavioral characteristics of individuals as a way of describing a group but also to understand and account for variation within a group.

Biocultural analyses are concerned with biological outcomes that are measurable at the level of the individual – that is, the body. The body is best thought of as a socially situated and culturally influenced biological entity that responds to forces in the environment that challenge its ability to function. Sociocultural phenomena can affect the body by shaping the behavioral decisions that individuals make and by determining the resources available to support the body's needs. In turn, the body affects sociocultural life most importantly by having needs that must be met

for survival. These requirements pose limits to the kinds of sociocultural systems that can be maintained.

The body has a history that affects its ability to function in a given environment; that is, it is an evolved entity. A body is not a random accumulation of cells and organs nor a perfectly designed machine; it is a form that has been shaped by a history of life within a particular lineage in a particular environment (Nesse and Williams 1994). That history was shaped by the forces of evolution that include, most importantly, natural selection, but also mutation, genetic drift, and gene flow. Natural selection, the contribution of Charles Darwin and Alfred Wallace to evolutionary theory in the nineteenth century, refers to the idea that the environment in which organisms live poses certain threats to survival, and individuals who are able to avoid these threats or overcome them survive and reproduce at a greater rate, and thus pass on their traits (in the form of genes) at a greater rate than do other individuals. Over time, these characteristics are found in more and more individuals in the population. These traits are referred to as adaptations, or adaptive traits, because they enhance reproductive success, which is measured as the product of survival through the reproductive years and the number of offspring produced. Since health is closely related to survival and reproductive outcomes, it is appropriate to investigate the health of an individual as part of evolutionary inquiry.

Bodies are the product of their evolutionary history, but they are also the product of their life history in a given environment. As noted before, human biology is plastic; it is capable of changing in response to conditions encountered over the course of the life span. The environment in which growth and development occurs is particularly important, as it can leave indelible marks on an individual's biology. Stresses encountered while an individual is growing up may manifest as reduced growth or compromised physiological or psychological function, and they can affect the way an adult responds to current stresses.

The other forces of evolution shape the body as well and have health implications. Mutation simply refers to random changes ("mistakes") made in the formation of egg and sperm cells. It is the source of variation on which natural selection can act, since natural selection can only "select" from an existing pool of individuals with variable traits, and thus without variation, natural selection cannot occur. Mutations are also responsible for many inherited genetic diseases (e.g., Tay-Sachs disease, sickle-cell anemia, cystic fibrosis), although these have likely reached relatively high frequencies in some populations as a function of natural selection (cf. Desowitz 1981; Diamond 1991; Gabriel et al. 1994). Some environmental conditions (e.g., UV radiation, pollutants of various kinds) can

stimulate mutanogenesis and increase the frequency of genetic diseases. Gene flow, also known as migration, can bring new characteristics into a population or remove variation from a population. This is particularly crucial at present, as the high rate of global migration over the past two centuries has brought many people to novel places. Individuals who live in environments different from those of their ancestors may find themselves with traits that are not well suited to their current environment. Last, genetic drift is an evolutionary process that affects only small populations. It refers to random events having disproportionately large effects on the diversity of traits within a population and to the historical impacts of relatively low genetic diversity.

Health

Health must of course be a central concept in medical anthropology, but, as with many key concepts, there is a range of definitions. Here health is defined as an individual's ability to respond effectively to the challenges of his or her environment, which may include infectious agents, food scarcity, extremes of temperature, psychological or social stress, or any environmental conditions that compromise biological (including reproductive) function (noxious chemicals, mutagens, etc.). Individuals have mechanisms to keep physiological function within homeostatic parameters that can be altered somewhat during stress (allostasis), so that the body can maintain functionality without excessive costs at least for short periods of time. If these challenges become chronic, or if an individual faces several at once, the body's ability to cope may be seriously compromised, and disease results. Thus, at any given time an individual's health status lies somewhere between the poles of basic survival and optimal function (Armelagos et al. 1978).

This is a very biological definition of health, and there is certainly a more subjective aspect to health as well. A person may not exhibit any evidence of physiological impairment yet say that he "doesn't feel well"; or someone may assert that she "feels fine" yet display evidence of physiological malfunction. Medical anthropologists thus make a distinction between the terms "disease" (a biological index) and "illness" (a subjective index of health). The broader concept of "well-being," which includes both a subjective and biological component, may be more inclusive than a strictly biological definition of health.

When viewed from this perspective, health is seen as a *relative* state, and those characteristics that describe health will vary by environmental context. There is unlikely to be one definition of "optimal" health for all humans. Descriptors of "health" or "normal human function" derived from

Western industrialized populations are not necessarily appropriate standards against which to judge the health status of other populations living in different contexts. For example, very high levels of hemoglobin might be seen as pathological among sea-level populations, but at high altitude this same phenomenon could be adaptive in the context of low levels of oxygen. At the same time, we need to recognize that health categories are not entirely relative and that dismal living conditions preclude the attainment of any kind of "optimal health" for much of the world's population. This is glaringly evident in the vast disparities in life expectancy[2] among countries – with the range between fifty-two in sub-Saharan African countries to over eighty in northern Europe and Japan. Differences in life expectancy mean that years of life are lost in some populations because of much greater disease burdens, and that these burdens fall disproportionately on the young.

The Environment

Interactions between the body and the environment are crucial to health, and here we define the environment to include abiotic (climate, geology, altitude, etc.), biotic (plant and animal life), social (other individuals, groups and communities and their organization), and cultural aspects (ideologies, worldviews, technologies, etc.). The abiotic features set the broad parameters within which all the others exist and interact. Key aspects of the biotic and abiotic environment, from the perspective of human biological function or health, are certain threats or various stresses that affect the body (e.g., cold or hypoxic stress, infectious disease, toxins, predation, treacherous landscapes). At the same time, the environment may provide resources for enhancing health (e.g., materials for shelter or protection, antimicrobial compounds, alternative food sources).

Similarly, aspects of the sociocultural environment, or socioecology, can act both as stressors and resources. Often these act by influencing access to, or use of resources, and access to resources (food, shelter, clean water, health care) is certainly among the most important determinants of health (Huss-Ashmore and Thomas 1997). For example, Wilkinson (1996) has convincingly demonstrated that health is negatively affected by social stratification, as countries with more egalitarian social and economic structures have better health indices. Stratification increases stress across the social hierarchy and also creates differentials in access to resources (Baer et al. 1986). Social cohesion and democratic participation in decision making tend to be associated with better health. Cultural understandings about how the body works (or how male, female, and children's bodies differ), religious dietary proscriptions, the causes of disease

(e.g., microbes versus witchcraft), and social ideologies such as racism and sexism can all influence disease vulnerabilities and access to adequate treatment. In sum, variation in environmental conditions is key to understanding health differences among and between populations, and the qualities of an environment, especially those that affect access to key resources, are primary determinants of health and well-being.

Adaptation

The concept of adaptation is fundamental to evolutionary theory and to biocultural studies in anthropology, although there has been considerable discussion of what exactly constitutes evidence for, and the meaning of, adaptation. As noted earlier, a very basic definition of adaptation is a trait (biological or behavioral) that enhances reproductive success, and the process that increases the frequency of these traits is called natural selection. Populations have evolutionary histories during which they have undergone the continual process of natural selection over generations in their environments. Therefore it is reasonable to expect that their members have traits that are adaptive – that enhance, rather than detract from, their well-being. However, it is important to recognize that populations are not likely to be exclusively characterized by traits that are adaptive in the *current* environment if it has in fact been subject to numerous modifications over historical time or if the population has only recently settled there. Under these conditions, we are more likely to observe the adaptive *process* rather than well-established adaptive *outcomes.* Hence the study of adaptation is, in part, a historical project.

For humans, as a species with tremendous behavioral flexibility and innovative ability, adaptations are often encoded in culturally specified behaviors that attempt to buffer the effect of environmental stresses on the body. Adaptation is not simply about passively responding to whatever challenges come up; it is proactive as well. One can *adapt to* as well as *adapt something* to meet one's needs. Thomas et al. (1979) outlined seven possible modes of adaptation: avoidance, modification, buffering, distribution, resistance, conformity, and change. One can act to avoid a stress, or if it is unavoidable, conform to it (as long as this is possible while maintaining internal homeostasis), or change in response to it (e.g., natural selection or adaptability). One can attempt to modify or redistribute the stressor, or buffer the body from it by using various technologies. Resistance is an attempt at adaptation, in the sense of manipulating the social organization to enhance health or reduce morbidity or mortality. All of these strategies can be assessed by their efficacy (how well do they solve the problem) and efficiency (what other costs do they produce). The net

effects of the efficiency and effectiveness of a response should enhance health and well-being.

Depending on the characteristics of the stress itself and the resources (material and biological) available to an individual or group, one or more of these adaptive responses may be engaged to deal with a challenge to well-being. Common goals or ideologies (i.e., culture) will influence how individuals experience the environment and prioritize their responses to stresses. Cultural traditions have a history, rendering them adaptive, neutral, or potentially maladaptive under current environmental conditions. Generally speaking, these traditions provide the parameters within which decisions are made; some traditions are quite entrenched and may preclude adaptive change; others may be more flexible and responsive to new conditions (Huss-Ashmore and Thomas 1988). Culture – like biology – is not static, but if stable environmental conditions prevail for long periods of time, one should expect to see little change in either. Some human populations live under such conditions; many others live in environments that are novel, highly variable, or unpredictable (e.g., rapidly urbanizing environments). As new threats to health emerge or as old threats diminish, different biological and behavioral strategies are called for. It is important to realize, however, that the ability to adapt is not unlimited, but can be overwhelmed by multiple stresses, particularly severe acute stresses, or by exposure to chronic stress. Disease, illness, debility, and ultimately death may result.

Behavioral or physiological adaptations are made in response to or to prevent sickness, a state in which the body cannot maintain adequate function. Documentation of this process is complicated by the fact that environmental stresses are not experienced one at a time. Instead, several stresses are often experienced at once and are responded to with available resources. Thus, responses to one stressor can easily result in negative effects with regard to another, just as responses that are adaptive in the short term can become problematic in the long term (Mazess 1975). The outcome of such actions is not likely to be a "perfect fit" between the individual and the environment. Adaptation is *compromise*; every response or preventive mechanism comes at some cost, and sometimes multiple stresses are acting simultaneously. Given the heterogeneity of resources available, challenges to, and priorities of an individual or group, adaptation in one realm is likely to have repercussions in other domains (it may be effective but inefficient). For example, many physiological responses to infectious disease can be considered adaptive, but they are biologically costly. Fever is a common response to infection and is effective in terms of raising the temperature of the body so as to reduce the growth rate of bacteria, but this requires substantial energetic resources and over time, may be detrimental to body tissues (Nesse and Williams 1994).

How do we know whether a biological or behavioral change is adaptive? That is, how do we measure adaptation? Indices of health are used as measures of adaptation, since they are linked – either directly or indirectly – to survival and/or reproduction (Little 1989). These are often quite standard biological measures such as hemoglobin status, infectious disease status or parasite load, child growth, blood pressure, reproductive outcomes such as miscarriage, or birthweight. All of these signal something about biological well-being that has significance for survival chances and overall reproductive success. Sometimes it is possible to measure survival and reproduction directly by looking at rates of death or birth. Ideally these measures can be linked together in a prospective study – that is, by assessing individual health characteristics and following that individual over longer periods of time to assess the person's fertility and survival (or age at death). Prospective studies are difficult to do, since they require monitoring of individuals over long periods of time. So, more often than not, health measures are used as proxies for adaptation if there is a demonstrable or theoretical link to survival or reproduction.

Biocultural Synthesis: High-Altitude Examples

Biocultural research grew out of human adaptability studies, many of which were carried out in high-altitude areas of the Andes. Although early studies emphasized hypoxia as the main stress there, more recent work has focused on the social sources of stress and how they compromise health, including a person's ability to respond to natural stresses such as hypoxia. Leonard and colleagues (1989) have shown that nutritional stress, which varies by socioeconomic status, alters the extent to which a child's growth and development will be affected by hypoxia. Other researchers have emphasized the historical roots of social stresses, which have created the current political economic conditions that enhance the well-being of some groups at the expense of the health of others. In Peru, Carey (1990) has shown how individuals in households that have been increasingly marginalized since the colonial period suffer from inadequate food supplies, resulting in malnutrition, infectious diseases, and lost days of work. Households respond to these very tangible threats to their well-being by forming cooperative support systems, which seem to be associated with better health of their members. Some households are so socially and economically impoverished as to be unable to participate in such networks, and their health status is reduced as a consequence. In another part of the same study, Leatherman (1998, 1996) has shown that illnesses (particularly chronic conditions) reduce net household productivity and income and further exacerbate poverty, resulting in a downward spiral of social and biological well-being.