ECOLOGICAL DIVERSITY AND MODERN HUMAN ADAPTATIONS

S. Stinson
Department of Anthropology, Queens College, City University of New York, USA

Keywords: acclimatization, body size variation, cold adaptation, diabetes, dietary adaptation, heat adaptation, high altitude adaptation, hypertension, infectious disease adaptation, lactose digestion, sickle cell anemia, skin color, vitamin D synthesis

Contents

UNESCO – EOLSS SAMPLE CHAPTERS

Summary

Humans exhibit a number of biological adaptations to the great variety of environments they occupy. The best example of human genetic adaptation to climate is skin color, which likely evolved as an adaptation to ultraviolet radiation. Variation among populations in body size and shape also may be at least partially related to adaptation to climate. We retain adaptations to extreme climates that evolved in our ancestors who had less technological ability to buffer environmental stress. In addition, we exhibit biological adaptations to environmental conditions, such as high altitude hypoxia, that cannot effectively be modified behaviorally. Many of our adaptations to climatic stress are not genetic adaptations, but acclimatizations that come about during our lifetimes.

One of the most important influences on human adaptation is our ability to modify the environment. This modification both reduces our exposure to the physical environment and creates new environmental conditions to which we much adapt. Human modification of the environment has altered our diet and the diseases we get. We see evidence of genetic adaptation to these changes, but also of failure to adapt. Several of the chronic diseases that are so frequent in industrialized countries today may result from the fact that we are consuming diets to which we are not biologically adapted.

While there are a number of biological adaptations to the environment evident in humans, one of the most apparent aspects of human adaptation is the relatively small number of biological adaptations to specific environments. Our behavioral flexibility and our ability to modify the environment lessen our need for biological adaptations. As adaptable as humans are, there are also limits to our adaptability. We see many of these limits reached under conditions of poverty. When resources are unavailable, even our great biological and behavioral flexibility may not be sufficient.

1. Introduction

Because of the fact that humans live in a greater variety of habitats than any other species, it is natural to ask how humans adapt to these varied environments. Human adaptation involves both biological and behavioral mechanisms. This essay describes some of the ecological adaptations that are evident in modern human populations, with an emphasis on biological adaptations. This is not to imply that biological adaptations are more important to humans than behavioral adaptations, for this is certainly not the case. Human behavioral ability to modify the environment is the major factor that has allowed us to occupy the diverse ecosystems that we do. In fact, many of the biological adaptations that we see in humans are adaptations to environmental conditions we ourselves have produced.

The term adaptation can be used in many different ways, but here it is used in its most general sense: adaptations are beneficial adjustments to the environment. A crucial aspect of the concept of adaptation is that an adaptation must convey some overall benefit. This does not mean, however, that adaptations are always totally without cost. Having one copy of the gene for sickle cell anemia is advantageous in environments with falciparum malaria, but every generation must pay the cost of this adaptation as individuals with two copies of the gene are likely to die from sickle cell anemia. Adaptations can occur at a variety of levels. Genetic adaptations are changes in the genetic makeup of populations that come about over generations as a result of natural selection. Genetic adaptations are fairly permanent adaptations because if one possesses the gene, one has it whether or not one is in the environment where the gene is advantageous. There are also less permanent types of adaptations. Acclimatizations are changes that come about during the lifetime of the individual in response to particular environmental stresses. Although the ability to undergo the acclimatization has a genetic basis, the actual response does not occur unless the individual experiences the environmental stress. Tanning in response to ultraviolet radiation is a good example of an acclimatization. Developmental adaptations (or developmental acclimatizations) are changes that occur in response to an environmental stress during the period of growth. Because developmental adaptations usually change the way that some part of the body grows or develops, they are generally more permanent than acclimatizations. Adaptation to high altitude involves developmental adaptation.

There are several methods for determining human biological adaptations to the physical environment. One is to look for global patterns of human variation that correlate with some aspect of the physical environment, such as temperature or solar radiation. If there is a strong relationship between the pattern of variation in the biological characteristic and the environmental variable, then this is evidence that the environmental factor may be the cause of the biological variation. The best evidence for genetic adaptation to

UNESCO – EOLSS SAMPLE CHAPTERS

climate on a global scale is the case of skin color as an adaptation that evolved as a result of selection due to ultraviolet radiation. There are global patterns of variation in body size and shape as well, but these are less pronounced than for skin color, and it is not always clear to what extent body size variation represents adaptation to climatic stress.

Another approach is to compare populations in terms of how they deal with climatic extremes. Such studies indicate that humans are basically a heat-adapted species, and there is little evidence for variation among populations in their biological ability to deal with heat stress. On the other hand, we are not biologically well adapted to deal with extreme cold. Because not all human populations share a history of exposure to cold climates, we do see evidence for variation among populations in ability to deal biologically with extreme cold. Humans adapt to the oxygen stress of high altitude with a complex combination of acclimatization, developmental adaptation, and genetic adaptation.

Although humans live in a great variety of climates, our behavioral adaptations buffer us from much climatic stress. Much of the environmental stress with which humans must deal is a result of our modification of the natural environment. Human alteration of the environment has affected the diseases we get and the foods that we eat. Sickle cell anemia and malaria is the classic example of human genetic adaptation to disease. Tay-Sachs disease and tuberculosis, and cystic fibrosis and cholera may represent similar types of adaptations. The best example of genetic adaptation to diet is the high adult lactase levels seen in dairying populations. Although there are examples of biological adaptations to changed environments, there are also cases where our environmental modification has resulted in health problems.

In considering human biological adaptations to the environment, there are several important points to keep in mind. First, although humans occupy a diversity of habitats, it is difficult to identify many genetic traits that are adaptations to specific environments. Rather, humans have a great ability to modify their behavior or biology during the lifetime in response to the environment. Second, we must always bear in mind that the conditions under which genetic adaptations evolved are very frequently not the conditions experienced by most humans today. There is considerable debate about the time frame over which the adaptations of living humans evolved. Some argue that all humans shared a common ancestor 100,000-200,000 years ago and that all the biological variation evident in human populations today has evolved over this relatively short (in evolutionary terms) period of time. The alternative view is that all living humans shared a common ancestor that lived 1-2 million years ago, and that the biological variation evident in living humans has evolved over this much longer period of time. Whichever is the case, many of the biological characteristics of living humans evolved during time periods when our technology was much less sophisticated than it is today. Biological characteristics that were limitations under past condition are frequently not limitations today. Conversely, traits that were advantageous in past environments may be detrimental today.

2. Global Patterns of Human Variation

UNESCO – EOLSS SAMPLE CHAPTERS

Gradual changes in the frequency of a trait over space are called clines. Worldwide clines, which are apparent when we map populations at their presumed locations before the extensive population movements of the last 500 years, are usually interpreted as being the result of adaptation to climatic factors. The most pronounced cline in living human populations is in skin color, which changes gradually from darkest in populations living near the equator to lightest in populations living far from the equator (see Figure 1). There are also less pronounced clines in human body size and shape (see Figure 2). Clinal variation in skin color is generally considered to be the result of natural selection due to ultraviolet radiation that took place during the course of human evolution. The interpretation of global patterns of variation in body size and shape is more problematic. These patterns may be the result of natural selection caused by climatic factors, they may be the result of the effect of the climate acting during individuals' lifetimes, or they may be at least partly unrelated to the direct effects of climate.

-
-
-

TO ACCESS ALL THE **19 PAGES** OF THIS CHAPTER,
Visit: http://www.eolss.net/Eolss-sampleAllChapter.aspx

UNESCO – EOLSS SAMPLE CHAPTERS

Bibliography

Beall C.M. (2000) Tibetan and Andean patterns of adaptation to high-altitude hypoxia. *Human Biology* **72,** 201-228. [This reviews the different patterns of high altitude adaptation in Tibetan and Andean natives].

Dean M., Carrington M., Winkler C., Huttley G.A., Smith M.W. et al. (1996) Genetic restriction of HIV-1 infection and progression to AIDS by a deletion allele of the CKR5 structural gene. *Science* **273**, 1856-1862. [This presents evidence for a genetic trait that confers resistance to AIDS].

Durham W.H. (1991) *Coevolution. Genes, Culture, and Human Diversity*. 629 p. Stanford, CA, USA: Stanford University Press. [This examines the relationship between human biological and cultural adaptation].

Frisancho A.R. (1993) *Human Adaptation and Accommodation*. 532 p. Ann Arbor, MI, USA: University of Michigan Press. [This presents an overview of biological human adaptation to climate and nutrition].

Goodman A.H. and Leatherman T.L. (eds.) (1998) *Building a New Biocultural Synthesis. Political-Economic Perspective on Human Biology*. 486 p. Ann Arbor, MI, USA: University of Michigan Press. [This argues that a political economic perspective is essential to understanding human adaptation].

Robins A.H. (1991) *Biological Perspectives on Human Pigmentation*. 253 pp. Cambridge: Cambridge University Press. [This presents an overview of social and biological aspects of human pigmentation].

Stinson S., Bogin B., Huss-Ashmore R. and O'Rourke D. (eds.) (2000) *Human Biology: An Evolutionary and Biocultural Perspective.* 639 p. New York: Wiley-Liss. [Chapters in this volume deal with nutritional, disease, and climate adaptation].

Biographical Sketch

Sara Stinson is a biological anthropologist specializing in biological variation in living human populations. She received her Ph.D. in Anthropology from the University of Michigan and is currently Associate Professor of Anthropology at Queens College, City University of New York. Her research has focused on the causes of variation in child growth, and she has conducted fieldwork among populations at high altitude in Bolivia and in the tropical forests of western Ecuador.

UNESCO – EOLSS
SAMPLE CHAPTERS