HUMAN BIOLOGY WITHIN THE FRAMEWORK OF PHYSICAL ANTHROPOLOGY

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Contents

Summary

This review highlights the evolutionary and genetic foundations of human biology as

practiced by biological anthropologists in the application of these principles to contemporary human populations. Human biology encompasses a number of domains including, but not limited to, human population genetics, medical genetics, molecular genetics (nuclear and mitochondrial DNA), human growth and development, human adaptability to physical and biological environmental stressors, epidemiology, demography, ecology and nutrition. Human biology originated as a discipline in the early 1960s in England and the USA with a focus on human adaptability to extreme climatic conditions of temperature and altitude. It currently is a discipline with practitioners around the world and a range of problem areas under study, using both field and laboratory techniques. As populations change through micro-evolutionary processes and our understanding grows of the human genome and population variability, human biology will document the new epidemiological challenges such as: the Human Immunodeficiency Virus (HIV); the impact of modernization causing a worldwide obesity epidemic associated with changing energy intake and expenditure patterns; genetic admixture at unprecedented levels due to increased travel and migration and the detrimental impact of increased exposure to natural and human-made ionizing radiation and toxic chemicals. Human biology is a generalist field and much of the work of human biology involves collaboration with scientists in other disciplines.

1. Introduction: Theory and history of human biology

1.1. Introduction

Human biology is the study of the biology of contemporary human populations using evolutionary theory as the primary explanatory framework for understanding the similarities and differences among human populations. Human biology is often used synonymously with *biological anthropology* although the latter term can include the study of *paleoanthropology* or the extinct relatives of modern humans and *primatology* or the study of prosimians—monkeys and apes. Human biologists study biological variation at all levels from the *genotype* of a single individual to the *demographic* parameters of populations. Humans are a highly diverse species both genetically and *phenotypically*. Features characterizing the human species and our prehistoric relatives are: the unique gate of *bipedalism* or walking on our hindlimbs; a large complicated brain with a highly developed capacity for symbolic thought; the complex communication system of human language; intricate and long lasting social relations; and elaborate cultural material that we depend on for our survival.

Human Biology is synthetic in its approach. It links approximate causes, for example climatic temperature with ultimate measures of evolutionary success such as *reproductive fitness.* A key to successful *Darwinian evolution* is adaptation linking the biological capacities of humans to the selective pressures of their environments.

1.2. History of Biological Anthropology

Although the roots of human biology can be traced to comparative anatomy in the Middle Ages, the discipline developed as part of physical or biological anthropology in the twentieth century. Human biology, the branch of physical anthropology investigating contemporary human variation through the lens of evolution, was primarily a descriptive endeavor until the mid 1950s when an influential essay by Sherwood Washburn (*American Journal of Physical Anthropology*, 1951) pointed in the direction of hypothesis testing and the search for the mechanisms responsible for genetic, physiological and anatomical variation.

In the 1960s and 1970s the International Biological Program (IBP) fostered the rapid development of field methods, multidisciplinary research teams and extensive data collection in human adaptability research. In the USA. Paul Baker and more than two dozen students were instrumental in developing the field of high altitude Andean research. Joseph Weiner, Gregory Harrison, James Tanner and others in the United Kingdom were leaders in the effort and more than 230 projects were conducted worldwide ranging from the Artic to Sub-Sahara Africa. UNESCO followed with the Man and the Biosphere (MaB) projects in the 1980s and 1990s.

The interest in human genetic variation can be traced to the discovery of blood groups in the early 1900s. Human biologists are interested in the mechanisms of microevolution, molecular variation and a broad range of phenotypes. The mapping of the human genome has given human biologists new tools and the Human Genome Diversity Project in the 1990s and now the HapMap project have a goal of documenting human genetic variation across the globe.

Work in the early 1900s by Franz Boas and others documented changes in growth of immigrant populations. This early work was followed by James Tanner in England and W.M. Krogman in the United States in the 1940s and 1950s, conducting cross-sectional, growth studies of very large samples. Most countries today carryout periodic studies to monitor changes in growth on a national level. The U.S. government has conducted periodic National Health and Nutritional Examination Surveys (NHANES) since the 1970s. Longitudinal studies over a number of generations of the same families, for example, at the Fels Institute in Ohio, USA, offer different insights. Human biologist are involved in theses studies.

Recent foci for human biological investigations have included chronic and infectious disease, fertility, nutrition and aging. Human biology is a multidisciplinary field with a basic interest in understanding the nexus of interactions of genotypes with various environmental variables as they are mediated by human behavior or culture.

1.3. Adaptation

Adaptation to the living or *biotic* and non-living *abiotic* environment is a fundamental concept in human biology. Individuals and populations demonstrate various levels of adaptive responses or modes of adjustment (Table 1). In the narrow sense *adaptation* refers to genetic changes in populations. For example, genes play a role in the increased ability of populations indigenous to cold climates, such as the Eskimos and Inuit, to efficiently rewarm their fingers and toes, thereby reducing the risk of frost bite. Populations indigenous to warm tropical areas are not as efficient at this physiological response.

Populations exposed to new environments also show immediate *acclimation* or physiological changes that are induced by climatic conditions. For example, individuals who climb mountains and are exposed to the low oxygen pressure at high altitudes will respond with an increased respiratory rate and begin to breathe faster. This is a physiological mechanism for increasing the amount of oxygen in the body. A third type of response is *acclimatization.* Acclimatization refers to the physiological alterations during the lifetime of an organism. These adjustments also include alterations in growth patterns or developmental *plasticity.* For example, populations at high altitudes often show larger chest diameters than individuals of comparable statue at lower altitudes. This indicates an increase in lung volume in response to low oxygen pressure at high altitudes. This low oxygen pressure produces *hypoxic stress*.

Behavior is also an adaptive mechanism. Culture influences behavioral responses to both the physical and social environment and the production and use of materials. Culture is both behavior and the products or artifacts created by human behavior.

For example, in hot humid environments individuals will wear little clothing or clothing designed for the circulation of air or convection flow across the body to enhance evaporative cooling and dissipate heat. The final type of response is *habituation*. Habituation is a psychological response usually reducing attentiveness to certain stimuli. For example, one can become “used to” the heat and not “mind it” as much as during the initial of phases of exposure. Human are capable of a wide variety of adaptive biological responses. These, in turn, are coupled with an even broader array of flexible behavioral responses that involve language, technology and complex social interactions.

In the past human biologists paid less attention to behavioral aspects of adaptability than physiological, anatomical and developmental aspects. However, bio-cultural approaches are becoming more prevalent among human biologists and biological anthropologists. Training in various aspects of behavioral and cultural anthropology are now pursued in graduate programs and integrated into human biology models. For example, culturally prescribed post-martial residence patterns may have a greater influence on the geographic patterns of communicable diseases than either genetic susceptibility or infective characteristics of disease causing-organisms.

Type	**Means**	**Speed**
Accommodation	Culture/behavior	Fast/slow
Acclimation	Physiology	Fast/slow
Acclimatization	Physiology	Slower
Plasticity	Morphology	Slower
Adaptation	Population genetics	Slowest

Habituation	Psychology	Fast

Table 1. Modes of adjustment

1.4. Maladaptation

Not all human behaviors confer an adaptive advantage. Some recent cultural patterns are maladaptive. For example, James McKenna demonstrated that the introduction of nurseries and cribs in American households is less adaptive than the more traditional co-sleeping arrangements that regulate infant respiration. The result is an increased risk of Sudden Infant Death Syndrome (SIDS) for infants with immature respiratory regulatory systems. In another example, Lawrence Schell's work demonstrated that children in poor urban neighborhoods compared to their suburban neighborhoods had higher environmental lead exposures and higher blood levels of lead from lead-based paints and car emissions. These high lead levels increased cognitive impairment, behavioral problems, learning deficits and lower education attainment. With fewer employment opportunities and lower income levels, poverty and poor living environments were perpetuated over a number of generations.

1.5. Evolutionary Theory

Modern evolutionary theory, a synthesis of Darwinian theory and genetics, is the theoretical foundation for human biology. Natural selection remains the predominant mechanism. Logic follows that more organisms are produced than can survive. These organisms within a species vary in their heritable traits. Variations in traits favorable for a particular environment confer a selective advantage on those individuals who have them. Those traits with a selective advantage are manifested in greater reproductive success or increased *reproductive fitness*. This leads to an increase in the representation of preferentially-selected genes in the next generation.

Natural selection operates on the individual but has consequences for the population by altering gene frequencies (see section 4). Changing environments lead to changes in selection pressures. Human biology is concerned with how different populations, given their varying genetic and phenotypic backgrounds, respond to environmental conditions. These responses can be the quick responses of behavioral changes or the intergenerational responses of genetic adaptations.

Sociobiology has a broad focus on the influence of non-reproductive behaviors. For example, differential feeding of offspring can influence survival; and therefore, reproductive success. There are many examples of differences in parenting effort or investment favoring the health, growth and reproductive success of some offspring over others.

1.6. Micro-evolutionary Forces

Human biologists focus on micro-evolutionary processes. In addition to natural selection, micro-evolutionary processes or evolutionary forces include: 1) *mutations* or changes in the DNA or chromosomes, 2) *gene flow* and genetic admixture—the impact of migration or movement of populations into new environments yielding new reproductive consequences, and 3) *genetic drift*—the dynamics of gene frequency changes associated with small populations. In section 4 we will describe these micro-evolutionary forces that are part of modern evolutionary theory.

Human biology has many examples of the impact of specific evolutionary forces that change genotype and phenotype frequencies. Among the Pennsylvania Dutch communities there is a rare type of dwarfism accompanied by extra fingers. This rare disorder arose through mutation, was carried by one or more individuals comprising the small founding population that migrated from Germany to Pennsylvania in the 1700s. The syndrome increased in frequency through a combination of genetic drift and non-random mating in this community that remained reproductively isolated because of religion and lifestyle. Historically, the random fluctuations in genetic variation or genetic drift are most evident in populations that have been reproductively isolated by geography, religion or socio-political boundaries.

Mutations arise by chance due to changes in the genes or chromosomes. Although there are *mutagens* in the environment, i.e. substances that can increase mutation such as ionizing radiation, there is little evidence that these mutagens target particular genes. In contrast, *selection* does not arise by chance and generally produces an impact that is directional or continues to increase the frequency of positively selected phenotypes or decrease the frequency of deleterious phenotypes in subsequent generations. This is *differential reproductive fitness.* For example, there has been a decreased frequency in the production of *melanin* or dark skin pigmentation in northern altitudes with low sunlight compared to populations in our ancestral environments of tropical Africa. Individuals with lighter skin color absorb more light in the lower layers of the skin and produce more vitamin D. Vitamin D enhances the absorption of calcium from the intestines. Calcium is a nutrient in the food we eat and it is the primary substrate for bones. Low calcium intake in the diet or malabsorption from the gut can lead to a deformation of bone or the disease *rickets*. Rickets reduces fertility and increases childhood mortality. Humans control, in part, natural selection through cultural inventions and behavioral changes. For example, we modify our exposure to the sun and ultraviolet radiation with clothing, sun blockers, and the built environment. Although natural selection focuses on reproductive success, human biologists often look at more proximate measures of adaptive success, such as health status, growth attainment, and work capacity.

The adaptationist model has been challenged. Steven J. Gould and Niles Eldridge suggest that much of human variation is serendipitous. That is, it is a consequence or by-product of other traits that do carry selective value. Adaptation is constrained by a population's history and prior exposure to the forces of evolution so that these must be considered when attributing a genotype or phenotype to natural selection.

Forces of Evolution	**Within Populations**	**Among Populations**
Mutation	↑	↑

Natural Selection	↓	↑
Genetic Drift	↓	↑
Gene Flow (Admixture)	↑ ↓	↑ ↓
Inbreeding Positive Assortative Mating	↓	↑

Table 2. Forces of evolution and variability increase or decrease

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Biographical Sketches

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