THE NATURE OF HUMAN BIOLOGICAL AND GENETIC VARIABILITY

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Summary

Human biological and genetic variation has many facets, most of which have been studied within the academic discipline of human biology or physical/biological anthropology. In this chapter the overall topic is divided into five principal sections, namely; history, anthropometry, race, adaptation and classical and molecular markers. The sections generally provide backgrounds and rationales along with specific studies and examples that might assist in covering why human variation is an important topic of scientific pursuit. The organizing theme of all of the discussion is human evolution, in theory as well as in representing our long past ancestors and then forward in time to the appearance of and variation within modern *Homo sapiens*. Where relevant, recent research findings in human variation are presented as these might indicate the directions for future development of human biology and physical/biological anthropology.

1. Introduction

As an observant and highly social and mobile species, humans have been made continually aware of biological variation among not only persons of closely related groups but also between populations living in all parts of the world. Of course, with present-day high-speed information and image transmission technology, exposure to diversity can be consumed in prodigious amounts. Recognition of both similarities and differences between individuals has been finely developed throughout the course of our evolution. In brief, biological diversity that we all observe today has been important for our long-term survival and it is incumbent on us to continue to expand our knowledge and enhance our understanding of this fundamental aspect of our human nature. While our outward physical appearance, and its myriad expressions, is what is most obvious to us, humans also possess a multitude of internal and generally unobservable biological characteristics that likewise can be variable. Fundamental to all of this variability underlies our inherited nature, that is, our genes and accompanying DNA variation. This chapter will provide a review of the major features of human biological and genetic variation with an eye toward explaining why we look and vary the way we do. Formal studies into this are conducted within the discipline of physical anthropology, which is referred to in some instances as biological anthropology, bioanthropology, and especially, as human biology. It is imperative to state that a considerable amount of human biological research is undertaken within a model that appreciates the connections and interdependencies of biology and behavior. Accordingly, since social and cultural aspects of human nature play an important role in defining our biological and genetic makeup, these too will be addressed where appropriate.

1.1. Historical Background

Human groups dating back into prehistoric times had to become aware of biological and cultural differences during periods of migration into new lands that were previously occupied. Along this line, it can only be speculated as to the manner of interaction that took place during meetings of Neanderthals (also spelled Neandertals) and other human groups in Upper Paleolithic Europe some tens of thousands of years ago. It is probable that early humans had evolved a survival tactic that cautioned against immediately accepting strangers, a tendency toward xenophobia that seems pervasive even today. Unfortunately, for our species' long prehistoric stretch of existence there is inadequate preservation of suitable documents or documentation as to how biological variation might have been viewed or treated, whether strangers were feared or welcomed at first contact.

1.2. Ancient Egypt

Ancient Egypt can serve as a starting place that clearly portrayed human biological variability. At various time periods and in several media, ancient Egyptian artists depicted what are considered to be "four races" coexisting in the same general region. For example, there are tomb paintings from rock-cut sepulchers dating to the Nineteenth and Twentieth dynasties (beginning roughly 3400 years ago)) showing figures of an Egyptian, an Asian, a Libyan, and an Ethiopian. Biological variation is mostly apparent in the different pigments used to represent skin color differences, but the figures also vary in dress and hair style. Considering the cross-road location of Egypt it is expected that different ethnic groups within this region came into regular contact. There is strong evidence that these encounters and relationships were not always harmonious but rather fraught with group discrimination that very likely was in part based on outward physical appearance. In general terms, physical appearance, notably skin color, could very well track to an early evolutionarily derived mechanism to assist in separating "in" groups from "outsiders" or "friends" from "foes". To that end, biological variation is likely to underlie some of the xenophobic feelings and even mildly cautious behaviors that strangers might express during initial encounters.

1.3. The World Discovered

Planned and chance meetings between different groups reached a crescendo during the Age of Exploration or Age of Discovery, a far-reaching endeavor systematically engaged in by European governments and seafarers that was launched in the fifteenth century and carried over the next two hundred years. Peoples new to the European world were “discovered” in Africa, Asia, the Pacific and the Americas. These engagements provided descriptions of physical differences that would later set the background for racial classification schemes of European scholars in the eighteenth century. This rather static and essentially descriptive effort to construct racial categories carried into the mid-twentieth century when it was superseded by a more sound scientific approach that emphasized dynamic processes that explained the origin, evolution, and continual development of our biological nature. The subsequent sections will discuss the various methods and approaches utilized by physical anthropologists and human biologists in their quest to fully comprehend our biological variability.

2. Anthropometry: Measuring Morphological Variation

2.1. Background

For more than 150 years anthropometry has been a firm foundation for measuring and analyzing morphological/anatomical variation of humans. In simplest terms, anthropometry and biometry refers to the taking of measurements of the human body according to standardized units, landmarks, and instruments. Two references are considered indispensible for this undertaking: *The Measurement of Human Growth* (Cameron, 1984) and *Anthropometric Standardization Reference Manual* (Lohman et al. 1988). These works spell out how to reduce sources of error and maximize the accuracy, reliability and validity of the measurements taken. For the most part, the SI or metric system has been employed universally in measurement taking, with the exception that pounds instead of kilograms for body weight seems to take precedence in the USA. Standardized anatomical landmarks, such as glabella (the midpoint between the browridges on the skull), have been fully accepted and applied worldwide. Measuring instruments require a great deal of precision and need to be of high quality in order to be consistently accurate. Two prominent names in this regard have been Martin (manufactured by GPM in Switzerland) and Harpenden (a British based research unit that designed many instruments). Human biological variation, as studied through anthropometric methods, can deal with either comparisons of groups (children or adults) living at the present time or between modern humans and any of our ancestral populations within our evolutionary history.

A corresponding method, traditionally known as anthroposcopy and more commonly referred to as biometric markers today, employs sets of standardized observations for traits not readily measured, such as the development stages of browridges on the skull. There has been a tendency to replace some subjective observations with quantifiable methods in order to achieve a higher level of consistency and reliability. However, observational or nonmetric data continue to be a major category of biological variation information, particularly with respect to human fossil and skeletal materials. Recent application of biometric markers, such as iris and fingerprint identification readers, has taken place in designing security devices for building entry and computer access, and eventually such biomarkers may be used on driver's licenses.

Anthropometry obviously deals with data in the form of numbers, and numbers naturally imply a formal procedure for handling them, namely, statistics. A very basic coverage of statistics is helpful here because in any discussion of biological variation, there must be a way of describing how important or how large that variation is. Our example will use the physical trait of adult human height or stature. Measuring the height of a large sample of men or women will yield a set of values or a distribution ranging from the shorter to the taller end.

The range can then be stated as the difference between the minimum and maximum heights. Range is in itself a measure of variation, since the greater it is the more variation there is. In contrast, if all of the individual values were added and then divided by the number of values this would define the arithmetic mean or the average of the distribution. Sample means, along with medians (middle value) and modes (most frequent value), give an idea of the central tendency or a one shot look at the distribution, but they don't provide any direct information on the amount of variation in that distribution of individual values. For this we turn to a calculated statistic called the variance (V). The variance is defined as the sum of the squared differences between the mean and each of the individual values divided by the mean. The square root of the variance is the standard deviation (SD). Customarily, means are reported along with SD units as an indicator of a distribution's degree of variation. Quite simply, the greater the variance and accompanying SD the more difference there is between the individual values of the distribution. Hence, variance and SD are highly informative measures of biological variation.

2.2. Measuring Human Growth

Anthropometry most obviously has been applied in the study of human growth (formally known as auxology), in either repeated measurements of the same children at regular time intervals (longitudinal) or in cohorts of children of the same age (cross-sectional). A premier example of the former is the Fels Longitudinal Study, originally carried out at the Fels Research Institute in Yellow Springs, and now located at Kettering, Ohio. This Study has been following multigenerational families since the late 1920s. Another prime example is the Harpenden Longitudinal Growth Study established in Britain in 1949. Longitudinal growth studies, measuring of and recording developmental stages of individual children from infancy to adulthood, were essential in discovering that boys and girls have differing growth patterns in timing of maturational events, such as the adolescent growth spurt. In addition, some children are early maturers while others have delayed or prolonged maturation rates. A large proportion of the distribution is, of course, clustered around the mean. As has been mentioned previously, variation is the hallmark of human biological expression, in this instance in terms of growth and development.

Typically, cross-sectional studies are used to establish standardized reference data (such as NHANES-National Health and Nutrition Estimation Survey), to compare the growth of a research population of children against the reference, or to examine subsets of children from similar ethnic background who are born and/or raised in different environments, such as rural/urban or lowland/high altitude settings, or to assess the growth status of a child in a pediatrician's office. The goal, of course, is to determine what role environmental factors, for instance, nutrition, disease, high altitude stress (hypoxia), or even psychosocial stress, have on the pattern and tempo of childhood growth. An important phenomenon called catch-up growth occurs in children who have experienced episodes of environmental stress during their growth and development, slowing their progress. When the stress is removed, these children may demonstrate an accelerated rate of growth that returns them to their growth potential, so long as the stress is not too intense or chronic.

It is important to note that there is likely to be sex-specific growth features that also imply an underlying genetic influence upon developmental timing and differential body composition, for instance fat tissue patterning, an example of a non-genital feature. This is referred to as sexual dimorphism. *Homo sapiens* is a dimorphic species, and in common with other such species, females and males differ from one another probably due to early evolution biobehavioral programming involving mate selection factors. In sum, environment and heredity, and of course, their interaction, all play roles in accounting for biological variation that occurs within and between the sexes, and this variation is established through growth and development.

2.3. Secular Trends

One of the more intriguing studies into human growth over many generations has been observed in secular trends in such measures as an increase in both childhood and adult height and an earlier attainment of sexual maturation. In brief, girls and boys are getting taller and becoming mature earlier in some areas of the world. Secular trend data, often height and weight measurements, have been reported for many countries, especially from those that have had or are currently experiencing increased amounts of calorie-dense processed foods and improved health care delivery both of which establish environments that tend to accelerate rates of growth and maturation. These trends were thought to have leveled off in most of the developed countries but recently there are concerns that increases in overweight and obesity might herald a new secular trend in weight. This phenomenon usually is attributed to developmental plasticity, an inherent ability of an organism to respond to changing environmental conditions either in positive or negative ways.

As would be predicted, secular trends tend to level off once accommodations to changing conditions are reached. However, concerns are now being expressed that certain chemicals released into the environment, such as those mimicking the hormone estrogen, have the potential for adversely altering fetal and childhood development, particularly that of males.

2.4. Body Composition

Anthropometry also is used in the estimation of adult body composition, often with an interest to assess nutritional status or factors influencing muscular or skeletal development. Instruments for this work employ the time-honored anthropometer for measuring height, limbs and body breadths, scales for weighing, skinfold calipers for estimating subcutaneous fat amounts, and various devices for ascertaining lean body mass, such as the bioelectrical impedance analyzers. Newer technologies allow the investigator to enter measurement data directly into a computer file via a remote transmitter, and there has been some use of whole body scans to obviate the need to take a long series of measurements directly on the person.

At the present time there is an overt applied aspect to assessing health status through such measures as Body Mass Index (BMI = kg/m^2), where body weight is given in kilograms and standing height is measured in meters. BMI, along with other indicators of body composition and health, have sparked an enormous industry related to diet controls and exercise regimens in face of what has been called an obesity epidemic among both children and adults. What seems not to be generally appreciated is that calculated BMI has limitations in its attempt to identify a broad range of persons from those who are too thin all the way to those who are morbidly obese. Furthermore, by itself BMI cannot differentiate between excess adipose (fat) tissue levels and an advanced stage of muscular development, such as observed in some professional athletes.

2.5. Asymmetry

Thirdly, there are anthropometric studies of asymmetry, or bilateral differences between paired structures, such as limbs, which can document preferred-use patterns of say left and right handed persons. Directional Asymmetry (DA) is side-to-side variation in which the average measurement on one side is significantly larger than the average on the other side. Fluctuating Asymmetry (FA) reflects a difference in side-to-side measurements that does not favor one side and it has been attributed to instability or disorganization during growth and development caused by hereditary/environmental factors. This assumes that symmetry is the goal of the developmental process and asymmetry is a measure of how close that goal is achieved.

A measure that has received consideration attention in recent years with regard to asymmetry research is the digit ratio (2D:4D), that compares the relative lengths of the index and ring fingers. It is proposed that this ratio is an approximate indicator of level of exposure to androgenic hormones during fetal development, the lower the 2D:4D ratio the higher the androgenic exposure. A genetic basis for the ratio also has been proposed, and perhaps indicating an evolutionarily broader context, the digit ratio has been reported in other animals, including the Great Apes. As might be anticipated, the digit ratio is sexually dimorphic in which males tend to have a shorter average index to ring finger length, while females show the opposite tendency, though not consistently.

Additionally, right hands appear to be more clearly sensitive to digit ratio differences, and population or ethnic group variation usually exceeds that of sexual dimorphism. Multiple studies into 2D:4D variability, usually through correlation analysis, have spanned the gamut from physiological and psychological matters, to behavioral and cognitive expression, including sexual orientation. Possibly, future research will clarify just how the digit ratio, and other prenatally derived variables, can shed some light on the influence the fetal period has in directing or controlling later stages of human life history.

2.6. Comparing Modern Humans

A traditional use of anthropometry has been the taking of measurements of the head and body (or skull and skeleton) for making comparisons within and between adults of historic or living populations. Standardized measurements, such as those taken on the head, capture size differences of the principal dimensions of length, breadth, height, and circumference, along with several specific measurements of the face, nose and jaw areas. In the earlier Background section were cited important references that spell out the methods for properly taking the myriad of measurements used in this line of research. Studies are continually being done to revise existing measurements for increased accuracy, and at times new variables are introduced that are designed to better represent anatomical variation or genetic influence. A major approach of this research employs variance estimates, and other statistics, of anthropometric measurement distributions that can be used for assessing degrees of relationship, on the assumption that the smaller the calculated biological distance, the more closely related the groups are evolutionarily. Biological distance serves here as a proxy for genetic differences that are presumed to underlie variation in anthropometric variables such as head dimensions.

This research approach can be illustrated through a study done by John Relethford (1988) on seven populations or villages located along the west coast of Ireland in the 1890s. He utilized data that had been collected from this time period consisting of ten anthropometric measurements (head and body variables) on 259 adult males. One of the significant findings of the study was that the two villages that had a known history of contact and admixture with persons from England some centuries earlier, stood apart from the remaining villages. Thus, they showed a greater biological distance and corresponding genetic divergence. This is interpreted as demonstrating how anthropometrics can be useful in assessing more recent historical events and processes.

2.7. Measuring our Ancestors

Extending this anthropometric framework back into time characterizes the study of our fossil ancestors, referred to as hominids in the earlier literature and hominins more recently. From a fairly overall extensive fossil record, researchers are able to address some very important questions pertaining to who are earliest ancestors were and what they looked like, how they settled some areas and migrated to new lands and continents, and how their physical appearance underwent evolutionary changes to become what we recognize as modern humans. This research is known formally as human paleontology when it primarily deals with the fossils themselves, or paleoanthropology, when it incorporates cultural materials such as stone tools, into the analysis. In general, studies of this kind have depicted our long-term evolution as a mosaic of several successive evolutionary trends including an increase in overall body size as we assumed an erect posture for standing and walking, an expansion of the brain, and a reduction in tooth size. These biological/anatomical characteristics were, of course, accompanied by interacting behaviors that were subjected to natural selection forces while adapting to becoming bipedal, enhancing cognitive abilities, and modifying dietary patterns.

Perhaps the most dramatic of these evolutionary trends was that of brain size increase. Brain size of *Homo sapiens* is approximately three times that of our ancestors, the australopithecines. Brain size measurement has been done using external dimensions of

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Biographical Sketch

Robert J. Meier is a human biologist. He currently is Chancellor's Professor Emeritus in the Department of Anthropology, Indiana University, Bloomington, IN USA. His PhD is from the University of Wisconsin-Madison in Human Biology. Principal research areas are in biological and genetic variation, primarily in the development and expression of dermatoglyphics. He has conducted field work among Easter Islanders and several Inupiat populations residing along the northwest coast and living in the Brooks Range Mountains of Alaska. He also has studied the biology of adult human twins and assortative mating practices in a twin panel recruited at the Indiana University Medical School. He carried out an assessment of genetic counseling clinics for the Indiana State Board of Health. His publications include two books, and more than 100 research articles, book chapters, abstracts and reviews. He has served as President of the American Dermatoglyphics Society, served on the Nominations/Elections Committees of the Human Biology Association and American Association of Physical Anthropologists, where he also was an Associate Editor. His honors include the Tracy M. Sonneborn Award for Excellence in Research and Teaching in 1989 and appointed as Chancellor's Professor in 1995, both at Indiana University. He was elected an Honorary Member of the Croatian Anthropological Society, in 1992.