Introduction

It is the purpose of this book to describe and interpret some of the evolutionary, physiological, socio-cultural, and mathematical patterns of human **growth**[1]. Throughout, a **biocultural approach** is taken, one that tries to seamlessly meld scientific exploration of the relationships between human biology and culture. Anthropologists have many definitions of human culture. Older proposals viewed culture as the sum of human technology, sociology, and ideology. The observations by Jane Goodall on wild chimpanzees, and by many researchers inspired by Goodall on other primate species, changed that older view. The technology and sociology of many nonhuman animals differs by degree, not kind, from human capacities. Contemporary theorists tend to focus their definitions of culture on ideology, that is, the justification of behavior. To justify behavior, we humans give meaning and purpose to our existence. Human purpose seems unique to our species (Jolly 1999). Ideology and purpose encompass the beliefs, norms, and values of a social group, which are transmitted across generations by means of informal and formal teaching and learning (Boyd & Richerson 1985). Human purpose spurred the technological change from chimpanzee hammer stones to the laptop I am using to write this sentence. Purpose took people to a moon landing, but also to the Nazi extermination of 11 million Jews, Gypsies, homosexuals, Catholic priests, people with mental or physical disabilities, communists, trade unionists, Jehovah's Witnesses, anarchists, Poles, and others. Human purpose underlies the social change from genetically-based chimpanzee hunting parties to socially and ideologically defined human gatherer-hunters and agro-industrialists. Human purpose provides my rationale for revising this book to bring it more "up-to-date" in terms of both scientific fact and my own interpretations of the science and humanities literature about human growth.

Given my purpose for this book, the title requires some explanation. A cell biologist might think of the phrase "patterns of growth" in terms of a series of genetically controlled cell duplication and division events. An embryologist might think of patterns of cell differentiation and integration leading to the **development** of a functionally complete human. The clinician interprets patterns of growth, especially deviations from expected or "normal" growth, as evidence of disease or other pathology in the patient. Each of these concepts of "pattern" may be biologically valid and useful in their own areas of specialization, but this book is about none of

[1] Formal definitions for all words in bold type are found in the Glossary.

them. The goal of this account is to consider the growth of the human body in a unified, holistic, and anthropological manner. The result, it is hoped, will be a synthesis of the forces that shaped the evolution of the human growth pattern, the biocultural factors that direct its expression in populations of living peoples, the intrinsic and extrinsic factors that regulate individual development, and the biomathematical approaches needed to analyze and interpret human growth.

The study of human growth in relation to evolutionary biology, biocultural factors, intrinsic and extrinsic factors, such as genes, **hormones**, the physical and social environment, and mathematics may seem like a strange brew of topics. In fact, it is a common mix for biological anthropologists. The rest of this book is designed to show the reader that the anthropological blend of scholarship and research is, in fact, a practical and rewarding combination.

Introductory students of human growth often assume that the field is primarily a part of pediatric medicine. Indeed, until the publication of the first edition of *Patterns of Human Growth* in 1988, all but one of the leading introductory texts were written by physicians, and were written with the medical student in mind, or as a practical guide for parents. The one exception is the book *Child Growth* (Krogman 1972), written by a biological anthropologist, but focused primarily on pediatric topics. While it may seem logical for human growth to be a subfield of medicine, it is more accurate, however, to view pediatric medicine and "parenting" as subfields of the study of human growth. In turn, human growth is a part of a much broader discipline, namely anthropology. A little bit of history, and an applied example, are provided here to justify this statement. Chapter 1 includes a more detailed history of the study of human growth.

Anthropology and Growth

The study of human growth has been a part of anthropology since the founding of the discipline. European anthropology of the early to mid-nineteenth century was basically anatomy and **anthropometry**, the science of human body measurements (Boyd 1980; Tanner 1981). Early practitioners of American anthropology, especially Franz Boas (1858–1942), are known as much for their studies of human growth as for work in cultural studies, archaeology, or linguistics. Boas was especially interested in the changes in body size and shape following **migration** from Europe to the United States.

At the time of those studies, around 1910, most anthropologists and anatomists believed that stature, and other measurable dimensions of the body such as head shape, could be used as "racial" markers. The word "race" is set in inverted commas here because it refers to the scientifically discredited notion that human beings can be organized into biologically distinct groups based on **phenotypes** (the physical appearance and behavior of a person). According to this fallacious idea, northern European "races" were tall and had relatively long and narrow heads, while southern and eastern European races were shorter and had relatively round skulls. Boas found that, generally, the children of Italian and eastern European Jewish **migrants** to the

United States were significantly taller and heavier than their parents. The children of the migrants even changed the shape of their heads; they grew up to have long narrow heads.

According to Boas, in the new environment of the United States, the children of recent southern European migrants grew up to look more like northern Europeans than their own parents. Boas used the changes in body size and shape to argue that environment and culture are more important than genes in determining the physical appearance of people. Boas used the concept of biological **plasticity**, the responsiveness of the body to environmental change, to account for the changes in size and shape. In Chapter 2 I return to the concept of plasticity in more detail.

In terms of environment, life in the United States afforded better nutrition, both in terms of the quantity and the variety of food. There were also greater opportunities for education and wage-paying labor. These nutritional and socioeconomic gains are now known to correlate with large body size. In terms of culture, especially child-rearing practices, there were other changes. In much of Europe infants were usually wrapped up tightly and placed on their backs to sleep, but the American practice at the turn of the century was to place infants in the prone position. To be "modern" the European immigrant parents often adopted the American practice. One effect on the infant was a change in skull shape, since pressure applied to the back of the infant's skull produces a rounder head, while pressure applied to the side of the skull produces a longer and narrower head. The sleeping position effect on skull shape was demonstrated first in Europe by Walcher (1905).

There has been lively debate about the work of Boas and his colleagues (Gravlee et al. 2003; Sparks & Jantz 2002), but all agree that an interest in human growth is natural for anthropologists. This is because the way in which a human being grows is the product of an interaction between the biology of our species, the physical environment in which we live, and the social-economic-political-emotional (SEPE) environment that every human culture creates. Moreover, the basic pattern of human growth is shared by all living people. That pattern is the outcome of the four-to-seven million-year evolutionary history of the **hominins**, living human beings and our bipedal fossil ancestors. Thus, human growth and development reflect the biocultural nature and evolutionary history of our species.

Maya in Disneyland

The biocultural nature of human growth may be appreciated by examples based on my own research in Guatemala, Mexico, and the United States on the impact of the SEPE environment on the growth and development of **Maya** children. Because this research will be used throughout this book, I provide some background to the Maya people here and then move on to describe the results of the research examples.

The living Maya are the biological and cultural descendants of people inhabiting a geographic region extending from the Yucatan Peninsula of southern Mexico, through Belize, Guatemala, El Salvador, and western Honduras (Figure I.1).

Figure I.1 Map of Maya Culture region.

By about the year AD 250 a Maya cultural identity was well established. Maya society was organized in several state-level groups, each ruled by a priest-king or queen and an elite class of political-religious leaders. Each Maya state group maintained a workforce of peasants that produced food and provided labor for construction, as well as classes of artisans, military specialists, and bureaucrats for government administration. After the year AD 900, many Maya state societies declined, likely due to internecine warfare and overexploitation of natural resources. European contact and conquest in the year AD 1500, found the Maya living in chiefdomship societies, still building monuments, and still fighting each other. Europeans dismantled these societies via a combination of diseases, military action, taxation, and enslavement. By the year AD 1600, Maya population numbers plummeted from about 2 million in 1500 to about 200,000 (Lovell & Lutz 1996). Maya became the underclass of the new Colonial societies of Yucatan and Central America.

The Maya population recovered in size during the following centuries and today there are an estimated 7–8 million Maya living in Mexico and the Central America region (Lovell 2010). This makes the Maya the largest Native American ethnic group. Common features of rural lifestyle, economic activities, kinship and marriage systems, religion, philosophy, and a brutal history of repression since the Conquest of the Americas binds all Maya together into a shared cultural identity. There are, however, 30 or more Maya languages, each associated with a specific Maya group (see Wikipedia, Mayan Languages).

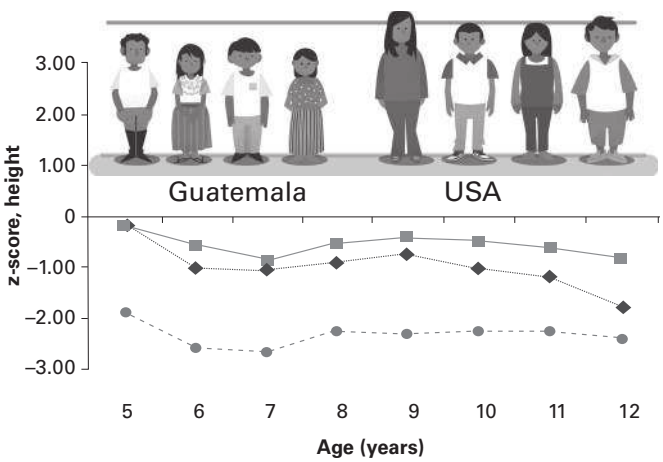

Figure I.2 Mean z-scores for height of Maya children from the GUATE-1998 (circles), USA-1992 (diamonds), and USA-2000 (squares) samples compared with the NHANES III reference means. From (Bogin et al. 2002). The illustrations are of 9-year-old Maya children (illustration copyright with Barry Bogin). The line indicates the average height of 9-year-olds according to the US growth references.

The following describes growth in height of three samples of Maya at the time of our fieldwork in 1992 and 2000 (Bogin & Loucky 1997; Bogin & Rios 2003; Bogin et al. 2002). One is a group living in their homeland of Guatemala, and the other two are migrants living in the United States. All three groups include girls and boys between the ages of 5 and 12 years old. Mean heights by age and sex are shown in Figure I.2. The heights are expressed as z-scores, that is, as a value indicating how many standard deviations a Maya mean height for a given age and sex differ from the mean of a reference for the same age and sex. The reference here is the Third United States National Health and Nutrition Examination Survey, 1988–1994 (NHANES III). This Survey included nationally representative samples of white (European-American), black (African-American), and Hispanic (mostly Mexican-American) people. The version of this reference published by Frisancho (2008) was used to calculate the z-scores.

The sample living in Guatemala are Maya schoolchildren (n = 1,347), measured in 1998 by an anthropometric team from Spain (Dr. Luis Rios of the National Museum of Natural History, Madrid kindly supplied these data). This sample is referred to as GUATE-1998. These children lived in the rural agricultural and fishing communities around Lake Atitlan in the western highlands of Guatemala. These Maya communities are of very low **socioeconomic status** (**SES**, see Box I.1 for definition of SES as used in this book) and many families lived below the poverty level. In these villages, basic human services, such as health care, safe drinking water, and supplementary food programs for women, infants, and children, were either very limited or totally absent. The incidence of infant and childhood morbidity and mortality from infectious disease and undernutrition was relatively high. Other deaths were due to military action and political repression, especially the civil war of 1960–1996. The

Box I.1 **Socioeconomic status**

Throughout this book there is discussion of the association between socioeconomic status (SES) with human growth, development, and **maturation**. In this book, and in the research literature, SES is often treated as a proxy for specific factors known to influence growth, such as nutrition, disease, and workloads. In this text box the concept of SES, as used in this book, is defined.

In its most widespread usage, SES is a concept devised by the social scientists, statisticians, and the governmental tax authorities[2] to measure some aspects of education, occupation, and social prestige of a person or a social group. One early usage was by the psychologist Raymond Cattel who claimed that the essence of socioeconomic status was the "prestige factor" (Cattell 1942). Prestige was derived from a person's occupation and was more important than income, property, or education, but prestige was highly correlated with these. Cattell (p. 300) wrote that, "Social status, in short, is a purely psychological entity. Such a statement must not be taken to mean that it is not real or that it cannot be measured or that it is not a precisely definable concept. It is to be defined and measured in terms of behavior, implying mental states behind behavior. The prestige of an occupation is resident in the minds of all people in the community and is to be measured by assessing their attitudes towards it at a given time." A key concept added by Cattell is that prestige, and its socioeconomic status, is measured by the people of a community – it is a community effect. The influence of community effects on biological growth is a theme of this book and is discussed in detail in Chapter 7.

In practice today, SES is measured in the wealthier industrialized nations by the years of formal education (schooling) and the occupation of an adult. In the United Kingdom the official classification is based on occupation only. In the lower-income nations, SES must often be measured by other criteria because formal education is unavailable to so many people and occupations are traditional sorts of farming or herding. In these traditional communities,

[2] Governments use socioeconomic status to target taxes, e.g., taxes on tobacco products and sugary drinks. In the United States, Mexico, and some other nations, people of lower SES tend to use more of these products. To discourage overuse, governments tax these products. There is another purpose of the taxes on these products – to increase revenue to the government. People of lower SES often earn less money and pay less income tax. Lower SES people purchase fewer expensive items such as houses, boats, and other luxury goods that are taxed at relatively high levels. As lower SES people make up the predominate share of the population (e.g., ~30% of the population in the USA is in poverty or near-poverty and 44% of the population in Mexico live below the poverty line) taxing the products that these low-income people use is one effective means to increase revenue. References: USA, Haymes et al. (2015); Mexico, www.telesurenglish.net/news/In-Mexico-7-out-of-10-Born-in-Poverty-Will-Die-in-Poverty-20180509-0008.html.

the size of land holdings or number of animals owned may be useful indicators of SES. Among the urban poor of the lower-income nations, the quality of the home, as indicated by the number of persons per room, the presence of running water and toilet facilities within the home, the ownership of various electrical appliances, and the type of cooking fuel used, are sometimes used as markers of SES. The SES of infants, children, juveniles, and most adolescents is ascribed to them based on the SES of their parents. Some societies have very rigid boundaries between people of different economic, educational, and occupational statuses. In these societies the boundaries establish well-defined social classes and a person's SES is, in many ways, constrained by that person's social class. Other societies allow varying degrees of mobility between social classes, and often that mobility is linked to the quantity and quality of formal education.

Examples of this relationship between education and social class exist today in the United States, the United Kingdom, Japan, and other WEIRD (Wealthy, Educated, Industrialized, Rich, Democratic) nations (Henrich et al. 2010). Graduates of certain prestigious universities are selectively employed by the largest corporations, by governments, and associate with the wealthiest individuals of their society. Many of the elite university graduates themselves come from well-to-do families, and therefore retain the social class of their parents. This has been well documented in the United Kingdom (Clark & Cummins 2014, discussed further in Chapter 7). Fewer students of elite universities were raised in middle SES or lower SES families, but some of these fortunate few may eventually supersede the social class of their parents. A popular cultural myth of the WEIRD nations is that they are relatively open societies, with equality of opportunity for upward and downward social mobility. But, empirical research shows this is not true and over the past 100 years there has been less social mobility of the lower SES groups toward the wealthiest, higher social status groups. This trend toward greater SES inequality intensified with the 2007–2008 global economic crisis[3] and is reported for most of the nations of the world (Marmot & Bell 2012; Sen 1999; Wilkinson & Pickett 2009b).

In all societies, whether totally rigid or relatively more open to social movement, social class and SES are powerful influences on human physical and psychological growth and development (Batty et al. 2009; Bogin et al. 2017; Mansukoski et al. 2019b; Steckel 2012; Wilkinson & Pickett 2009a). Conversely, stature, **body composition** (fatness and muscularity), and rate of maturation influence the social, emotional, and economic status of children, youth, and adults. An appreciation of these **synergistic** and seamless biosocial interactions between growth and socioeconomic status has been realized only

[3] www.oecd.org/social/inequality.htm

in the past 200 years and are still being researched today. Some of the history of findings, their conventional explanations, and novel mechanisms for SES biosocial interactions are explored in the chapters of this book.

residents of the Lake Atitlan region were caught up in the military hostilities of that time and suffered some of the worst atrocities of the civil war.[4] They also suffered from reduced food availability due to the collapse of the Guatemalan economy during the 1980s and a cholera epidemic of the early 1990s (Bogin & Keep 1999).

The Maya children in the United States are the offspring of Maya adults who emigrated from Guatemala, mostly from the late 1970s to the early 1990s. All the adult Maya refugees were born in Guatemala and prior to migration most lived in rural villages in the Q'anjob'al-speaking language area (northwest Guatemala highlands). My colleagues and I analyzed data for the height of children measured in 1992, called the USA-1992 sample (n = 211). About 50% of the children in the 1992 sample were born in the United States and the remainder were born in Guatemala or Mexico. All had lived for at least two years in the US and there was no significant difference in height between those born in the different countries. We also measured the heights of Maya children in the United States in 1999 and 2000 – the USA-2000 sample consisting of 431 Maya American children, 93% were born in the United States. There were approximately equal numbers of girls and boys in all samples and no statistically significant differences in height, so sexes were combined for analysis.

The Maya families in the United States lived in two communities, one in rural Florida and the other in Los Angeles, California – not so far from the theme parks that name this section "Maya in Disneyland." There were no differences in height between the two communities. In both locales, adult Maya worked as day laborers in low paying jobs. Some Maya worked as teacher aids, nursing aids, or had small businesses such as grocery stores. All the Maya-USA children in the sample qualified for free breakfast and lunch programs at the schools they attended. The Maya-USA samples, although of low SES for the USA, lived under much more favorable conditions for growth and development than did the Maya sample in Guatemala. The Maya-USA children benefited from safe drinking water, medical screening at the schools, medical care in their communities, and supplementary feeding programs. The parents of the Maya-USA children capitalized on the economic prosperity in the United States of the 1990s via relatively steady employment and freedom from state-sponsored violence.

[4] See Cultural Survival Quarterly Magazine, 1991, Massacre In Santiago Atitlan, www.culturalsurvival.org/publications/cultural-survival-quarterly/massacre-santiago-atitlan-turning-point-maya-struggle.

The growth in height (as well as weight, fatness, and muscularity which are not shown here) of Maya children living in Guatemala was significantly retarded compared with the NHANES reference data (Figure I.2).

At all ages the mean z-score for height is near or below −2.0. When average heights of a group of children are less than −2.0 z-scores, that group is considered stunted, that is, within the shortest 2.3% of a growth reference or growth standard.[5] In the 1980s and early 1990s, some researchers argued that the small size of impoverished, and likely malnourished, communities such as the Guatemala Maya is a genetic adaptation to their poor environmental conditions. Being small protected them against the need for even more food to support larger bodies. If this argument were true, then a change in the economic, social, or political environment would not influence growth. The notion that the small size of the Maya is primarily genetic is clearly wrong, for as also shown in Figure I.2, the USA-resident Maya averaged about −1.0 z-scores. While still short in comparison with the US reference, these Maya were significantly taller than Maya children living in Guatemala. We also reported that Maya children in the United States attained virtually the same weight as the US reference due to increased fatness and muscularity.

Our analysis indicated that the USA-1992 sample was, on average, 8.9 cm taller than the GUATE-1998 sample. For the USA-2000 sample, the height difference increased to an average of 11.5 cm. These increases occurred within single generations, that is, as the parents of the children moved from Guatemala to the United States. These are the largest such increases in mean height between migrant children and **sedentes** (those remaining in their homeland) ever reported in the literature. To place this in context, the immigrant children measured by Boas averaged about 2.0 cm taller than their sedente counterparts back in Europe.

Even more impressive is that of the total height increase for the USA-2000 children, 4.7 cm was due to greater sitting height (length of the trunk, neck, and head of the body) and 6.8 cm was due to greater leg length. The growth of the legs of infants and children seem to be more sensitive to the environment than growth of the upper body – a topic that is explored in more detail in Chapter 5. That the Maya children in the United States changed in shape, as well as growing taller, is more evidence of Boasian biological plasticity.

The reasons for the increase in body size of the Maya children are similar to those for the European immigrant children measured by Boas. In the United States there is greater food security, which means not only more food and a greater variety of food than in rural Guatemala, but more importantly the reliable access to a sufficient quantity of affordable food. The public supply of safe drinking water in the United States eliminates the constant exposure to bacteria, parasites, agricultural pesticides, and fertilizers that contaminate drinking water in rural Guatemala. The Maya-USA children benefit from social services that are unavailable in rural Guatemala, including food supplementation programs such as free school breakfast and lunch for low

[5] See www.who.int/childgrowth/en/ for World Health Organization growth standards.

income students and free or subsidized health care. These services improve the biological, social, and emotional environment for human growth. The emotional/psychological environment, discussed in later chapters, is as powerful an influence on physical growth as any nutrient or illness. Part of the emotional/psychological difference in the United States is the absence of overt political repression and the threat of military violence. To be sure, most of the Maya families in the United States were low income and many parents were undocumented and without legal status or citizenship. These impose economic and emotional stress on all members of the family, as parents could be seized and deported (children of immigrants born in the United States are given citizenship). Many families in Los Angeles lived in high-crime neighborhoods. Even so, the relative security and political freedom for Maya in the United States allowed parents to pursue their goals for the healthy growth and development of their children.

Parents around the world share highly similar goals for their offspring. Robert LeVine (1988), an anthropologist of the family and of children, proposed a universal evolutionary hierarchy of human parental goals. The primary goal is to encourage the survival and the health of a child. Secondary goals relate to developing the child into a self-supporting adult and instilling cultural beliefs and behavioral norms. Economic and political conditions in Guatemala make it difficult for parents to achieve these goals for their children. The political economy of the United States offers real possibilities for success, and Maya parents seize upon these, just as other immigrants have done before them.

As Boas argued for nearly 50 years, the study of human growth provides a mirror of the human condition. Reflected in the patterns of growth of human populations are the "material and moral conditions of that society" (Tanner 1987). The forces holding back growth in Guatemala are severe indeed, and the growth differences between Maya of Guatemala and the United States may be used as a measure to assess the magnitude of change in SEPE conditions.

Growth and Evolution

The pattern of human growth serves as another type of mirror; one that reflects the biocultural evolution of our species. **Biological evolution** is the continuous process of genetic adaptation of organisms to their environments. **Natural selection** determines the direction of evolutionary change and operates by **differential mortality** between individual organisms prior to reproductive maturation and by **differential fertility** of mature organisms. Thus, genetic adaptations that enhance the survival of individuals to reproductive age, and that increase the production of similarly successful offspring, will increase in frequency in the population over time.

Human ideology and purpose also evolved and interacted with genetic adaptations. The combined biocultural evolution produced the pattern **of growth and development** that converts a single fertilized cell, with its full complement of **deoxyribonucleic acid (DNA)** and cytoplasm, into a multicellular human organism composed of hundreds of different tissues, organs, behavioral capabilities, and