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# Biological Anthropology of Latin America Historical Development and Recent Advances

*Edited by*  
*Douglas H. Ubelaker and Sonia E. Colantonio*

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WASHINGTON, D.C.

2019

## ABSTRACT

Ubelaker, Douglas H., and Sonia E. Colantonio, editors. *Biological Anthropology of Latin America: Historical Development and Recent Advances*. *Smithsonian Contributions to Anthropology*, number 51, xiv + 385 pages, 24 figures, 67 tables, 2019. — Despite significant positive developments within topics of biological anthropology, archaeology, and related academic areas in Latin America, we noted a lack of coordination and communication among them. Available publications provide syntheses within different areas of biological anthropology, yet few have attempted integration of the distinct subfields. We decided to address the development and current issues of most major areas of Latin American biological anthropology in a single volume with chapters by distinguished, experienced scholars who live and work in Latin America, are knowledgeable about the topics, have published extensively on them, and who were recommended by specialists within six geographical regions of interest: Brazil and northeastern South America, Mexico, Central America, the Caribbean, northwestern South America, and southern South America. Six subdisciplines within biological anthropology were defined for academic coverage: (1) biodemography and epidemiology; (2) bioarchaeology and skeletal biology; (3) paleopathology; (4) forensic anthropology; (5) population genetics; and (6) growth, development, health, and nutrition. Though these six subdisciplines overlap to an extent, each offers a distinct history of development and presents unique issues to address. Chapters generally cover topics of history, the state of knowledge, methodological perspective, and areas in need of additional research. Although the text is in English, abstracts in English, Spanish, and Portuguese are included.

Cover image: Houses in the Caxiunã National Forest. Courtesy Hilton Silva.

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Published by SMITHSONIAN INSTITUTION SCHOLARLY PRESS  
P.O. Box 37012, MRC 957, Washington, D.C. 20013-7012  
<https://scholarlypress.si.edu>

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### Library of Congress Cataloging-in-Publication Data

Names: Ubelaker, Douglas H., editor. | Colantonio, Sonia, editor. | Smithsonian Institution Scholarly Press, publisher.

Title: *Biological anthropology of Latin America : historical development and recent advances* / edited by Douglas H.

Ubelaker and Sonia E. Colantonio.

Other titles: *Smithsonian contributions to anthropology* ; no. 51. 0081-0223

Description: Washington, D.C. : Smithsonian Institution Scholarly Press, 2018. | Series: *Smithsonian contributions to anthropology*, ISSN 0081-0223 ; number 51 | Includes bibliographical references and index. | Compilation copyright 2018 Smithsonian Institution

Identifiers: LCCN 2018003446

Subjects: LCSH: Physical anthropology—Latin America. | Epidemiology—Latin America. | Human remains (Archaeology)—Latin America. | Paleopathology—Latin America. | Forensic anthropology—Latin America. | Population genetics—Latin America. | Nutritional anthropology—Latin America.

Classification: LCC GN50.45.L29 B56 2018 | DDC 599.9098—dc23 | SUDOC SI 1.33:51

LC record available at <https://lcn.loc.gov/2018003446>

ISSNs: 1943-6661 (online); 0081-0223 (print)

Publication date (online): 13 December 2019

© The paper used in this publication meets the minimum requirements of the American National Standard for Permanence of Paper for Printed Library Materials Z39.48-1992.

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# Preface

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The project reflected in this volume began in late 2013 in Argentina. Following a professional meeting in Buenos Aires, the editors spent several delightful days in the Colantonio country home near Cordoba, Argentina. Conversation touched on many topics of biological anthropology, archaeology, and related areas of academia. Our discussions noted many significant positive developments within these academic areas but also noted a lack of coordination and communication among them, especially in Latin America. Publications that were available provided syntheses within different areas of biological anthropology, however few attempted integration of the distinct subfields. Through this discussion an idea emerged to organize a project to address the development and current issues within most major areas of biological anthropology in Latin America. The ultimate goal was to be a single published volume that would provide the intended coverage with chapters largely written by distinguished, experienced colleagues within Latin America.

To coalesce the content into a single volume, it became clear that space would not permit chapters dedicated to individual countries. Thus, geographical coverage was organized into six Latin America regions: Brazil and northeastern South America, Mexico, Central America, the Caribbean, northwestern South America, and southern South America. For the purposes of this volume, these regions include the countries listed:

Region	Countries
Brazil and northeastern South America	Brazil, French Guiana, Guyana, Suriname
Mexico	Mexico
Central America	Belize, Costa Rica, El Salvador Guatemala, Honduras, Nicaragua, Panama
Caribbean	Anguilla, Antigua and Barbuda, Aruba, The Bahamas, Barbados, British Virgin Islands, Cayman Islands, Cuba, Curacao, Dominica, Dominican Republic, Grenada, Guadalupe, Haiti, Jamaica, Martinique, Montserrat, Puerto Rico, Saint Barthélemy, Saint Kitts and Nevis, Saint Lucia, Collectivity of Saint Martin,

	Saint Vincent and the Grenadines, Sint Maarten, Trinidad and Tobago, Turks and Caicos Islands, U.S. Virgin Islands
Northwestern South America	Colombia, Ecuador, Peru, Venezuela
Southern South America	Argentina, Bolivia, Chile, Paraguay, Uruguay

Six academic subdisciplines within biological anthropology were defined. These are: (1) biodemography and epidemiology; (2) bioarchaeology and skeletal biology; (3) paleopathology; (4) forensic anthropology; (5) population genetics; and (6) growth, development, health, and nutrition. While these six subdisciplines overlap to some extent, each offers a distinct history of development and currently presents unique issues to address.

In collaboration with colleagues and other regional experts, the editors selected these authors based on their scholarship and experience within each defined region.

The responses of Latin American colleagues to this proposed project have been uniformly positive, and the editors thank all their colleagues who were approached about participating in this volume. Ultimately, selection of authors was limited by constraints of time, publishing format, and the desire to produce a publication in English. The editors gratefully acknowledge the sacrifices made by each author to prioritize their contributions to this volume.

Authors were asked generally to cover topics of history, state of knowledge, methodological perspective, and areas in need of additional research in chapters limited to approximately 7,000 words. Although the text had to be in English, abstracts were requested in English, Spanish, and Portuguese. Chapters generally follow a uniform format and organization, although authors vary widely in their scholarly approach to their subjects and considerable leeway was given to them to choose the scope of the intellectual content and the weight given to each topic. While this presents some variation within the volume, it reflects the preferences of the authors and their unique understanding of their specialties.

This project has been challenging for all involved in many different ways; however, the most challenging paths usually lead to the most fruitful rewards. The editors hope that this volume showcases in an integrated way the amazing work and progress conducted in Latin American biological anthropology.



# History of Human Population Genetics and Genomics in Brazil

*Francisco M. Salzano*<sup>†</sup>

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**ABSTRACT.** A brief survey of human population genetics and genomics at the worldwide level is followed by a review covering about one century of these studies in Brazil. Most recent research is then considered, including (a) investigations into the remote past of hominins; (b) Brazilian history and ethnicity; and (c) Amerindian genetics and genomics and evolution. These areas of research in Brazil closely follow the main global trends, and investigations are being developed in several centers throughout the country. In keeping with the tradition of excellence established by Brazilian geneticists, recent studies of human genetics are providing important contributions to international (and certainly Latin American) knowledge in this field.

**RESUMEN.** Una breve revisión de la genética y genómica de poblaciones humanas a nivel mundial es seguida por una revisión que abarca alrededor de un siglo de estos estudios en Brasil. Fueron así consideradas las más recientes investigaciones, las cuales involucran (a) investigaciones sobre el remoto pasado hominino; (b) historia y etnicidad en Brasil; y (c) genética y genómica amerindia y evolución. Estas áreas de estudios en Brasil están siguiendo estrechamente las principales tendencias mundiales, y las investigaciones se están llevando a cabo en toda la extensión del país. En concordancia con la tradición de investigación de excelencia desarrollada en general por los genetistas de Brasil, los estudios en humanos están aportando importantes contribuciones al conocimiento mundial (y por supuesto latinoamericano).

**RESUMO.** Uma breve avaliação da genética e genômica de populações humanas em nível internacional foi seguida por uma revisão cobrindo cerca de um século desses estudos no Brasil. Posteriormente foram consideradas as investigações mais recentes, que incluíram (a) estudos sobre o passado hominíneo remoto; (b) história e etnicidade no Brasil; e (c) genética e genômica de Ameríndios e evolução. Essas áreas de estudos, no Brasil, estão acompanhando as principais tendências mundiais, e as investigações estão sendo desenvolvidas em diversos centros localizados no país. De acordo com a tradição de pesquisa de ponta desenvolvida por geneticistas brasileiros, os estudos em humanos estão fornecendo contribuições importantes ao conhecimento internacional (e certamente latino-americano).

---

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

## INTRODUCTION

The field of human population genetics (genomics) in Brazil traditionally followed global research trends. Table 1 provides a highly simplified timeline of significant events, from the establishment of the Hardy-Weinberg principle in 1908 up to the present era of genomic studies. Statistical–demographic analyses of genetic traits affected by population behavior (population subdivision, inbreeding, adaptive and random processes,

**TABLE 1.** Timeline of important international developments in human population genetics and genomics.

Year	Development
1908	Prediction of population behavior based on Mendelian traits (The Hardy-Weinberg principle).
1919	Racial (ethnic) variation in blood groups.
1928–1948	Statistical and demographic analyses of the population behavior of genetic traits (population subdivision, inbreeding, natural selection, random-drift, selection intensity, genetic relationship, and covariance).
1930–1950	Formulation of the synthetic theory of evolution.
1953	Discovery and description of the double-helical structure of DNA.
1954	Recognition of relationship between the sickle-cell gene and <i>malaria</i> .
1955	Development of the starch gel electrophoresis technique.
1956	Quantification of the genetic load.
1957	Enzyme identification after starch gel electrophoresis.
1966	Genetic code deciphered.
1977	Publication of DNA sequencing methods.
1978	Description of first human restriction fragment length polymorphisms (RFLP).
1984	Development of minisatellites methods.
1985	Description of the polymerase chain reaction (PCR) method.
1989	Implementation of sequencing capillary electrophoresis.
1990	Description of first human microsatellites.
2002	Release of Human Genome Diversity Project (HGDP) Cell Line Panel.
2005	Publication of first-generation of human Haplotype Map (HapMap).
2005	First development of next-generation sequencing methods.
2007	Release of second-generation HapMap.
2015	Publication of 1000 Genomes Project study; mapping of structural variation in an extensive series of human genomes.
2016	Release of extensive population and clinical data by the Simons Genome Diversity Project and the DiscoverEHR study.

Sources: Salzano (1977); Jobling et al. (2014); Structural Variation Analysis Group (2015); The 1000 Genomes Project Consortium (2015); DiscoverEHR Study (2016); Simons Genome Diversity Project (2016).

and intra- and interpopulation variability patterns) were initiated as early as 1928. But their correlation with genetic (and more recently, genomic) data could not be determined before the development of equipment and technology that could adequately assess this kind of material.

Population variability can be broadly divided into two categories: rare or frequent traits. Rare traits are generally influenced by negative selection (the process that keeps non-adaptive traits at a very low population frequency). Frequent traits, however, are especially important in evolutionary terms because they reflect positive selective agents, and those that are nearly neutral can furnish unique and valuable information about population history.

Three historical transitions can be seen in the study of frequent (polymorphic) variants: (a) starting in 1919, antigenic differences in blood groups were the preferred way to interpret human population variability; (b) with development of starch gel electrophoresis in 1955 and the enzyme identification procedure applied to bands separated this way in 1957, new perspectives were gained through study of protein variation in populations; and (c) starting in the 1970s, investigations at the DNA level took advantage of techniques that made it possible to study DNA sequences (1977), restriction fragment length polymorphisms (1978), minisatellites (1984), microsatellites (1990), and whole genomes (around 2001). The polymerase chain reaction method, first described in 1985, was especially important for testing in laboratories with limited funding.

Advancements in technology and automation have brought about the era of “next generation sequencing methods,” with fantastic developments in their efficiency and coverage. These innovations have caused the costs of sequencing DNA to drop dramatically in the past decade. Characteristics of some of the techniques currently available at the time were reported by MacArthur and Lek (2012), but developments are happening so rapidly that only the companies themselves can furnish up-to-date information. As a result of these developments, several databases now provide free access to extremely valuable information obtained through the Human Genome Diversity Project, HapMap, and 1000 Genomes Project initiatives (Table 1).

## DEVELOPMENTS IN BRAZIL

The evolution of human population genetics and genomics in Brazil derives from and was most influenced by the history of general genetics in this country. It is generally acknowledged that everything started due to the marked influence of the so-called “holy trinity,” Carlos A. Krug (1906–1973), Friedrich G. Brieger (1900–1985), and André Dreyfus (1898–1952). The first two were applied plant geneticists, but Dreyfus was a physician with a strong interest in academic science. He was responsible for inviting Theodosius Dobzhansky (1900–1975) to work in a joint collaborative research project with Brazilian specialists that lasted for almost three decades. Centered at the University of São Paulo, this collaboration led to the formation of a key set of distinguished scholars who decisively influenced the course of genetics in Brazil.

Important research in human population genetics and genomics progressed throughout the twentieth century (Table 2).

TABLE 2. Selected list of the main studies of human population genetics performed in Brazil during the twentieth century.

Approximate year of start	Studies	Primary researchers
1939–1952	Blood group and sickle-cell gene frequencies in Amerindian and neo-Brazilian populations <sup>a</sup>	C. S. Lacaz, F. Ottensooser, E. M. da Silva, P. C. Junqueira
1952	Genetic implications of demographic data	N. Freire-Maia, O. Frota-Pessoa, A. Freire-Maia
1956–1961	Genetic markers, population structure, ethnic admixture	P. H. Saldanha, L. Montenegro, F. M. Salzano, S. M. Callegari-Jacques, H. Krieger, P. H. Cabello, N. E. Morton, M. Ayres
1962	Morphology, genetic markers in neo-Brazilian populations	B. Beiguelman, E. S. Azevêdo
1964	Microevolution in Brazilian Amerindians	J. V. Neel
1969	HLA, immunologic traits in Amerindians	F. L. Black
1969–1973	Blood groups and other genetic markers in neo-Brazilian populations	M. Palatnik, M. A. Mestriner, A. L. Simões
1983	Genetic markers in Amerindian and neo-Brazilian populations	E. A. Chautard-Freire-Maia, J. F. Guerreiro, S. E. B. Santos, M. A. Zago, M. L. Petzl-Erler, S. D. J. Pena, A. K. C. Ribeiro-dos-Santos, M. H. L. P. Franco, T. A. Weimer
1992–1999	Population genetics at the molecular level, ethnic admixture	M. C. Bortolini, F. R. Santos, R. V. Santos, S. F. Oliveira

<sup>a</sup> Neo-Brazilians refer to modern Brazilian populations, derived from the intercrossing of Europeans, Africans, and Amerindians.

The beginning was marked by population surveys investigating blood groups and the genetic variation associated with sickle cell anemia and other coagulation pathologies conducted by C. S. Lacaz, F. Ottensooser, E. M. da Silva, and P. C. Junqueira. Their academic backgrounds were not in genetics, but they began obtaining valuable genetic information from Brazilian populations. Starting in the 1950s, the genetic implications of demographic data were studied in depth by N. Freire-Maia, O. Frota-Pessoa, and A. Freire-Maia. The Freire-Maia brothers focused their investigations on the prevalence and consequences of inbreeding, while Frota-Pessoa was more concerned with Gunnar Dahlberg's (1893–1956) concept of isolated populations (Dahlberg, 1948) and other aspects of human mating.

My own interest in the field of genetics began after I obtained my doctoral degree, for which I investigated *Drosophila* results (a reflection of Dobzhansky's influence). In the 1950s, research in human genetics was gaining interest despite challenges posed by lengthy human generation timespans and the impossibility of influencing direct mating, which previously discouraged most scientific efforts. My advisor, Antonio R. Cordeiro, and I contacted James V. Neel at the University of Michigan Medical School, and he agreed to receive me as a postdoctoral fellow in his department in 1956. This was the beginning of a fruitful collaboration between Brazilians and U.S. colleagues that lasted for more than three decades.

Other key Brazilian researchers in this field between the 1950s and 1990s are identified in Table 2. Active research was under way and continues to the present in São Paulo, Ribeirão

Preto, Campinas, Rio de Janeiro, Curitiba, Belo Horizonte, Brasília, Bahia, and Belém.

## RECENT RESEARCH

### INVESTIGATING THE REMOTE PAST

The availability of databases with complete genomes of both extinct and extant humans and nonhumans provides a unique opportunity to explore our evolutionary past. Paixão-Côrtes et al. (2012), using this information, compared in detail the genomes of the chimpanzee (*Pan troglodytes*), extant *Homo sapiens*, archaic *Homo neanderthalensis*, and Denisovans. The focus was on nonsynonymous mutations, since they may have a direct effect on the adaptation of individuals. A total of 10,447 nonsynonymous substitutions were found in which the derived allele is fixed or nearly fixed in humans as compared to chimpanzees. Overall, the radical amino acid changes were present in all three hominin genomes. Eight new alleles were identified in the Neanderthal and Denisovan gene pools, while four others, possibly affecting cognition, occurred in both the *sapiens* and the two other archaic genomes.

To further investigate possible differences in cognition between these taxa, 93 nonsynonymous substitutions in 51 cognitive genes—in which the derived allele was present in the hominins and the ancestral allele in nonhuman primates—were considered (Paixão-Côrtes et al., 2013). The three taxa proved to be virtually

equal in relation to these molecular changes. Therefore, the selective sweep that gave rise to *Homo sapiens* could have been initiated before the divergence of modern and archaic humans.

The concentration of pigmentation due to levels of melanin in humans is one of the most widely used characteristics in descriptions of population variability. Several methods have been used to adequately describe and quantify it; molecular approaches are now being considered, and Cerqueira et al. (2011) reviewed them focusing both on applied (forensic) and academic (evolutionary) aspects. Comparisons between predicted and documented phenotypes yielded different results depending on the feature considered (skin, hair, eyes) and the methods employed. Of course, the prediction of the phenotypes of archaic, prehistoric individuals cannot be validated because they are extinct. However, Lalueza-Fox et al. (2007) found a melanocortin 1 receptor (*MC1R*) gene variant in two Neanderthals from Italy and Spain, and on this basis suggested that they would have pale skin and possibly red hair, as observed in modern humans. Cerqueira et al. (2012) compared predicted and observed phenotypic data through an analysis of 124 single nucleotide polymorphisms (SNPs) in 33 genic and seven intergenic regions of 30 subjects, five of them prehistoric, whose complete genomes were available in databases. The percentage of agreement varied somewhat depending on the characteristic considered. It was as high as 91% in relation to freckles, but overall it was calculated as 59%–63%. In relation specifically to archaic subjects, they could not find the variant described by Lalueza-Fox et al. (2007) in the specimens considered (three Neanderthals, one Denisovan, and one Paleo-Eskimo) but found that four of them (no data for the Paleo-Eskimo) should have had darker skin and red or brown hair.

#### HISTORY AND ETHNICITY

Genetic and genomic approaches have been largely employed in the assessment of ethnic formation processes in populations of different origins. Latin America in general, and Brazil especially, provide ideal material for such studies, due to the distinct factors that influenced the Amerindian, European, and African components in the gene pools of different populations. My research group has been interested in these processes for many decades (for early information see Callegari-Jacques et al., 2003), and I provide information here on our most recent research.

Along with colleagues from four other Latin American countries, my research group is currently engaged in an ambitious project to investigate complex interactions between sociocultural, phenotypic, and genetic factors responsible for the perceived enormous human variability present in our continent. This project is called Consortium for the Analysis of the Diversity and Evolution of Latin America (CANDELA).

Initial results from the CANDELA project were recently published in a paper that compared geographic structure, phenotypic diversity, and self-perception of ancestry based on a sample of 7,342 individuals living in five countries (Brazil, Chile, Colombia, Mexico, and Peru; Ruiz-Linares et al., 2014). The main

**TABLE 3.** Results of two studies comparing estimates of ethnic (continental) ancestries in populations of five Latin American countries; AIMs = ancestry informative markers; STRs = short tandem repeats.

Collecting location and characteristics considered	Ruiz-Linares et al. (2014) <sup>a</sup>	Salzano and Sans (2014) <sup>b</sup>
Mexico (Mexico City)		
Sample size	1,622	1,310
Type and number of markers	30 AIMs	446 AIMs
% Ancestry: European	38	32
Amerindian	57	64
African	5	4
Colombia (Medellin)		
Sample size	1,659	849
Type and number of markers	30 AIMs	75 AIMs
% Ancestry: European	60	60
Amerindian	29	28
African	11	12
Peru (Lima)		
Sample size	906	43
Type and number of markers	30 AIMs	40 AIMs
% Ancestry: European	32	14
Amerindian	68	84
African	0	2
Brazil (Porto Alegre)		
Sample size	1,594	104
Type and number of markers	30 AIMs	9 STRs
% Ancestry: European	82	86
Amerindian	9	11
African	9	13
Chile (Arica) <sup>c</sup>		
Sample size	1,561	20
Type and number of markers	30 AIMs	678 STRs
% Ancestry: European	48	45
Amerindian	47	53
African	5	2

<sup>a</sup> Frequencies slightly adjusted to achieve 100%.

<sup>b</sup> Values singled out from a meta-analysis.

<sup>c</sup> No specific independent samples were available for the comparison of the numbers obtained in Study 1; the values in Study 2 are an average between those obtained in Paposo and Quetalmahue.

ethnic (continental) ancestries estimated for populations of these five countries are compared (Table 3) with information given in a meta-analysis recently performed by Salzano and Sans (2014). The CANDELA study used 30 highly informative ancestry informative markers (AIMs) for estimating African, Amerindian, and European ancestry selected from an initial list of 5,000

variants and compared them with data derived from 876 individuals sampled in the putative parental (original) populations.

The five countries can be divided into three groups according to historical ancestry: (a) Mexico and Peru have a predominantly Amerindian component (57% and 68%, respectively); (b) Colombia and Brazil have mainly European influence (60%, 82%); and (c) in Chile the Amerindian and European components are about equal (47%, 48%). The African component is 11% in Colombia and lower (single digits) or negligible in the other four countries. Comparisons with similar analyses made independently (reviewed in Salzano and Sans, 2014) show generally similar results except in Peru, in which Sandoval et al. (2013) estimated a higher Amerindian component (84%).

It should be emphasized, however, that significant heterogeneity can be found in different regions of these countries. In Brazil, for example, more European influence is observed in the southeast and south (as high as 89%), while the African component predominates in the northeast (maximum estimated to be 30%) and the Amerindian in the north (as much as 19%). The center–west estimates correlate most closely with the northern values (Salzano and Sans, 2014).

Ruiz-Linares et al. (2014) also considered the relationship between self-perception of ancestry (as assessed by four categories: “Black,” “White,” “Native,” and “Mixed”) and the genetic estimates. Coefficients of correlation were highly significant but showed differences in relation to the ancestry categories. People self-identified as European (White) tended to underestimate their genetic European component, and those self-identified as African (Black) tended to overestimate their African component. People with increasing levels of Amerindian (Native) ancestry first underestimated and then overestimated their Amerindian genetic component.

Other relatively recent ancestry studies were conducted by professor Maria Cátira Bortolini, head of the Human and Molecular Evolution Laboratory of the Universidade Federal do Rio Grande do Sul, located in Porto Alegre: (a) the use of mitochondrial DNA (mtDNA) and Y-chromosome markers to estimate the origins of people with African descent from Rio de Janeiro and Porto Alegre (Hünemeier et al., 2007); (b) characterization of the *Gaucho*, a distinct population of the Pampas region of Rio Grande do Sul, in southern Brazil (Marrero et al., 2007); and (c) the search for genetic signatures in individuals with African and European ancestries from Porto Alegre (Guerreiro-Junior et al., 2009).

Sérgio D. J. Pena and his colleagues have also been investigating the ethnic composition of the Brazilian people for many years. Three recent studies from his laboratory can be summarized as follows: (a) an interdisciplinary approach to the same relationship discussed above (genetic and race or color perception) in school children (aged 15–19 years) from Metropolitan Rio de Janeiro (Santos et al., 2009); (b) the association of SNPs related to human pigmentation to predict color in Brazilians; and (c) with the use of 40 AIMS, the analysis of 934 self-categorized “White,” “Brown,” and “Black” subjects from four of the most populous Brazilian regions.

In Pena’s second study, fifteen SNPs were analyzed in 243 persons from Rio de Janeiro self-identified as “White,” “Brown,” or “Black” and in 212 persons from São Paulo self-identified as “White” or “Black.” Neither genotypes of these SNPs nor their combination with biogeographical ancestry could predict self-assessed color at an individual level, as tested by principal component analysis. However, significant correlations emerged at group level (Durso et al., 2014). In the third study, ancestry proportions were estimated independently of skin color and multiplied to the proportions of a given ancestry in a given color category established by the official census information on color. The result was a higher than expected level of homogeneity, the European component ranging from 61% in the northeast to 78% in the south (Pena et al., 2011).

A different group of investigators, headed by Sidney E. B. dos Santos and Ândrea K. C. Ribeiro-dos-Santos, focused primarily in the Amazonian region. They first devised a kit of 48 AIMS, different from that used by Pena et al. (2011), cited above (Santos et al., 2010); they then applied this kit to estimate the ethnic components of seven Amazonian populations. The Y-chromosome markers were also tested in basically the same individuals (Palha et al., 2011). The male ancestry markers showed much less variable and different admixture proportions compared with previous estimates based on mtDNA. Another X-linked, insertion–deletion multiplex kit was also developed by Ribeiro-Rodrigues et al. (2009) and tested on Africans, Europeans, Amerindians, and persons identified as admixed from Belém, the capital of the Brazilian state of Pará in northern Brazil.

Another team of researchers, headed by Silviene F. Oliveira, has investigated several Afro-Brazilian, semi-isolated rural communities (quilombos). One of their recent studies was described in Amorim et al. (2011).

Aguinaldo L. Simões, Celso T. Mendes Junior, and Eduardo A. Donadi also have been interested in the genetic and genomic diversity of the populations in Brazil for many years. These researchers are based in Ribeirão Preto, São Paulo, and most recently investigated the Human leucocyte antigen-G (HLA-G), a major histocompatibility non-classical class I system. Comparison of individuals of the northeast in relation to the southeast for its 3’ untranslated region (one insertion/deletion, seven polymorphic sites) showed, with one exception (the +3003 locus), similar distributions in both populations but distinct haplotype diversity (Lucena-Silva et al., 2012).

#### AMERINDIAN GENETICS (GENOMICS) AND EVOLUTION

I have been working on this subject for half a century now. Selected aspects of some of the main, most recent studies will be reviewed below.

The initial focus must be that of Amerindian origins. The prehistoric peopling of the Americas has been the subject of extensive genetic and genomic, archeological, and linguistic research, but despite more than one century of consideration,

central questions remain unanswered. The genetic and non-genetic evidence was reviewed by Salzano (2007, 2011). Our group participated in an international consortium which studied 52 Amerindian and 17 Siberian populations to identify no fewer than 364,470 SNPs. The results suggested that most descended from a single ancestral population known today as the First Americans. However, two other streams of Asian gene flow should have occurred, giving rise to the Eskimo–Aleut populations of the Arctic, and the Na-Dene speakers of northern North America (Reich et al., 2012). These data took us back to a much-debated proposal made almost three decades ago (Greenberg et al., 1986). Other analyses indicated that migrations followed a southward expansion mainly along the Pacific coast, with sequential population splits and reduced gene flow after the divergence, especially in South America. A reverse stream from south to north should have occurred across the isthmus of Panama, by speakers of the Chibchan language (Reich et al., 2012). An unexpected finding of Skoglund et al. (2015) was the presence of a genomic signature among Amazonians closely related to Australasian populations, and not present to the same extent or at all in present-day Amerindian populations of North and Central America.

Another question that has been extensively debated is the number of founding groups responsible for this prehistoric colonization. Fagundes et al. (2018) approached this question using autosomal DNA from nine, independent regions—a total of about 17,500 base pairs in a set of Asian, Siberian, and Amerindian subjects. This information was subjected to an extensive statistical demographic analysis (including Bayesian analysis). The results suggested that the effective population size (the size that matters in population genetics analyses, generally estimated as one-third of the actual size of a given population) of the Amerindian founders was small, most likely on the order of a few hundred individuals, with point estimates close to 250. This result is important for adequate analyses of the gene pool and the factors influencing it in this ethnic group.

The question of Amerindian origins was considered in a different way by the Belém group. Using the next-generation sequencing technology they obtained no fewer than 36.8 billion base pairs from one Amerindian. This high-throughput sequence was then compared to other fully sequenced genomes available from the human haplotype map (HapMap) and 1,000 Genomes Project databases. As expected, there was a close relationship with East Asian populations, but surprisingly also with the genome of an Australian Aborigine. They also identified 32,275 potentially new SNPs, a significant contribution to the understanding of the Amerindian gene pool (Ribeiro-dos-Santos et al., 2013).

Several other studies conducted by the Porto Alegre group are summarized in Table 4. They can be classified in seven categories: (a) review of uniparental data; (b) distribution of specific polymorphisms; (c) genome-linguistic relationships; (d) demographic expansions; (e) adaptation to tropical forests; (f)

gene-culture coevolution; and (g) epidemiology and immunological investigations. It is clear that Amerindians provide excellent material for the adequate investigation of microevolutionary processes in humans.

Curitiba is one of the oldest centers of population genetics research in Brazil. Founded by Newton Freire-Maia (1918–2002) in the 1950s, it remains a center of excellence in the area. Currently, its leading figure is Maria Luiza Petzl-Erler, who specializes in the complex field of immunogenetics. A recent study conducted by her group investigated the killer cell immunoglobulin-like receptors (KIR), expressed on natural killer (NK) cells and subsets of T cells. Gene and allele prevalence in four populations of Brazilian Amerindians was compared with ten other Amerindian groups, as well as with European, African, and Eastern Asian populations. Demographic factors (founder and bottleneck effects) seem to have had a major influence in shaping the gene and haplotype distributions in the four Amerindian populations that were tested. Additionally, and contrary to a previous independent investigation, no correlation was found between the frequencies of KIR and HLA systems among them. The absence of individuals who lack functional KIR recognition, however, gives evidence that natural selection may also be involved in the evolution of KIR in these groups (Augusto et al., 2013).

## CONCLUSION

Human population genetics and genomics in Brazil closely follow primary international trends. A review of nearly a century of investigation discloses important contributions to the world of science and, more specifically, to a better understanding of the Brazilian population, as compared to populations from elsewhere in Latin America and the rest of the world. This research is being conducted in several key centers located throughout the country and includes single specific polymorphisms to extensive DNA regions, investigating their variability in relation to demographic and cultural (for instance, linguistic) factors. The results can only be beneficial to the proper understanding of human nature—exploring the past, identifying the present, and furnishing prospects for our evolutionary future.

## ACKNOWLEDGMENTS

This research was financed by Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) [National Council of Scientific and Technologic Development] and Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul, Programa de Apoio a Núcleos de Excelência (FAPERGS/PRONEX) [State Foundation for the Advancement of Science of Rio Grande do Sul, Support of Excellence Nuclei Program].

**TABLE 4.** Studies conducted by the Porto Alegre group involving Amerindian microevolution, 2012–2016.

- 1. Review of uniparental data** (Bisso-Machado et al., 2012)  
Variability in the Y-chromosome haplogroups was assessed in 68 populations and 1,814 individuals, and in 108 populations and 6,697 persons for mitochondrial DNA (mtDNA). Y-chromosome haplogroup Q1a3a\* was generally the most prevalent; while mtDNA A and D haplogroups correlated positively and negatively, respectively, with latitude.
- 2. Distribution of specific polymorphisms**
  - 2.1. 5' regulatory region of the serotonin transporter gene (5-HTTLPR) (Bisso-Machado et al., 2013; Hünemeier et al., 2015)  
A total of 170 Amerindians from 21 populations were tested and compared with information from Europe (N=5,843), Asia (N=1,771), and Africa (N=614). Amerindians showed the highest frequency of the S allele observed thus far (90%).
  - 2.2. Alpha-actinin skeletal muscle isoform 3 R577X (*ACTN3*\*R577X) (Amorim et al., 2015a)  
Data from three databases (1,000 Genomes Project, HapMap, and Human Genetic Diversity Panel) yielded information for 2,806 individuals and 121 populations, distributed as follows: Africa: 794; Middle East: 146; Europe: 445; Asia: 992; Oceania: 35; Americas: 394. The 577\*X prevalence increases in frequency with distance from Africa, from a low 7% to the highest prevalence, found in South America (76%). Positive selection, detected by an extended haplotype homozygosity test, was consistent only with the Eurasian data, but simulations with neutral models could not fully explain the results found in the Americas.
  - 2.3. N-acetyltransferase 2 (*NAT2*) (Bisso-Machado et al., 2016)  
A total of 286 Amerindian and Andean and Mexican Mestizos living in 21 populations were genotyped for this gene, and about 44,000 base pairs surrounding it were studied in 1,175 individuals from Africa, Asia, Europe, and America. A new haplotype, probably related to the slow phenotype, was identified in two Amerindians of tribes geographically located far apart, and speaking languages from different major linguistic branches.
  - 2.4. TP53 Pathway (Jacovas et al., 2015)  
Five TP53 single nucleotide polymorphisms (SNPs) were studied in 282 subjects of several Amerindian groups living at high and low altitudes, and three alleles were found to be associated with an adaptation to high altitude in the Andes.
- 3. Genome/linguistic relationships** (Amorim et al., 2013)  
Data from 381 autosomic short tandem repeats (STRs) were studied in populations representing the five main Amerindian linguistic groups in South America: Andean, Arawakan, Chibchan-Paezan, Macro-Jê, and Tupi. Discordant models classifying their relationships were then tested under an approximate Bayesian computation (ABC).
- 4. Demographic expansions** (Ramallo et al., 2013)  
Analysis of Amerindian mtDNA complete control region from nine populations plus high variable segment 1 (HVS-I) sequences from 1,176 samples were considered. Their relationships were then investigated through median-joining networks and genetic, geographic, and linguistic correlations with Mantel tests, and spatial autocorrelation analyses. Both Tupi and Jê speakers showed general traces of ancient or more recent fission-fusion processes, but a very different pattern of demographic expansion. Tupi populations displayed a classical isolation-by-distance pattern, while Jê groups presented an intricate and nonlinear mode of dispersion. Collective memory and other cultural processes could have significantly influenced these events.
- 5. Adaptation to tropical forests** (Amorim et al., 2015b) **and the Beringian environment** (Amorim et al., 2017)  
5.1. Signals of natural selection at the fatty acid desaturases (*FADS*) genes throughout the Americas suggested a single and strong adaptive event that occurred in Beringia before the prehistoric Amerindian expansion.
- 6. Gene-culture coevolution**
  - 6.1. Lactase gene and its enhancer region (Friedrich et al., 2012)  
Twelve polymorphisms were genotyped by the polymerase chain reaction (PCR) method in four Brazilian Amerindian populations from three tribes. The enhancer region, situated 14 kilobases upstream of the lactase persistent (*LCT*) gene showed only the European variant (-13910\*T), whose presence in Amerindians are probably due to interethnic admixture. However, the *LCT* 5' flanking and coding regions were highly variable, displaying 15 haplotypes with a heterogeneous distribution among the four populations. Previous studies of the -13910\*T variant associated it with milk consumption in non-Amerindian populations, and its absence in nonadmixed Amerindians agrees with their lack of a traditional pastoralist way of living. The haplotypic diversity, on the other hand, needs additional analyses for its explanation. Nevertheless, the absence of original variability in the enhancer region, and the high variability in its neighborhood, indicates that different evolutionary factors can be at play in relatively close DNA portions.
  - 6.2. Rapid phenotypic evolution (Hünemeier et al., 2012)  
Cephalometric data taken from 1,203 individuals were analyzed in combination with genetic, climatic, social, and life-history data from six South American Amerindian populations. They are compatible with a scenario of rapid genetic and phenotypic evolution, probably mediated by cultural shifts, in the Xavante. They showed a remarkable rate of morphological change, that could be best explained through culturally mediated sexual selection.
- 7. Epidemiological** (Godoy et al., 2016) **and immunological** (Lindenau et al., 2016) **investigations**
  - 7.1. Prevalences of Hepatitis B Virus (HBV) infection in South American Amerindians (38 populations, 1,070 individuals) indicated a recent (1945–1965) expansion probably related to Amazonian economic developments.
  - 7.2. Average heterozygosities in 14 innate immune systems of five South American Amerindian samples showed similarity to those of other continents, but the frequencies of polymorphisms in these genes significantly differed between Amerindians and Africans.

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# 2

## Bioarchaeology in Brazil

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**ABSTRACT.** Bioarchaeology is a discipline that uses biological, sociocultural, and environmental theories to investigate the human biological component of the archaeological record. Brazilian physical anthropology has been practiced since the nineteenth century at Brazil's National Museum in Rio de Janeiro, but only in the 1980s was a truly integrated bioarchaeological approach formed in the country. In this chapter, we undertake a broad review of bioarchaeological studies during the past 15 years in Brazil. We categorized these studies into three main areas with their own history of institutional dialogues: population history and structure, mortuary archaeology and identity, and health and lifestyle. Finally, we propose some directions for future studies.

**RESUMEN.** Bioarqueología es una disciplina emergente que utiliza teorías biológicas, socioculturales y ambientales para investigar el componente biológico humano del registro arqueológico. La antropología física brasileña se ha practicado desde el siglo diecinueve en el Museo Nacional en Río de Janeiro, pero sólo en la década de 1980 un enfoque bioarqueológico verdaderamente integrado ocurrió. En este capítulo presentamos una amplia revisión de los estudios bioarqueológicos en los últimos 15 años en Brasil. Hemos clasificado los estudios en tres áreas principales con su propia historia de diálogos institucionales: historia y estructura de la población, arqueología funeraria e identidad, y salud y estilo de vida. Finalmente, proponemos algunas direcciones para futuros estudios.

**RESUMO.** Bioarqueologia é uma disciplina emergente que usa teorias biológicas, socioculturais e ambientais para investigar o componente biológico humano do registro arqueológico. A antropologia física brasileira tem sido praticada desde o século dezanove no Museu Nacional no Rio de Janeiro, mas apenas na década de 1980 uma abordagem bioarqueológica verdadeiramente integrada veio à tona. Neste capítulo, realizamos uma ampla revisão dos estudos bioarqueológicos nos últimos 15 anos no Brasil. Categorizamos os estudos em três áreas principais com a sua própria história de diálogos institucionais: história e estrutura populacional, arqueologia mortuária e identidade, e saúde e estilo de vida. Por fim, propomos algumas direções para estudos futuros.

### INTRODUCTION

The field of bioarchaeology can be defined as “the study of human remains from archaeological contexts” (Larsen, 2015:3). This field uses biological, sociocultural, and environmental theories to investigate the human biological component of the archaeological record. In this sense, bioarchaeology is essentially an interdisciplinary science, encompassing human biology, osteology, archaeology, anthropology, chemistry, etc. (Larsen, 2006). Other researchers emphasize the mortuary component of the archaeological record, defining the task of bioarchaeologists as “to reconstruct the lives and deaths of past persons and their communities by means of human remains that are inextricably linked to their mortuary context” (Buikstra et al., 2012:13). Bioarchaeology emerged in the 1970s within the context of New Archaeology and population-based studies (Buikstra, 1977, 2006), and during the 1980s and 1990s, the field advanced notably in terms

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

of number of studies, methods, and scope (Larsen, 2015). Bioarchaeology not only concerns the descriptions of skeletons but also aims to reconstruct past behavior (Neves, 1984a). To accomplish this goal, instead of staying in the laboratory doing specialized analyses, the bioarchaeologist needs to participate actively in all steps of archaeological research, including research design, data collection, quantitative analyses, and interpretation.

This chapter provides a broad review of bioarchaeological studies in Brazil, aiming to include the main research topics approached in the past 15 years. Following the precepts of bioarchaeology defined above, we preferentially selected studies that showed a clear connection between biological remains and archaeology. We divided the studies into three main topics: population history and structure, mortuary archaeology and identity, and health and lifestyle. At the end of this chapter, we discuss limitations and future directions of Brazilian bioarchaeology.

## HISTORY OF BIOARCHAEOLOGY IN BRAZIL

The practice of bioarchaeology in Brazil derives from a much older tradition of physical anthropology research (Mendonça de Souza, 2014a). Since the nineteenth century, the Brazil's National Museum in Rio de Janeiro has been the leading institution in physical anthropology in Brazil, housing researchers such as João Batista de Lacerda (1846–1915), Bastos de Ávila (1888–?), and Edgar Roquette-Pinto (1884–1954). They worked with topics ranging from the prehistoric inhabitants of the continent (Lacerda and Peixoto, 1876; Gonçalves et al., 2012) to the biological basis of racial types in living populations (Santos, 2012; Souza, 2012).

Marília Carvalho de Mello e Alvim (1931–1995) took on the anthropometric tradition of the National Museum, studying several Brazilian collections such as the prehistoric skeletons of Lagoa Santa in Minas Gerais and of coastal shell mound sites (sambaquis; e.g., Mello e Alvim, 1977, 1978). Although other researchers undertook studies with human physical remains, such as Pedro Estevam de Lima (Lima, 1954), Tarcísio Torres Messias (Messias and Mello e Alvim, 1962), and Ernesto de Mello Sales Cunha (Salles Cunha, 1961), Mello e Alvim was the biggest contributor of Brazilian physical anthropology in the mid-twentieth century (Mendonça de Souza and Cook, 2006). She applied a very meticulous and methodologically oriented approach to the skeletal collections, aiming to characterize them biologically. However, she did not properly incorporate archaeological and modern evolutionary theory in her research, making her work part of the old paradigm of physical anthropology (Washburn, 1951). At the end of her career, she approached topics related to health and past behavior, such as her studies of porotic hyperostosis in sambaquis (Mello e Alvim and Oliveira Gomes, 1989).

Bioarchaeology in Brazil started properly only in the 1980s, with the beginning of the integration of human remains and archaeological studies. As a pioneer of this field, Walter Neves investigated Brazilian coastal skeletons using cranial traits (Neves, 1982, 1988) and osteological indicators of health (Neves et al.,

1984). In one of his texts, he concluded that prehistoric physical anthropology must reconstruct human behavior (Neves, 1984a). In fact, he had an important role in spreading modern biological anthropology to Latin America (Bordach et al., 2014:21). In turn, Lília Maria Cheuiche Machado, another pioneer researcher, studied aspects of mortuary ritual, paleodemography, and subsistence in prehistoric coastal populations of Rio de Janeiro (Turner and Machado, 1983; Machado, 1984). Both researchers had international experience in the United States, bringing population and biocultural approaches back to Brazil.

In the 1990s, after the initial development of Brazilian bioarchaeology, some centers dedicated to bioarchaeology appeared in Brazil. Walter Neves founded a laboratory for human evolutionary studies in the Biosciences Institute at the University of São Paulo. Later, in the same institution, Sabine Eggers established a laboratory of biological anthropology. Recently, Veronica Wesolowski assumed the position of physical anthropologist of the Museum of Archaeology and Ethnology at the University of São Paulo. In Rio de Janeiro, after the retirement of Marília de Mello e Alvim, Ricardo Ventura Santos and Claudia Rodrigues Carvalho took the position of physical anthropologists of the National Museum, later recruiting other researchers: Andrea Lessa, Andersen Liryo, and Adilson Salles. At the Oswaldo Cruz Foundation, bioarchaeology is practiced by Sheila Mendonça de Souza, with an emphasis on paleopathology. She works at the same institution as researchers of paleoparasitology, such as Aduino Araújo and Alena Mayo Iñiguez. Other centers of bioarchaeology have appeared in Brazil in recent years, led by Olivia Alexandre de Carvalho at the Federal University of Sergipe, Sérgio Francisco da Silva at the Federal University of Pernambuco, and Danilo Vicensotto Bernardo at the Federal University of Rio Grande. These new centers are the result of not only a second generation of professionals in bioarchaeology but also a recent demand for undergraduate and graduate programs in archaeology. In the following sections, we approach some of the most relevant discussions produced by bioarchaeologists in Brazil in the past 15 years.

## POPULATION HISTORY AND STRUCTURE

The most important bioarchaeological research group studying population history and structure in Brazil was led by Walter Neves at the University of São Paulo. His work differentiated from previous cranial studies by incorporating multivariate statistics, archaeology, and evolutionary biology concepts. Instead of describing skulls, he was interested in testing models of human occupation of and dispersion into and within the Americas. During his career, he had actively been involved in archaeological excavations, including a large archaeological project in the Lagoa Santa region (Neves and Piló, 2008; Bernardo et al., 2016).

Neves's research started in the early 1980s with the study of nonmetric traits of crania of Brazilian coastal populations from the states of Santa Catarina and Paraná (Neves, 1988). He identified two different preceramic groups in that coastal region.

In the subsequent ceramic period, he detected a demic diffusion from inland to the Santa Catarina coast and a change in the social systems of the inhabitants of the central coast of Santa Catarina. Analyzing males and females separately in the latter region, he detected a change from uxori-local residence to viri-local residence, showing how his methods could give information about the social structure of past populations. Later, using a metric perspective, Hubbe et al. (2009) confirmed the change in social organization after the introduction of ceramics. Two of Neves's doctoral students approached the Brazilian coastal skeletal collections from a population perspective. Hubbe (2006) showed that the preceramic skeletons of the sambaqui of Porto do Rio Vermelho II, Santa Catarina, have morphological affinities with modern Native Americans but not with Paleoamericans. Okumura (2008) applied metric and nonmetric approaches to coastal skeleton collections from Rio de Janeiro to the Santa Catarina coast. She identified two morphologically distinct groups: Rio de Janeiro and São Paulo populations in one group and Santa Catarina populations in another. Skeletons from the Paraná coast showed an intermediate morphology. In addition, she detected a morphological distinction between the preceramic coastal populations and the inland inhabitants. Okumura showed that biological continuity between the preceramic and ceramic periods varied from place to place, occurring on the Santa Catarina Island (Florianópolis) but not along the continental Santa Catarina coastal line. All these inferences were connected with archaeological models of dispersion and with patterns of material culture, such as pottery occurrence (Okumura, 2014).

Under the supervision of Sabine Eggers, also from the Biosciences Institute of the University of São Paulo, two studies with skeletons of fluvial shell mounds from São Paulo State were undertaken. Bartolomucci (2006), using nonmetric dental traits, found a biological association between coastal Paraná series and fluvial populations from São Paulo. In turn, Fillippini and Eggers (2005–2006), using nonmetric cranial traits, found a significant difference between coastal populations and fluvial populations from São Paulo State, whereas Neves and Okumura (2005) showed contrary results using metric traits. Using metric variables, Neves et al. (2005) found similarity between a fluvial skeleton dated to 8860 BP and Paleoamericans from eastern central Brazil. These results show the complexity of the interactions between coastal and inland populations in Brazil.

The population history research with the highest international impact on Brazilian bioarchaeology is the study of the Paleoamericans of eastern central Brazil. Studying cranial metric variables of Paleoamerican skeletons from Lagoa Santa, Minas Gerais, Neves and colleagues proposed the model of two main biological components for New World settlement (Neves and Pucciarelli, 1991; Neves et al., 1999, 2003). This model proposes that the first biological wave to enter the Americas had a generalized cranial morphology, which is similar to the one found today in African and Australo-Melanesian populations. The second biological wave consisted of populations with an Asiatic cranial morphology, which is a derived morphology found in

modern East Asians and in Native Americans. Later, after a large effort to contextualize chronologically the Lagoa Santa collection, Neves and colleagues confirmed their model, analyzing 81 Paleoamerican crania of Lagoa Santa and comparing them with a global sample from the Howells database (Howells, 1989). In addition, they were able to show that Paleoamerican skeletons from the United States, Mexico, Colombia, Chile, and south and northeast Brazil also showed the generalized morphology, distinct from modern Native Americans (e.g., Neves and Hubbe, 2005; Neves et al., 2005; Hubbe et al., 2007).

Neves's research program of population history of the early Americans generated several theses and dissertations at the University of São Paulo. Munford (1999), using the Howells database, and Bernardo (2007), using the Hanihara database (Hanihara, 2000), showed the difference between Lagoa Santa and Colombian skeletons from modern Native Americans regarding metric cranial variables (Neves et al., 2007). Atuí (2005) showed the similarities between the crania of Botocudo, a historic Indian population of eastern central Brazil, and those of the Paleoamericans of Lagoa Santa, indicating a later survival of the first wave of colonization into the Americas (Strauss et al., 2015). Nunes (2010), using the dental metric database of Hanihara, also confirmed the model of two main biological components. Mark Hubbe and colleagues published a series of research articles testing dispersion scenarios of colonization of the Americas (Hubbe et al., 2010, 2014). Their models supported the view of two morphologically distinct waves of colonization into the Americas. In addition, Hubbe et al. (2011) found similarities between Upper Paleolithic skulls from East Asia and Europe and Paleoamerican skulls, which are morphologically different from those of modern Native Americans. The Neves's model of early settlement of the Americas is not the only proposed model (see the opposite view in González-José et al., 2008), but it became a necessary part of any discussion of New World settlement.

Studies with other skeletal collections in Brazil are prevented by the small sample size and their low archaeological context. For example, Umbu crania from southern Brazil, dating to the middle Holocene, showed similarities with those of Paleoamericans in Neves et al.'s (2004) study, whereas Hubbe et al. (2014) detected biological affinities with modern Native Americans. Regarding the dispersion of Tupi-Guarani populations in Brazil, Neves et al. (2011) found morphological similarity between Tupi-Guarani and Amazonian crania, suggesting an Amazonian origin of these populations. All these studies have allowed the development of models of dispersion in South America (Pucciarelli et al., 2006) and in Brazil (Hubbe et al. 2014), providing testable hypotheses for future archaeological research.

## MORTUARY ARCHAEOLOGY AND IDENTITY

Studies of mortuary archaeology and identity involve the dialogue between archaeology and cultural anthropology. Differing from the population history studies, this field of analysis

has been undertaken in several research centers in Brazil using multiple approaches. Pioneer studies were done at the Corondó site in Rio de Janeiro (Machado, 1984) and in the rock shelters of central and northeastern Brazil (Machado, 1990).

Excavations of the shell mounds from coastal Brazil provided a large number of associated skeletons. Silva (2005) studied the mortuary archaeology of coastal populations from São Paulo State, including osteological and cultural data associated with the burials. He observed that this prehistoric population employed mostly primary burials in mortuary sites, suggesting low seasonal mobility in stable territories (see Strauss, 2012, for a different view). In turn, Pompeu (2015) carried out a survey of the mortuary characteristics of 13 shell mounds from the states of Santa Catarina and Paraná. This study showed five different mortuary patterns in the region, exposing some spatial and temporal variability in the way these populations buried their dead.

A well-studied coastal site is the sambaqui of Jabuticabeira-II in Santa Catarina State. It has been considered an unequivocal cemetery site, containing hundreds of burials that formed a monumental structure likely symbolizing the importance of deceased people to their society (Gaspar et al., 2014). Okumura and Eggers (2014) found several cultural processes applied to the bodies in Jabuticabeira-II, including a pattern of secondary burials with hyperflexed individuals. Klokler (2014) showed that animals, especially small fishes, played a central role in feasts performed in honor to dead people. These fishes were captured in local lagoons and estuaries and were processed and cooked in places different from the burial site. According to Gaspar and DeBlasis (2012), the coastal cemetery mounds should be understood as the result of ceremonial activities aimed to preserve the body, instead of reducing or manipulating it as done by the Tupi and Macro-Jê Brazilian populations.

Another perspective of interpretation of these sites is gender archaeology. Gaspar et al. (2011), studying funerary goods of Rio de Janeiro coastal populations, concluded that the traditional sex roles expected of a hunter-gatherer population were not found. They observed similar funerary goods for women and men, including instruments of hunting and gathering. On the other hand, De Masi (2012), using a processual approach, found distinctions of funerary goods based on sex and age in the sambaqui of Porto do Rio Vermelho II in Santa Catarina. In short, mortuary archaeology of Brazilian coast populations has been studied from multiple perspectives, aiming to integrate burials and the archaeological record.

Another important Brazilian archaeological region is the state of Minas Gerais. Paleoamerican burials in the Lagoa Santa region were believed to be simple and homogeneous, composed of flexed primary burials in very shallow graves topped by small blocks (Neves and Hubbe, 2005). After the excavation of the Lapa das Boieiras and Lapa do Santo sites using detailed methods of spatial recording, a much more complex mortuary scenario was detected, with instances of decapitation, anatomical selection, tooth removal, cutting of bone extremities, and cremation (Neves et al., 2002; Strauss et al., 2016). Recently, a

reexamination of the old skeletal collections from Lagoa Santa found 23 cut bone extremities, similar to the pattern found at Lapa do Santo (Da-Gloria et al., 2011). These new findings highlight the diversity of mortuary rituals early in the occupation of the South American continent. In fact, Mendonça de Souza and Rodrigues-Carvalho (2013) stressed the importance of detailed field observations and spatial records to extract the most information from the burial context.

Studying horticultural populations at Gruta do Gentio II, northwest Minas Gerais, Sene (2007) applied a postprocessual approach to understanding social and gender roles in the past. She found differences in mortuary goods between men and women, such as the presence of pottery only with the latter group. The presence of funerary goods at this site contrasts the intense manipulation of the body and lack of mortuary goods of early inhabitants of Minas Gerais. On the other hand, in a context with no ceramics at the Lapa do Caboclo site, northern Minas Gerais, four secondary burials dated to the late Holocene were found with cut marks, red ochre, use of resin, and secondary arrangement of bones in tree bark and hide cases (Solari et al., 2012).

Mortuary studies in northeast Brazil are being undertaken by researchers from the Federal University of Sergipe and the Federal University of Pernambuco. Cisneiros (2006) studied the Serra da Capivara region in Piauí State, describing tentative burial patterns during the Holocene. Vergne (2007), using a processual approach, detected indicators of social complexity and hierarchy through the study of mortuary context of the Justino site in the São Francisco Valley. Later, these same burials were studied using an archaeoethnology approach, which includes a total description of the burial context and osteological profile of the skeleton (Carvalho, 2007; Santana, 2013; Silva and Carvalho, 2013). In Pernambuco State, several archaeological sites in the transition from the Atlantic forest and caatinga environments contained human burials (Leite et al., 2014). The most well-known among them is the Furna do Estrago site with 80 burials of mostly primary skeletons and a few examples of manipulated skeletons (Lima, 2012). Burials in ceramic urns are also common in the northeast Brazil, such as the Serra do Evaristo I site in the state of Ceará (Castro et al., 2015). At that site, six burials deposited in urns were dated to around 750 BP.

In the Amazonian region, the lack of bioarchaeological studies is usually attributed to poor preservation of bone material in tropical regions. However, the absence of Brazilian researchers interested in bioarchaeology seems to be the real cause (Mendonça de Souza, 2010). Some sites, for example, preserved osteological remains because of the chemical composition of the soil or the type of burial conditions, as in the case of the Hatahara site (Py-Daniel, 2010), Amanã Lake urns in Amazonas State (Costa et al., 2012), and the Maracá urns in Amapá State (Guapindaia, 2008). The Hatahara skeletons were found in mounds, which were probably funerary and habitation structures, whereas the remaining skeletons were found in funerary urns. Using archaeological and ethnographical reports, Py-Daniel (2016) provided

the first regional survey of Amazonian funerary practices, showing a great diversity of practices across the region.

Distinct mortuary patterns were found in the landscape of southern Brazil's highlands, such as depositions in rock shelters and cremated individuals buried in mounds (Saldanha, 2008). One of these mortuary structures, the tradition of mound and enclosure complexes, was built between 1000 BP and the eighteenth century, and its mounds contained cremated bones with associated ceramics, lithics, and fauna (Iriarte et al., 2013). These mounds are believed to have been formed in a moment of resistance of the Jê linguistic population against a wave of expansion of Tupi-Guarani groups (De Souza et al., 2016). These sites revealed a tradition of ceremonial site construction, using fire to treat the dead in a way similar to that found in ethno-historic accounts of the Jê group Xokleng (De Masi, 2009a). Ulguim (2016) undertook a bioarchaeological analysis of four sites of this tradition, describing primary and secondary burials with the common characteristics of high-temperature cremation (500°C–1000°C) of bodies with flesh and the subsequent deposition of these remains in mounds.

Last, we discuss a contribution of bioarchaeology to understanding identity in historical contexts. Liryo et al. (2011) studied the slave cemeteries of Pretos Novos, Rio de Janeiro, and the old Sé de Salvador, Bahia, which have remains dated to the seventeenth and nineteenth centuries. They revealed several patterns of dental mutilation, which were distinct in the two cemeteries. Combining historical, cultural, and dental information, they identified possible places of origin of the slaves and the multiple ways they used their teeth to display cultural filiation. This study is an exception to the otherwise underrepresented field of identity in Brazilian bioarchaeology.

In short, studies of mortuary archaeology have been done in all the major regions in Brazil (see a brief review in Prous et al., 2011). Even so, much more work still needs to be done to understand the diversity of mortuary rituals of historic and prehistoric people in Brazil.

## HEALTH AND LIFESTYLE

Research on health and lifestyle demands an intense dialogue between biology and archaeology. In Brazil, studies in this topic have been concentrated at the University of São Paulo, the National Museum, and the Oswaldo Cruz Foundation in Rio de Janeiro. These centers have had a history of collaboration among their archaeological, biological, and medical departments.

A large number of health and lifestyle studies were conducted on Brazilian coastal populations after the pioneering studies of Neves et al. (1984) and Neves (1984b). Before we generalize about their lifestyle, we should keep in mind their spatial and temporal variability (see, for example, variation in lifestyles of coastal populations of Rio de Janeiro State in Lessa and Rodrigues-Carvalho, 2015). Different aspects of their lives have been investigated using osteological indicators of health,

including their diet, physical activity, and violence. Mendonça de Souza et al. (2009) surveyed 119 papers dealing with health in Brazilian coastal populations. Regarding dental indicators, sambaquis showed a low prevalence of caries and dental loss and a high degree of tooth wear and dental calculus. This general pattern can be tentatively explained by a low cariogenic diet based on protein and the presence of sand in the food (Okumura and Eggers, 2005). On the other hand, in the sambaqui of Cabeçuda, lower incisive antemortem tooth loss could be indicative of labial ornaments used by the male population (Rodrigues-Carvalho and Mendonça de Souza, 1998). Other researchers showed some variation in the prevalence of caries along the Brazilian coast populations, raising the issue of diet diversity in sambaquis (Wesolowski, 2000; Neves and Wesolowski, 2002). Studies retrieving starch grains and phytoliths from human dental calculus found evidence of consumption of yams, sweet potatoes, and Paraná pine, attesting to the presence of plant foods in the diet of some coastal populations (Wesolowski et al., 2010; Boyadjian and Eggers, 2014).

Regarding physical activities in coastal populations, studies of degenerative joint diseases (DJDs) and muscle stress markers (MSMs) have been performed (see Rodrigues-Carvalho et al., 2009, for a synthesis). Even considering some variability in MSMs from different coastal sites, the upper limbs of sambaqui skeletons seem to have marked MSMs, probably related to water activities such as rowing and fishing (Rodrigues-Carvalho and Mendonça de Souza, 2005). Rodrigues-Carvalho (2004) found that populations living near the open sea have more MSMs than populations living near lagoons. At the Jabuticabeira-II site, Santa Catarina, Abbas (2013) observed severe MSMs, especially in the lower limbs, whereas Petronilho (2005) found intense DJDs in the upper limbs. On Santa Catarina Island, Scherer et al. (2015) analyzed MSMs from the lower limbs, with men showing higher mobility than women, mostly at the site Praia da Tapera. Also concerned with physical activities, Lessa (2011a) found a high prevalence of spondylolysis in Santa Catarina shell mounds, which was associated with intense lumbar rotation and hypertension due to fishing activities and continuous weight carrying. Interestingly, shell mounds in Rio de Janeiro show a different prevalence of this disease (Lessa and Coelho, 2010).

Regarding skeletal trauma, shell mound builders showed fewer violent traumas than ceramists that lived on the coast, especially the males (Lessa, 2005; Lessa and Scherer, 2008). Sambaqui skeletons also showed fewer fractures in general, which can be explained by living in resource-rich environments with low mobility (Okumura and Eggers, 2005). Some exceptions were found in the sambaqui of Zé Espinho, Rio de Janeiro, which showed a high prevalence of violent trauma in women (Rodrigues-Carvalho et al., 2009), and in a study involving Rio de Janeiro and Santa Catarina sites that showed a high prevalence of lower limb fractures, interpreted as resulting from falls (Lessa, 2011b).

Infections are generally high in sambaqui populations, possibly because of low mobility and an aggregated population living

in a tropical setting (Mendonça de Souza et al., 2009). Treponematoses seems to have been a common disease along the coast, supporting a pre-Columbian presence of syphilis in the Americas (Melo et al., 2010; Fillippini, 2012). In addition, the presence of porotic hyperostosis suggests some degree of parasitism (Mello e Alvim and Oliveira Gomes, 1989) or infectious diseases (Mendonça de Souza et al., 2009) in that population. Other aspects of health and lifestyle, such as stress (Mendonça de Souza, 1999) and paleodemography (Mendonça de Souza, 2014b), have also been approached by Brazilian researchers.

The Lagoa Santa collection is another large skeletal series from Brazil. However, the number of studies on indicators of health is much lower. Comprehensive reviews of osteological markers of health were carried out only recently in that collection (Cornero, 2005; Da-Gloria, 2012). With a large database from the Western Hemisphere Project (Steckel and Rose, 2002) as a reference, this early hunter-gatherer population showed an unexpected pattern of a high prevalence of stress and pathological markers (Da-Gloria, 2012). For instance, Lagoa Santa skeletons showed a high prevalence of caries and abscesses compared to other hunter-gatherer populations (Neves and Kipnis, 2004). Da-Gloria and Larsen (2014, 2017) suggested that a combination of wild tubers and cariogenic fruits from a tropical setting is a possible explanation for this pattern, which is much more accentuated in females.

Another significant collection studied in Brazil is Furna do Estrago from Pernambuco State. The stress markers (Mendonça de Souza, 1995) and the dental indicators (Rodrigues-Carvalho, 1997) were compared with those from the sambaqui of Cabeçuda, Santa Catarina. The former study interpreted these markers as indicators of good adaptation of Furna do Estrago inhabitants to the semiarid environment of northeast Brazil. In turn, the latter study found a high prevalence of oral pathologies in the Furna do Estrago collection, suggesting a significant presence of carbohydrates in their diet. Also in the northeast of Brazil, Cook and Mendonça de Souza (2012) undertook a detailed paleopathological analysis of 20 individuals from the Tocas dos Gongo, state of Piauí, dated to around 2000 BP. They found evidence of pathologies such as caries, abscesses, rheumatoid arthritis, traumas, and cranial infections. Studies of traumas at the Justino site, Sergipe (Santana and Carvalho, 2013), and of mobility using cortical cross-sectional geometry of tibiae of Tenetehara skeletal series from Maranhão State (Suby et al., 2011) show some other examples of the otherwise modest geographic diversity of health and lifestyle studies in Brazil.

Finally, microscopic and isotopic approaches have contributed to understanding health in past Brazilian populations. Studies of molecular paleoparasitology, for example, have diagnosed *Ascaris* sp. from coprolites in diverse Brazilian archaeological sites (Leles et al., 2008). In turn, Jaeger et al. (2012) detected tuberculosis in human skeletons from the seventeenth century in Rio de Janeiro. The field of paleoparasitology is well developed at the Oswaldo Cruz Foundation in Rio de Janeiro (see Ferreira et al., 2011).

Regarding isotopic approaches, Hermenegildo (2009) employed analyses of isotopes of carbon and nitrogen to show the terrestrial diets of prehistoric inhabitants of Minas Gerais. De Masi (2009b) applied similar methods to show the great importance of marine fishes to the coastal populations of southern Brazil, even though some individuals with deviations toward terrestrial diets were also found. Conversely, in the highlands of southern Brazil, he detected an isotopic signature of terrestrial diets, with one individual whose isotopic values suggest maize consumption around 650 BP. From a different research group, Colonese et al. (2014) showed that coastal shell mound populations had either marine or mixed diets, whereas the fluvial shell mound populations had terrestrial diets, even though both had high protein consumption. Remarkably, they found that coastal ceramic sites around 1500 BP had a predominantly marine diet. Using strontium isotopes from dental enamel, Bastos et al. (2011) detected that the majority of the individuals buried at the sambaqui of Forte Marechal Luz, Santa Catarina, were locals ( $n = 29$ ), except three individuals who came from preceramic and ceramic periods. The same local origin was obtained for individuals from a ceramic site on the Island of Santa Catarina (Bastos et al., 2015). These results show the importance of molecular approaches to understanding long-debated questions about subsistence, the origin of ceramic coastal sites, and the degree of contact between the coast and inland.

Isotopic methods were also used in the study of historical slave cemeteries from the cities of Rio de Janeiro and Salvador. Using strontium isotopes, Bastos et al. (2016) showed multiple origins within Africa, whereas, using carbon and nitrogen values, they showed the low consumption of protein of these populations. Macroscopic analyses of the dentition of slaves who had recently arrived in Rio de Janeiro also showed the use of chewing sticks as a method of oral hygiene in Africa (Cook et al., 2015). All these studies reveal the diversity of approaches that can be taken using skeletons from archaeological origins.

## FUTURE DIRECTIONS

In light of the material reviewed in this chapter, a clear expansion of research scope and the number of centers practicing bioarchaeology in Brazil occurred in the previous decade. However, some shortcomings can be identified. Some works are only in the form of theses and dissertations and have never been published as peer-reviewed articles or accessible books and monographs. Furthermore, a considerable number of the studies have been published in Portuguese in Brazilian journals with little international impact, mostly on the topic of mortuary rituals. This scenario decreases the dialogue of Brazilian bioarchaeologists with international researchers in North America and Europe. In contrast, population history studies of skeletons from Lagoa Santa and health and lifestyle studies related to sambaquis have appeared in the greatest number of international publications. In fact, they are the major topics of Brazilian bioarchaeology. Molecular



approaches, such as paleoparasitology, have also had broad exposure in the international community. In general, international cooperation and the effort of proposing local ideas in international forums have markedly advanced, but international recognition is still a big challenge for contemporary Brazilian bioarchaeologists.

We outline here some suggested new directions for each of the three main fields of bioarchaeology in Brazil. Regarding population history and structure, new studies are testing models of occupation using sophisticated statistical tools (e.g., Hubbe et al. 2014). Furthermore, new technologies for recording skull shape, such as geometric morphometrics and cranial tomographies, can provide new insights about the biological features of our morphology. Other advances include new techniques for recovering ancient DNA that are revolutionizing our understanding of biological similarities in the past. In Brazil, geneticists have retrieved DNA from sambaquis (Marinho et al., 2006), Amazonia (Ribeiro-dos-Santos et al., 2010), and Botocudo Indians (Gonçalves et al., 2013). From a morphological perspective, very few studies in Brazil have approached intrasite biological variation, which could give us a better sense of the social structure of past populations (Stojanowski and Schillaci, 2006).

Regarding mortuary archaeology, there are two major challenges in Brazilian bioarchaeology. First, we need well-contextualized skeletons exhumed by bioarchaeology-oriented researchers. The quality of data recording methods in the field is essential to the interpretation of funerary rituals (see Mendonça de Souza and Rodrigues-Carvalho, 2013). Second, a solid base in anthropological theory is essential to avoid purely descriptive studies. Because of the diversity of theoretical approaches available in this area, the researcher needs to be explicit about his or her approach.

Regarding health and lifestyle, we need to deal with the increasing complexity of the etiology of the osteological markers usually employed in bioarchaeology (Klaus, 2014). We cannot just record prevalence; we also need to reconstruct past scenarios that include environmental, social, and biological aspects. The expansion of new techniques in Brazil, such as isotopes, dental microwear, and cross-section geometry, can help with this task. However, even more important, it is essential to have solid interpretative biocultural models. The elaboration of interpretative models may come from ethnographic context, experimental approaches, or large osteological databases. We need to be prepared to deal with complex biocultural reconstructions.

Finally, we would like to emphasize that bioarchaeology aims essentially to integrate archaeology and human biological remains in order to recover past behaviors. In light of the expansion of archaeological programs in Brazil, bioarchaeological knowledge needs to be an important part of the training of professionals in this area. This knowledge is even more important because of the large number of human skeletons already housed in Brazilian museums, not counting the ones that will be exhumed in the future. These skeletons should be better packed and preserved in adequate rooms because they can be part of the way we understand our past.

## ACKNOWLEDGMENTS

This study would have been impossible without the support from Fundação de Amparo à Pesquisa do Estado de São Paulo (processes 2013/00069-0) granted to one of us (PD).

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# Contributions to the History of Paleopathology in Brazil

*Claudia Rodrigues-Carvalho*

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**ABSTRACT.** Despite studies on skeletal remains dating back to the nineteenth century, systematic research on paleopathology in Brazil was developed only in the second half of the twentieth century. The consolidation of the field was possible through the interdisciplinary integration of physical anthropologists, archaeologists, and biologists, among others, and interinstitutional partnerships. Here we present some of this history, focusing on people who helped to consolidate paleopathology in Brazil.

**RESUMEN.** A pesar de los estudios en restos de esqueletos que datan del siglo XIX, la investigación sistemática sobre Paleopatología en Brasil se desarrollan sólo desde la segunda mitad del siglo XX. La consolidación del campo fue posible a partir de la integración interdisciplinaria de los antropólogos físicos, arqueólogos, biólogos, entre otros, y las articulaciones interinstitucionales. Aquí presentamos parte de esta trayectoria, centrándose en algunos de los personajes que ayudaron a consolidar Paleopatología en Brasil.

**RESUMO.** Apesar dos estudos em remanescentes esqueléticos remontarem ao século dezenove, pesquisas sistemáticas em paleopatologia no Brasil foram desenvolvidas apenas a partir da segunda metade do século vinte. A consolidação do campo foi possível a partir da integração interdisciplinar de antropólogos físicos, arqueólogos, biólogos, entre outros, e de articulações interinstituições. Apresentamos aqui um pouco dessa trajetória, com foco em alguns dos personagens que ajudaram a consolidar a paleopatologia no Brasil.

## INTRODUCTION

The scientific study of human remains in Brazil dates back to the nineteenth century when physical anthropology and archaeology were also beginning as fields of investigation. The finding of ancient human remains in the Lagoa Santa region (southeast Brazil) by the Danish naturalist Peter Wilhelm Lund was one of the main triggers of wide discussions in both fields regarding human origins and the antiquity of the peopling of the Americas. Studies involving prehistoric and historic human remains from Brazil and some archaeological sites attracted the attention of the local and international scientific community, including scientists dealing with the monogenic-polygenic debate about race and associated issues.

Such discussions about humanity and its emergence attracted the attention of Brazilian Emperor Pedro II. As a science enthusiast who actively participated in scientific forums and associations, his concerns and questions about Darwin's ideas found support in the thoughts of physician, naturalist, and anthropologist Armand de Quatrefages. This relationship resulted in the exchange of abundant correspondence and even the shipment of Lagoa Santa materials by the emperor to his correspondent (Domingues and Sá, 2003).

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*Manuscript received 28 April 2016; accepted  
10 November 2017.*

In addition to Lagoa Santa sites, shell mounds (*sambaquis*) also became a relevant topic of debate. Distributed along the Brazilian coast, these artificial hills could reach more than 20 m high in some regions (mainly in the south, Santa Catarina State). Their curious contents—artifacts, animal bones, and burials mixed in a shell matrix—fascinated earlier archeology enthusiasts. Unfortunately, increasing coastal urbanization and intense economic exploration of shells for lime production destroyed countless sites and encouraged the random collection of many archeological items without context. Artifacts and human bones were sometimes gathered and registered by amateur investigators and were occasionally sent to scientific institutions, a practice that lasted until the twentieth century, with the beginning of systematic archeological excavations of those sites. Such situations led to the removal of data and materials from Santa Catarina shell mounds (including two skulls) for study by the renowned German researcher Rudolf Virchow (Faria, 2003).

In this context, not only the physical aspects of shell mound builders but also the very nature of shell mounds were under scrutiny. Despite the substantial quantity of artifacts and human bones, some researchers continued to deny an artificial origin for these sites, a discussion that also extended into the first decades of the twentieth century (Gaspar et al., 2014).

## EARLY CONTRIBUTIONS

The Royal Museum (later renamed the National Museum) in Rio de Janeiro was the earliest center for anthropological and archaeological studies in Brazil. The first volume of the museum's journal, *Archivos do Museu Nacional*, had among its inaugural papers two regarding shell mounds (Weiner, 1876; Ferreira Penna, 1876) and the classic "Contributions to the Anthropological Study of Indigenous Races in Brazil" by Lacerda Filho and Peixoto (1876). The study summarized the perspectives of anthropology practiced at the time, as stated by Sá et al. (2008:198):

Based on the evolutionist model and largely underpinned by typological approaches, physical anthropology research during the late nineteenth and early twentieth centuries endeavored above all to understand the natural history of the human species and how it has diversified over time. Within this context, the "racial" and similar approaches were predominant.

In the following years, Lagoa Santa and other shell mound groups were understood as distinct (but related) morphological units (Gaspar et al., 2014), further enhancing the studies and hypotheses about their contribution to modern Indian diversity.

Probably the first observations associated with paleopathology by local investigators were registered in an addendum to Lacerda Filho and Peixoto's (1876) article: a note written by Lacerda about the teeth from studied crania (Lacerda Filho, 1876).

The anatomical discussion included observations about intense dental wear and the low presence of caries. Similar considerations were also present in Lund's and Virchow's descriptions of Brazilian materials (Faria, 2003; Birgitte and Sterll, 2011). Nevertheless, health issues and pathologies were far from the focus of these investigations and for decades remained described mostly as punctual facts in the framework of physical anthropology and archeology studies.

By the end of the nineteenth century and the beginning of the Republic, Museu Paulista in São Paulo and Museu Paraense (later Goeldi Museum) in Pará State were also contributing vigorously with new data and ideas for the same questions. The first half of the twentieth century witnessed the emergence of more institutes and organizations devoted to the study, interpretation, and preservation of the past. Three institutions of the time excelled in the promotion of archeology: the **Centro de Estudos Arqueológicos** [Archaeological Study Center] in Rio de Janeiro, later incorporated into the National Museum; the **Comissão Estadual de Pré-História** [Prehistory Commission] in São Paulo (the origin of the former Institute of Prehistory); and the **Centro de Estudos e Pesquisas Arqueológicas** [Archaeological Studies and Research Center] in Paraná (Barreto, 1999–2000).

Despite the increase in archaeological research, discussions regarding the origin and diversity of human groups continued. As suggested by Gaspar et al. (2014:92), "until the first half of the 20th century, the goal of most of the archaeological excavations was to produce skeletons used to establish human types considered representative of the past."

At the same time and as the twentieth century progressed, physical anthropologists were dealing with issues regarding the contemporary Brazilian population and its morphological diversity, trading craniometry for somatology and other topics (Faria, 1952). The study of human remains recovered in prehistoric or historical/modern contexts remained mostly secondary but never interrupted the hegemony of morphology as the core of investigations prevailing over other approaches.

## INFLUENCE OF ERNESTO DE SALLES CUNHA

With archaeology having been discussed and practiced across the country in museums and institutions, finally, in 1961 the federal government enacted a law for the protection of archaeological sites and monuments. The beginning of 1960 also registered the development, although incipient, of the perspective that includes paleopathological observations as a subject of study and reflection on the reconstruction of the past. The book *Shell Mounds and Other Archaeological Sites: Dental Paleopathology and Other Subjects*, by dentist and archaeology enthusiast Ernesto de Salles Cunha in 1963, is probably the first to have used the term *paleopathology* in Brazilian literature. A professor at Fluminense Federal University in Niterói, Rio de



Janeiro State, Salles Cunha also performed archaeological excavations and never restricted his studies to dental anthropology/paleopathology, although it was his main topic of interest. Salles Cunha created and directed the Dentistry Museum at the Fluminense Federal University. The museum collection had some human remains and artifacts that were products of his archaeological activities (Salles Cunha, 1966, 1967). Topics involving oral health, dental mutilations, dental wear, and extraction, for example, were investigated not only by Salles Cunha (1964, 1969) but also by some of his colleagues at the university (Andrade, 1964; Nesi, 1969a, 1969b). Although a significant portion of Salles Cunha and colleagues' works had eminently descriptive characteristics, there were also attempts to interpret the phenomena studied in the context of the environment and cultural practices.

One of Salles Cunha's goals was to characterize past populations' pathological and associated conditions. Shell mounds from Espírito Santo and Rio de Janeiro states were the most studied sites with regard to this concern. Salles Cunha's association with different archaeological institutions can be observed in his analyses of teeth from Niterói past populations (Salles Cunha et al., 1970). This study analyzed materials belonging to the National Museum, the Brazilian Center for Archaeology, and the Brazilian Institute of Archaeology, among others.

According to Sheila Mendonça de Souza (2011), paleopathology as a systematic field emerged in Brazil through three independent efforts. The first one was led by Salles Cunha and colleagues, the second was associated with the first undergraduate course of archaeology at the College of Archaeology and Museology "Marechal Rondon" (later incorporated to Estácio de Sá Integrated Colleges), and the third was the development of paleoparasitology at the National School of Public Health of the Oswaldo Cruz Foundation (Fiocruz).

## OTHER PIONEERS IN THE FIELD

Most of the efforts made by Salles Cunha were, unfortunately, discontinued after his death. Likewise, the expectation of the systematic contribution of odontologists to the field became faint. Marília de Sá Carvalho de Mello e Alvim, contemporary of Salles Cunha and a physical anthropologist at the Museu Nacional, should be considered a special contributor to the growth of studies on human remains and the beginning of paleopathology in the last decades of the twentieth century. In addition to her great scientific output, one of her important achievements was the training and encouragement of many researchers throughout the fields of physical anthropology, paleopathology, and bioarchaeology. According to Powell et al. (2006:185), "a whole generation of archaeologists and physical anthropologists in Brazil learned from her expertise, and many of them subsequently coauthored publications with her." It is no coincidence that the first doctoral thesis on paleopathology had Mello e Alvim as the author's advisor. That author was the paleontologist Jorge Ferigolo, who

discussed vertebrate paleopathology (including human remains) from collections recovered in the Lagoa Santa area and from a shell mound in Santa Catarina State (Ferigolo, 1987).

Marília Mello e Alvim produced an extensive body of scientific literature that includes, but is not limited to, physical anthropology and paleopathological studies. Different analyses of Lagoa Santa and shell mound populations can be found among her publications. Many issues regarding Brazilian prehistory remained on debate (Mello e Alvim, 1963, 1977a, 1977b; Mello e Alvim and Mello Filho, 1965, 1967–1968; Mello e Alvim and Seyferth, 1968–1969, 1971; Mello e Alvim et al., 1975; Mello e Alvim and Uchôa, 1995–1996, 1996; Mello e Alvim et al., 1991).

Two other important researchers in the development of paleopathology in Brazil also linked to Marília Mello e Alvim were Lília Cheuiche Machado and Sheila Mendonça de Souza. Both residents of Rio de Janeiro, they pursued different paths.

Lília Machado's institutional history was tied to the Institute of Brazilian Archaeology, probably the oldest private institute of archaeology in the country still in activity. While living in Washington, D.C., Machado had the opportunity to improve her knowledge at the Smithsonian Institution. This period allowed her to experience new approaches and methods of study in this field. In Brazil, she was the first to use a paleodemographic perspective in the study of prehistoric populations (Machado, 1985, 1991, 1992a, 1992b) and proposed major interpretations of diet, health, and lifestyles from dental paleopathological studies (Turner and Machado, 1983; Machado and Kneip, 1994). She was also one of the first to assume a biocultural approach (Machado et al., 1989a; Machado, 2006) and discuss funerary practices, symbolism, identity, and similar issues from a bio-anthropological point of view (Machado et al., 1989b, 1994; Machado and Sene, 2001). An example of her diverse production and collaborations is the study combining funerary practices and paleoparasitology with colleagues from Fiocruz (Machado et al., 1981–1982). Her sudden death in 2005 interrupted a solid career, but her contributions to the field still inspire many students, discussions, and new investigations.

Sheila Mendonça de Souza's trajectory is linked to two cornerstones she described for the establishment of paleopathology in Brazil: the first undergraduate course of archaeology in Brazil, in Rio de Janeiro at the Estácio de Sá Integrated Colleges (no longer in operation) and the research group at Fiocruz. The undergraduate course of archaeology had a discipline in bone paleopathology under her direction (Mendonça de Souza, 2014), which allowed many students their first steps into the field with a clear archaeological perspective.

With an extensive bibliography in paleopathology ranging from case studies to populational ones and theoretical discussions (e.g., Mendonça de Souza, 1992, 1995a, 1999a, 1999b, 2008, 2014; Mendonça de Souza et al., 2003, 2006), Mendonça de Souza herself is directly responsible for training several current researchers, many of them undergraduates in archaeology.

Despite Rio de Janeiro's influence and confluence of people interested in paleopathology, São Paulo has also been a relevant

place for human remains studies. Marília Mello e Alvim often collaborates with the archaeologist Dorath Pinto Uchôa, a researcher at the Museum of Archeology and Ethnology, University of São Paulo, whose training in physical anthropology is evident through some of her papers dealing with cranial morphology (Uchôa, 1971, 1979).

Walter Neves is another prominent scholar in this field. Although he founded the Laboratory for Human Evolution Studies at the University of São Paulo's Institute of Biosciences, his activities are better suited to bioanthropological approaches. Nevertheless, he has made seminal contributions to paleopathology. Examples include the study of osteoarthritis (Neves, 1984a), the use and dissemination of the osteobiographic concept (Neves, 1984b; Neves and Costa, 1987), and others topics regarding trauma, oral health, etc. (Neves et al., 1999a, 1999b).

In Rio de Janeiro, meanwhile, the last decades of the twentieth century witnessed development of paleoparasitology at the National School of Public Health at Fiocruz. A small team of researchers, inspired by the work of Olympio da Fonseca Filho on parasitism and prehistoric migrations, decided to invest in the study of parasites recovered in archaeological contexts (Gonçalves et al., 2002). A paper presented at the Brazilian Congress of Parasitology in 1979 by Luiz Fernando Ferreira, Adauto Araújo, and Ulisses Confaloniere marks the official beginning of paleoparasitology in Brazil (Araújo and Ferreira, 1997). Soon after, paleoparasitology became an important tool beyond questions about health and environments in prehistory. Discussions and works about parasites and the peopling of the Americas accounted for a repositioning of paleopathological studies on the construction of the past (Araújo et al., 1988; Araújo and Ferreira, 1996, 1997; Araújo et al., 2006). This new approach was possible only because of the team's efforts to establish cooperation with archaeologists and many researchers associated with paleopathology and paleoparasitology. As a result, a solid network of collaboration turned the National School of Public Health into the main center of study and discussion of not only paleoparasitology but paleopathology as a whole.

In 1991, the group's vocation for teaching and training created a specialization course in paleopathology in close collaboration with Della Collins Cook of Indiana University. Among the first students, Mendonça de Souza and Veronica Wesolowski stand out, the latter a former student of the archaeology college in Rio de Janeiro and now a professor at the Museum of Archeology and Ethnology, University of São Paulo. The course had new offerings until the first decade of the twenty-first century, and some former students became teachers as they evolved in the discipline.

### IMPORTANCE OF LITERATURE AND CONFERENCES

Production of specialized literature in Portuguese was essential in promoting the field. In addition to many papers presented

at scientific meetings, articles in diverse journals, and some book chapters on the theme, the book *Paleopatologia e paleoepidemiologia: Estudos multidisciplinares* (Paleopathology and paleoepidemiology: Multidisciplinary studies, edited by Araújo and Ferreira, 1992) reviewed group activities in the last decade of the twentieth century and became mandatory reading. The volume presented articles on the diversity of paleopathological studies and related fields in development at that time. A special chapter about paleopathology by Buikstra and Cook (1992) presented the state of the art of the field and became a guideline for further studies. Topics such as paleodemography, vertebral trauma, porotic hyperostosis, vertebrate pathology, hypoplasia, and coprolites investigations, along with contributions from archaeology and related areas, complete the book.<sup>1</sup>

As a result of these efforts, many students chose the National School of Public Health for master and doctoral courses with a paleopathological framework. For nearly two decades, different themes regarding biocultural approaches, the pathocenosis concept, the investigation of unspecific stress markers, and paleoepidemiological perspectives were among the topics of research aligned with theoretical discussions and international trends with particular influence from North American paleopathology. Violence, infections, developmental anomalies, oral health, diet, and lifestyle investigations were some topics of study. Methods and techniques varied from macroscopic visual inspection to analysis at the molecular scale (Carvalho, 1995; Mendonça de Souza, 1995b; Rodrigues, 1997; Iñiguez, 1998; Rodrigues-Carvalho, 2004; Lessa, 2005; Wesolowski, 2007; Liryo, 2008).

Important for Brazil and all of Latin America was the first Paleopathology Association meeting in South America (PAMinSA I) in 2005, held at the National School of Public Health with the collaboration of the National Museum. The meeting was a symbolic milestone in international recognition of South American paleopathologists' contributions to the field. The event had two short courses: "Paleoparasitology in Brazil," taught by Adauto Araújo, Marcelo Gonçalves, and Karl Reinhard, and "Bone Paleopathology in Brasil: A Short Course," with Della Cook, Claudia Rodrigues-Carvalho, and Veronica Wesolowski.<sup>2</sup> An exhibition on paleopathology and Lagoa Santa that remains at the National Museum was also part of the program. The main themes were related to migration and disease, coastal populations' adaptation, historical research, forensic anthropology, infections, Chagas disease, theory and methods in paleopathology, ancient DNA, and paleoparasitology, among others.

The PAMinSA I was successful as a result of the pioneering spirit and unwavering determination of a small group who built solid foundations for growth and establishment of paleopathological investigations in the Brazil. As pointed out by Powell and Cook (2006:5) in the introduction of a special issue of *Memórias do Instituto Oswaldo Cruz* related to the meeting, "Rio de Janeiro was a highly appropriate venue for PAMinSA I because of the outstanding contributions to paleopathology (and

in particular, to paleoparasitology) made by Brazilian scholars at Fiocruz over the past quarter century.”

## CONCLUSIONS

A decade after PAMinSA I the field maintains an inter- and multidisciplinary character that has allowed the development of different approaches and the use of distinct methodologies. From the efforts of the above mentioned researchers and research groups engaged in the study of human remains, a new team of investigators was attracted to the field and, after receiving training in paleopathology, has been working in different parts of the country. From north to south, undergraduate and postgraduate courses dealing with the past include paleopathology as a curricular discipline or the main topic of bioarchaeological studies. Health and lifestyles are no longer peripheral issues in archaeological studies. The field is now established, and it is up to this mixture of pioneers and beginners to maintain and expand paleopathological studies in the country.

## NOTES

1. Also relevant for students' education were two special issues of the journal *Memórias do Instituto Oswaldo Cruz* (volume 98, supplement 1, 2003, and volume 101, supplement 2, 2006) regarding paleopathology and paleoparasitology and the more recent book *Foundations of Paleoparasitology*, which is already considered a classic (Ferreira et al., 2014).
2. Karl Reinhard was another long-term collaborator of the Fiocruz team. Because of their numerous collaborations and international partnerships, Karl Reinhard and Della Cook can be regarded as major partners in the development of paleopathology in Brazil.

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# 4

## Forensic Anthropology and Archaeology in Brazil

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**ABSTRACT.** This chapter presents aspects of the configuration of forensic anthropology and forensic archeology in Brazil, discussing concepts, methodological and technical specificities, and the needs of these disciplines as well as the difficulties of conducting research. These fields are interdisciplinary and multidisciplinary, even though they are subordinated within legal medicine. From 1900 to the present, forensic anthropology has shown no continuity, as evidenced by the lack of any publications or anthropological reports in professional journals, including those in the fields of physical anthropology and archeology. The formation of new auxiliary forensic science justifies the sudden rise of forensic anthropology, especially linked to the difficulty of solving political cases related to totalitarian governments imposed during the years 1930–1980, the training of legal professionals, and the formation of subjects and courses of expertise in these areas. International consultancy, with the exchange of knowledge and new methodological and conceptual adjustments, is essential in these cases because of the significant experience accumulated in countries such as the United States, the United Kingdom, and Argentina. These developments relate to the management and development of mechanisms of scientific research disciplines in forensic anthropology and archeology in Brazil. The criminal case models can be found in official documents produced by anthropology laboratories of police institutions, representing the roots of forensic anthropology and rare experimental simulations of forensic archaeological excavation practiced in Brazilian university courses and taught at forensic institutions. Databases and cases related to the establishment of biological profiles are scattered, with rare exceptions associated with national scientific output.

**RESUMEN.** El artículo presenta aspectos de la configuración de la antropología forense y la arqueología forense en Brasil, retomando conceptos, especificidades metodológicas y técnicas, y necesidades de esas disciplinas, así como las dificultades de la implantación de sus líneas de investigación. Se verifica la interdisciplinariedad y multidisciplinariedad de esas disciplinas, a pesar de que están subordinadas, en medios forenses, a la medicina legal. Entre 1900 hasta la actualidad, la antropología forense no mostró continuidad en la producción de investigación básica o aplicada, siendo éstas representadas por publicaciones eventuales de informes antropológicos en revistas especializadas y en el campo de la antropología física y arqueología. La formación de nuevas ciencias forenses auxiliares justifica el ascenso repentino de la antropología forense en Brasil, especialmente vinculada con casos políticos de difícil solución en relación a los gobiernos totalitarios impuestos durante los años 1930 a 1980, a la formación de profesionales forenses y a la formación de disciplinas y cursos de especialización en esas áreas. La consultora internacional con intercambio de conocimientos y nuevos ajustes metodológicos y conceptuales, es esencial en esos casos debido a las experiencias significativas acumuladas en países como los EE.UU., Reino Unido y Argentina, representando uno de los mecanismos de gestión y desarrollo de las líneas de investigación científica de la antropología y arqueología forenses en Brasil. Modelos de casos criminales en Brasil se pueden encontrar en los documentos oficiales producidos en los laboratorios de antropología de las instituciones policiales, donde se verifica el origen de la práctica de la antropología forense y de las raras simulaciones experimentales de excavaciones arqueológicas forenses practicadas en cursos universitarios e instituciones de enseñanza forenses. La reconstrucción del perfil biológico a partir de los restos óseos humanos incluye la determinación del sexo, edad, ancestralidad, traumatismos, enfermedades, anomalías, altura y señas particulares, cuyas bases de datos y de casos se encuentran dispersos y con raras expresiones en la producción científica nacional.

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

**RESUMO.** O texto apresenta aspectos da configuração da antropologia forense e da arqueologia forense no Brasil, retomando conceitos, especificidades metodológicas e técnicas e carências dessas

disciplinas, bem como as dificuldades da implantação de suas linhas de pesquisa. Verifica-se a interdisciplinaridade e a multidisciplinaridade dessas disciplinas, muito embora estejam subordinadas, em meio forense, à medicina legal. Entre 1900 até o presente, a antropologia forense não apresentou continuidade de produção de pesquisa básica ou aplicada, sendo estas representadas pelas publicações eventuais de laudos antropológicos em periódicos especializados e no campo da antropologia física e arqueologia. A formação de novas ciências forenses auxiliares justificam a ascensão repentina da antropologia forense no Brasil, especialmente vinculada aos casos políticos de difícil solução relacionados aos governos totalitários durante os anos 1930 a 1980, ao treinamento de profissionais forenses e à formação de disciplinas e cursos de especialização nessas áreas. A consultoria internacional com troca de conhecimentos e novas adequações metodológicas e conceituais é essencial nesses casos devido às experiências significativas acumuladas em países como os EUA, UK e Argentina, representando um dos mecanismos de gerenciamento e desenvolvimento das linhas de pesquisa científica em antropologia e arqueologia forenses no Brasil. As casuísticas brasileiras advêm dos documentos oficiais produzidos em laboratórios de antropologia das instituições policiais, onde se verifica a origem da prática da antropologia forense e das raras simulações experimentais de escavações arqueológicas forenses praticadas em disciplinas de universidades e no ensino em instituições forenses. A reconstrução do perfil biológico a partir dos remanescentes ósseos humanos inclui a determinação do sexo, idade, ancestralidade, traumas, doenças, anomalias, estatura e sinais particulares, cujos bancos de dados e de casos encontram-se dispersos e com raras expressões na produção científica nacional.

## INTRODUCTION

Forensic anthropology involves the application of methods in anthropology and archaeology to remains recovered in a medico-legal context. In Brazil, anthropology in a forensic context is closely related to forensic medicine. As in other parts of the world, forensic anthropologists in Brazil analyze recovered remains to determine species, number of individuals represented, time since death, features that can lead to identification, and any evidence relating to cause and manner of death (Krogman and İşcan, 1986; Carvalho et al., 1987; Arbenz, 1988; Croce and Croce, 1996; Siegel et al., 2000; Silva, 2000; White and Folkens, 2000; Hunter et al., 2002; Hunter and Cox, 2005; Byers, 2008; Cox et al., 2008; Komar and Buikstra, 2008; Blau and Ubelaker, 2009). This chapter presents the historical development of forensic anthropology in Brazil and its current status.

The development of forensic anthropology in Brazil since 1900 involves early French and Italian influence, as well as Spanish and North American training in physical anthropology and, more recently, forensic anthropology. Trends include the formation of forensic anthropology as a branch of forensic medicine and forensic anthropology jointly with the emerging field of forensic archaeology. These fields also relate to forensic medicine and forensic dentistry.

## HISTORICAL DEVELOPMENT OF FORENSIC ANTHROPOLOGY IN BRAZIL

Forensic anthropology refers to the collection of scientific knowledge of biological (physical) and cultural anthropology

that can be applied in the practice and administration of the law. Croce and Croce (1996) define the term as the very practical application of the body of knowledge of general anthropology. This application seeks to address issues related to forensic identity. The identification process involves the use of medical knowledge and related sciences, including anthropometric and fingerprint analysis.

The concept of forensic anthropology, employed by Arbenz (1988), Croce and Croce (1996), and Lessa (2010), emphasizes practical aspects of applications related to identification. The application of forensic archaeology methods in conjunction with forensic anthropology was pioneered in Brazil by Monteiro da Silva and R. Oliveira (2005), Monteiro da Silva and Calvo (2007), Monteiro da Silva and M. Oliveira (2009), and Monteiro da Silva et al. (2009, 2012). Similar approaches have been described by Carvalho and Funari (2009), Fuzinato et al. (2009), and Zarankin and Funari (2009). The joint participation of international researchers is described in an article by Hunter (2009) that discusses methodological aspects of forensic archaeology.

A historical perspective provided by Byers (2008) suggests forensic anthropology in the United States has three main periods: (1) the formative period (1800–1938), (2) the consolidation period (1939–1971), and (3) the modern period (1972 to present). This division aims to group data to understand the paths that led to highly academic and late institutionalization of anthropology in forensic applications. In South America, the institutionalization of forensic anthropology began around 1980 in Argentina, with the creation of *Equipo Argentino de Antropología Forense*, which was followed in subsequent decades by the formation of groups in neighboring countries such as Peru, Venezuela, Chile, and Colombia. These teams were often linked to addressing problems produced by the actions of totalitarian regimes. In Brazil, historical development can be grouped into (1) the training period (1900–1990), (2) the consolidation period (1991–2010), and (3) the current period (2011 to present). The training period includes the production of forensic, scientific, and technical publications as well as works that were not published (e.g., expert technical reports and anthropological reports). These products reflect the first basic and sporadically applied research without academic institutionalization and without the support of any society or association.

The consolidation period features government social and political rulings related to official institutions or centers of anthropology and forensic archaeology (the course of forensic anthropology at Museu Nacional, Universidade Federal do Rio de Janeiro; the first course of forensic archaeology and laboratory of forensic anthropology at the Civil Police Academy of São Paulo; Centro de Medicina Legal, Centro de Apoio da Faculdade de Medicina de Ribeirão Preto, Universidade de São Paulo; the initiative of the Ministry of Justice and Public Prosecution of Brazil to create a working group to plan a National Unit of Forensic Anthropology and Archaeology; the discipline of forensic archaeology at Faculdades Oswaldo Cruz, São Paulo; and others). This period also includes demands for international policy, establishing basic research on the subject, and the beginning of official training



courses at forensic institutions and universities. This period is characterized by rare experiments in the field and laboratory predominantly aimed at solving cases of political crimes.

The current period marks the formation of forensic anthropology and forensic archaeology as established disciplines. Specialized and extended courses devoted to these themes were created, along with research centers aimed at the development of forensic anthropology and forensic archeology to resolve cases of political crimes of previous totalitarian regimes.

All these periods involved the participation of scientists from other countries, such as Alberto Rubio-Fuentes (Spain) in 1970, Douglas H. Ubelaker (United States) in 2002, and John Hunter (England) in 2009, among others. The late emergence of Brazilian research centers is the result of the policies of totalitarian government regimes in two stages between 1930 and 1985 and the precarious and insufficient development of scientific research in forensic medicine and related fields of anthropology. In addition, universities were associated with eugenics practices in European totalitarian governments, such as in Germany and Italy in the first half of the twentieth century. Anthropometric and osteometric instruments were rarely found at universities, such as the Museu de Arqueologia e Etnologia da Universidade de São Paulo. Such instruments remained unknown to criminalists in Brazil, resulting in improvisation and the use of inappropriate equipment, as well as the employment of outdated techniques. A key factor in this inadequacy was the lack of scientific societies actually linked to the production of knowledge in the field of forensic anthropology and directed toward forensic investigation of problems of Brazilian society, including common crimes (domestic homicides), suicides, accidents, disasters, and crimes of a political nature. Forensic anthropology in South America, when institutionalized, was almost exclusively focused on political crimes, which represent an internationally visible demand, without contributing as strongly to the implementation of institutionalized forensic practices that address other issues at the national level.<sup>1</sup>

In Brazil, forensic anthropology outside strictly academic institutions, represented by schools, foundations (e.g., Fundação Oswaldo Cruz, Rio de Janeiro), and research centers at federal universities (e.g., the Museu Nacional of the Universidade Federal do Rio de Janeiro), is an accepted field of science and a discipline linked to the judicial problem of identification, with a focus on skeletonized remains. The Instituto Médico Legal of São Paulo, for example, contains two significant centers, the Centro de Antropología Forense and the Centro de Odontologia Legal. These nuclei consider responses to legal questions through examination of bones and dental remains from crime scenes and judicial exhumations, processing severely decayed corpses and macerated samples. Data regarding remains are recorded in pre-established forms (Monteiro da Silva, 2009) and in databases specific to the institution. The participation of legal professionals from official institutions in concealing evidence in cases of deceased and missing persons during totalitarian regimes between 1930 and 1980 has resulted in unofficial interinstitutional conflicts with university researchers, medical examiners, coroners, and forensic dentists.

Monteiro da Silva (2009) suggests that a historical source for forensic anthropology can be found in the technical work in reports and publications of medical and scholarly studies of fingerprints in the first half of the twentieth century. These scholars developed their techniques to examine human skeletal remains at anthropology laboratories of forensic institutes. Noteworthy texts include those of Godoy (1936a, 1936b, 1937, 1947), Daunt and Godoy (1937), Martins (1939), and Godoy and Moncau (1947). Avila (1958) and Arbenz (1988) were also important in the production of scientific knowledge of physical anthropology. Later works related to the study of human identification in the context of forensic anthropology consist of contributions by Arbenz (1988) and the monographs of Coiradas (2008) and Tiradentes (2009).

Currently, biological anthropology includes the specialty of forensic anthropology, a discipline that is closely related to legal medicine but also includes aspects of human biology, physical anthropology, and bioarchaeology in its structure. The discipline was strengthened internationally in 1972 when a Physical Anthropology Section was established within the American Academy of Forensic Sciences. Important momentum was also gained in 1977 with the formation of the American Board of Forensic Anthropology in the United States. Forensic anthropology is considered by Stewart (1954, 1979) as an applied field of physical anthropology that is aimed at identifying more or less skeletonized human remains to meet legal purposes. The field is concerned with the establishment of a biological profile from the recovered human remains, determining sex, age, ancestry, stature, and individual characteristics (antemortem fractures, signs of illness, etc.), with the goal of positive human identification.

In Brazil, forensic anthropology has been considered a specialty of doctors and dentists in forensic applications. A discipline-oriented course in this subject was officially established at the São Paulo State Civil Police Academy (Monteiro da Silva and R. Oliveira, 2005; Monteiro da Silva and M. Oliveira, 2009; Monteiro da Silva et al., 2009). This course focused specifically on the experimental practice of forensic archaeology, with the participation of archaeologists and experts from the fields of bioanthropology and forensic science. Participants include police officers in training or those specializing in police education and coroners. In this context, the discipline of forensic archaeology was created, and positions for teachers of these subjects at the police school were established in 2005. Legal professional specialization courses, conducted between 2005 and 2010, utilized translations and parts of the following works: Sprague (1968), Angel (1974), Morse et al. (1976), Bass and Birkby (1978), Ubelaker (1980, 1989), Brothwell (1981), Pallestrini and Morais (1982), Ubelaker and Scammell (1992), Buikstra and Ubelaker (1994), Bass (1995), Haglund and Sorg (1997), Hoshower (1998), Mays (1999), Hunter (2000), Cox and Mays (2000), Siegel et al. (2000), White and Folkens (2000), Brothwell and Pollard (2001), Taylor (2001), Roksandic (2002), Queiroz (2004), Dupras et al. (2005), Connor (2007), Coelho and Jorge (2008), and Cox et al. (2008).

Comas (1957) emphasizes the difference between physical anthropology and other sciences such as biology, anatomy, and

human physiology since the second half of the twentieth century. Although there are close relationships among these groups of sciences, it seemed clear to Comas (1957) that each had working methods and techniques for different purposes. Anthropology is also closely related to the medical field, as noted by the Rubio-Fuentes (1975), who taught a course in physical anthropology at the old Instituto de Pré-História of Universidade de São Paulo in 1970.

Noteworthy Brazilian anthropologists and doctors include José Bastos de Avila<sup>2</sup> and Arthur Ramos.<sup>3</sup> A contemporary to Avila, Berardinelli (1942) published *Tratado de biotipologia e patologia constitucional*, focused on somatic/physical studies of Brazilians. Also from Rio de Janeiro, Castro Faria (1952) published “Pesquisas de antropologia física no Brasil” in *Boletim do Museu Nacional*, and Alvaro Fróes da Fonseca (1957) established the normative principles to the study of race and miscegenation in Brazil. Pedro Estevam de Lima (1952, 1954) studied morphology of the upper incisors and their anthropological significance and dental mutilation among Tenetehara. Later, other anthropologists such as Arbenz (1988) contributed to the construction of physical anthropology in Brazil. Marília Carvalho de Mello e Alvim, an anthropologist at the Museu Nacional in Rio de Janeiro in the Departamento de Antropologia of the Divisão de Antropologia Biológica da Universidade Federal do Rio de Janeiro, together with dentist Bidegain Cleber Pereira, published the *Manual para estudos cranioscópicos e craniométricos* in 1979.

According to Avila (1958), Paul Broca (1824–1880) boosted physical anthropology through his creation of the Anthropology Laboratory of the School of Higher Studies (École des Hautes Études) in 1871 and School of Anthropology of Paris in 1876. In Brazil, this French school influenced the development of physical anthropology in the second half of the nineteenth century. The most prominent researchers in the study of Anthropology in Brazil were João Batista de Lacerda, José Rodrigues Peixoto, Edgar Roquette-Pinto, and Alvaro Fróes da Fonseca.

In regard to criminal investigation, anthropometry has historically dominated techniques for human identification. In Brazil, since 1879, the work of Alphonse Bertillon (1887) relating anthropometric data to identification was quite influential before the introduction of more efficient processes, represented by papiloscopia, fingerprinting, and, more recently, comparative biomolecular analysis.

### **CURRENT STATUS OF FORENSIC ANTHROPOLOGICAL KNOWLEDGE AND USUAL METHODOLOGICAL PERSPECTIVES OF APPLICATION**

Methods of studying criminal anthropology (later known as criminal sociology) in the early twentieth century that still impact current practice include craniometric measurements, cranial morphology and related graphical representations, skull

abnormalities, dental anomalies, brain development, the study of the living individual, identification, fingerprinting, psychic characters, biographical and ethnogeographic (*normotipos*) data, height and weight, experimental psychology, plethysmography (record of the psyche), criminal craniology, comparative anthropometry, psychic anomalies, and organic atavism. The recurrence of some of these themes in modern forensic anthropology is related to the individual identification process (deceased or living) and behavioral studies. The technical requirements set by Bertillon for human identification based on the uniqueness of anthropometric characteristics, the immutability of certain characteristics after the age of 20 years, and the feasibility of the measurement and classification of individual anthropometric data are still considered valid and repeatedly compiled in forensic practice in Brazil.

Carvalho et al. (1987) note that forensic identification is accomplished utilizing diverse data. Identification must also consider the complex processes of postmortem change.

The methodologies and techniques of forensic anthropology employed in Brazil include the following:

1. Individual bone units should be identified through rearticulation of the skeleton. The minimum number of individuals (MNI) should be established through the characteristics, frequency, and recurrence of certain skeletal elements. The species of the bones should be determined (human or nonhuman; Angel, 1974), and then the bones must undergo a controlled cleaning processes, unlike the cleaning performed in archeology laboratories, with restoration and numbering. During this step samples are collected for trauma, toxicology, pathology odontology, and DNA analysis, among others. Forensic practice in legal medical institutes indicates the use of preliminary registration forms.

2. The ancestry group or ethnic-racial affinity should be evaluated through craniometry and craniology (Carvalho et al., 1987; Croce and Croce, 1996). In such cases there are programs that analyze cranial indices such as the characteristics of the anterior nasal aperture (nasal index); maxillary prognathism; cranial index; and orbital morphology (for example) to collectively evaluate ancestry. Certain cranial traits may indicate affinities of ancestry, such as the development and morphology of the zygomatic bone, the shape of the nasal bones and orbits, occipital conformation, significant features in the chin and gonion, differences in the angles of the face, aspects of maxillomandibular prognathism, and bowing of the femur. Certain epigenetic characters such as shovel-shaped incisors, parietal suture foramen, and mandibular morphology may indicate certain ancestry (European, American, African, Asian, or Australian).

3. Sex is diagnosed through morphoscopic and morphometric analysis of the skull, pelvic bones, femur, and other long bones. A comprehensive bibliography has been produced by various authors for both eclectic studies focused on physical anthropology and forensic anthropology (Sousa, 1954; Pereira and Mello e Alvim, 1979; Carvalho et al., 1987; Arbenz, 1988; Mendonça de Souza, 1990; Croce and Croce 1996). Among the variables used in the diagnosis of sex is morphoscopic analysis

of the skull and mandible: aspects of the front slope and prominence of the glabella and superciliary arches; angularity of the frontonasal joint; development of the supraorbital ridges; development, width, and height of the mastoid process; mandibular arching, strength, development, and curvature of the mental region; morphology of sites of muscular attachments; size of the mandibular angle; metric characters, length, and width of the occipital condyles; size of the styloid apophysis; development of the external occipital protuberance; expression of the nuchal crest; length and width of the foramen magnum, etc. In the pelvic bones important features are the predominance of vertical and horizontal dimensions, the degree of subpubic angle, the ventral arc, the depth of aperture and index of the greater sciatic notch, and the morphology of the sacrum. In the long bones, key features include the septal aperture in the distal humerus, aspects of the development of the regions of skeletal muscle insertions, the diameter of the femoral head (as in the humerus), and the angle between the longitudinal axis of the shaft and the plane on which the condyles of the distal epiphysis are supported. The dimorphic features for estimating biological sex should be considered together and in relation to contextual data.

4. The calculation of an individual's height considers the length of the long bones of the appendicular skeleton (humerus, ulna, radius, femur, tibia, fibula, and metacarpal and metatarsal bones; Carvalho et al., 1987; Arbenz, 1988; Croce and Croce, 1996) or fragmentary remains (following international literature, e.g., Steele and Bramblett, 1989). The skeleton should be considered as a whole with articulated elements. Prior articulation of the skull, vertebrae, pelvis, femur, tibia, talus, and calcaneus in sequence may indicate the bone height of the body, which can be compared to the statistical result for the living body.

5. Estimated biological age or estimated age at death should, whenever possible, consider the skeleton as a whole. A greater number of observed variables increases the accuracy of the test. Estimating age at death considers macro- and microscopic characteristics, such as the stages of tooth development, mitochondrial DNA, and bone development (Carvalho et al., 1987; Croce and Croce, 1999). The synostosis of the cranial sutures, associated with the closure of the epiphyseal lines during the development of the long bones, ribs (aspect of the sternal ends), hip bones (aspect of the pubic symphysis), features in the scapula, and vertebrae are indicative of the likely age of an individual. Stages of skeletal degeneration, such as the formation of osteophytes in the vertebral bodies and the wear and abrasion of teeth and tooth loss, may indicate skeletal age older than 30 years. Age indicators of the teeth and bones are considered together and observed macroscopically.

6. Identification of injuries, traumas, osteopathology, anomalies, and traces of bone stress from work activities are key aspects of analysis. For example, Gimenez and Fava (2005) elucidate the fracture of the hyoid bone, analyzing conformation of the apophysis axis of the vertebral body of the atlas and axis, as well as displacement of the axis in cases of mechanical asphyxia by constriction of the neck by hanging or strangulation in the

case of homicide (accidents and suicide are unlikely). A scanning electron microscope is employed by experts for the identification of elements such as lead peaks, iron, and aluminum in bone regions to suggest firearm trauma or sharp force trauma. Certain types of instruments of crime or accidents correlate with specific types of trauma and bone lesions (e.g., fractures; Croce and Croce, 1996) and may produce evidence in the bone.

7. Cause of death is determined from various types of skeletal evidence. Analysis of judicial exhumations can identify and interpret traumatic lesions not previously located or intentionally hidden during earlier examinations. Examples include evidence of projectiles from firearms and skull fractures caused by blows, as well as trauma in the cervical vertebrae and hyoid bone.

8. Determination or verification of personal identity through dental evidence is accomplished in the most part through forensic dentistry (Arbenz, 1988; Oliveira et al., 2002) but is related to forensic anthropology. Factors considered include tooth loss, supernumerary teeth, position anomalies, occlusion, congenital anomalies, changes premortem by type of occupation, accidents, diseases, ancestral traits, restorations, burns, bite marks, age calculation in children, and identifying tooth fragments. Other tests include radiographic comparisons and other medical documents associated with the remains. Frequent comparative features include articular surfaces, sinus frontalis dimensions, paranasal sinus, dental characteristics, prostheses, dimensions of bones, antemortem diseases, and traumas.

9. Techniques involving three-dimensional and two-dimensional facial reconstruction from the skull and cranial photographic superimposition are also practiced to help identify missing persons. Comparative antemortem/postmortem methods, digital facial reconstruction programs, and even forensic sculpture and design manuals are useful when adjustments are made to the population sample under study. Police in Brazil (forensic art experts in the São Paulo civil police) utilize sketches from descriptions and also from skulls to assist in criminal investigations.

Other information not addressed in the above list includes the actual location of discovery, context of burial and exhumation, and procedures for lifting evidence (such as fingerprints and tire impressions) with graphic visual recognition (*reconhecimento visuográfica*) of the crime scene (Desgualdo, 1999). The stratigraphic distribution, both horizontal and vertical, of the scene as well as relative and absolute dating of the context relate to methods of archeology. Dating can be established by the presence of clothes, personal items, buttons, etc., that can be compared to lists of datable products by manufacturers. Information about brands of clothes and footwear and their market dates, prostheses (internal or external), and individual use of objects can help provide dates for each case. Contacts and information from friends and family are always essential to the progress of an investigation. Analysis of microtaphonomic changes, depending on environmental and anthropogenic factors, may indicate deterioration levels and their chronology.

The process of exhumation (*desenterramento*) of remains in a burial context (not hidden in a criminal way, but officially

buried) has legal formalities provided for in article 6, section I, of the Código de Processo Penal (CPP; see Nucci, 2007), and failure to follow this code results in a penalty, in accordance with article 67 of the Lei de Contravenções Penais. For Silva (2000), the exhumations were divided into two major groups: (1) legal, further subdivided into voluntary (removal, repatriation, and scientific), administrative, and judicial; and (2) illegal. For example, Croce and Croce (1996) distinguish administrative burials carried out in cemeteries from those improvised in concealment of human corpses at crime scenes. One differs from the other by the presence or absence of a relation to a criminal event and the depositional context.

The photographic record of the position in which the coffin and corpse (or skeletal remains) are found is outlined in article 164 of the CPP. Samples of bones, hair, and soil from the pit and surrounding area may be collected by experts (Resolução 194/1999 of Secretaria da Segurança Pública do Estado de São Paulo). The methods of disclosure and exhumation of skeletal remains of interred corpses are among the frameworks of archaeological science. Commonly, this task is left in the hands of gravediggers or the fire service. Even in cases of criminal burials, rather than official burials in cemeteries, firefighters perform the localization tasks, excavation, and removal of human remains. Eventually, a medical examiner or an expert and auxiliary personnel are operationally involved in this activity. Forensic archaeology plays a key role in systematic excavation, through disclosure, documentation, mapping, removal, and pretreatment of bone material for subsequent medical-legal and forensic anthropological analysis.

The object of forensic anthropology, when compared with the objectives of criminal investigations or other police activities and criminal or civil judgment, is related to human identification a priori. It is essential to identify the individuals in cases of infanticide and inheritance disputes in which corpses or skeletons of individuals are found without documents or other indicative signs of identity, especially in relation to victims and offenders (Carvalho et al., 1987). In this sense, forensic anthropology constitutes a multidisciplinary field related to legal medicine, legal dentistry, forensic pathology, and forensic archaeology (Blau and Ubelaker, 2009).

### **TOPICS THAT REQUIRE NEW METHODOLOGICAL APPROACHES AND CONCLUSION**

Research conducted by Lessa (2005) for the Secretaria Nacional de Segurança Pública resulted in collection of quantitative and qualitative data on state-of-the-art technical and operational procedures of experts in forensic anthropology in five Brazilian capitals, stressing the need for the presence of (and thus hiring of) expert forensic anthropologists at official institutions while simultaneously indicating the lack of undergraduate and graduate programs in this field in Brazil. Lessa's research included a

questionnaire distributed to samples of forensic professionals that made it possible to quantitatively and qualitatively evaluate their training and the adequacy of procedures they performed. This evaluation represents an important first step, in addition to the translations and comments made by historian Pedro Paulo Funari at the Universidade de Campinas on the state of the practice of forensic archaeology policy in Latin America, and the efforts of Monteiro da Silva (2009), in regard to improving archaeological methods and techniques between 2004 and 2010, together with legal professionals in the state of São Paulo. Before creation of the first working groups in the Ministério da Justiça of Brazil for establishing standard procedures for national use in forensic anthropology and archeology, the establishment of the Centro de Estudo de Medicina Legal da Faculdade de Medicina de Ribeirão Preto, and the Centro de Antropologia e Arqueologia Forense da Universidade Federal de São Paulo, these contributions were essential for the comprehension of the conformation of archaeology and anthropology in the forensic environment in Brazil.<sup>4</sup> Recently, some Brazilian federal universities, such as the Universidade Federal do Rio de Janeiro, the Universidade Federal do Pará, Universidade Federal de Sergipe, and the Universidade Federal de Pernambuco, have offered courses in the fields of forensic anthropology, biological anthropology, forensic archaeology, and bioarchaeology.<sup>5</sup> A testament to this growth can be found in the references cited in Buikstra and Beck (2006) and Blau and Ubelaker (2009), which include some Brazilian researchers (anthropologists and archaeologists) and colleagues in neighboring countries.

The prospecting (systematic onsite searching and scanning), location, intervention (systematic archaeological excavation), recovery, and study of skeletal remains of participants of the Guerrilha do Araguaia have been in progress since the first ordinances that established research groups and work (the Grupo de Trabalho Araguaia) on the subject (Portaria Interministerial No. 1669 of 21 July 2011, Portaria Interministerial No. 1 of 5 May 2011, and Portaria Interministerial No. 1102 of 5 June 2012, repealed by Portaria Interministerial No. 1.540 of 8 September 2014). This effort has produced technical reports and cooperation between professionals at public institutions responsible for forensic studies in anthropology and archaeology, with participation of families, under the Secretaria de Direitos Humanos da Presidência da República, the Ministério da Defesa, and the Ministério da Justiça of Brazil. Participants include members of the federal and civil police (doctors and experts) and archaeologists from public universities.

In the field of forensic anthropology, the following actions are needed regarding human skeletal remains and government policies in Brazil:

- Creation of graduate-level courses in forensic anthropology and forensic archaeology in Brazil and the establishment of the profession of forensic anthropology and archaeology.
- Modeling of standard procedures adapted to the national (Brazilian) population for newly created research

centers and foundations that are appropriate for forensic anthropology related to the systematic treatment of samples, identification of biological species, MNI calculation, diagnosis of sex, estimation of biological age (age at death), calculation of stature, determination of ancestry, diagnosis of diseases and anomalies, identification and interpretation of trauma and injuries, inference of cause of death, facial reconstruction, and personal identification.

- Creation of appropriate standards in forensic archaeology and anthropology focused on the exploration for and location, excavation, recovery, and eventual laboratory treatment of skeletons and associated evidence.

There is at once a certain closeness and distance between archaeological approaches and forensic approaches during excavation to recover human remains, apart from the problems of archaeological research or criminal investigation. For Komar and Buikstra (2008), although many of the themes and methods used in archeology and forensic science are the same, it is important to remember that the objectives of each type of research are clearly distinct. Their methods and approaches may vary. Many forensic anthropologists, in addition to doctors, learn archaeological excavation techniques in initial training that emphasize the excavation of standard units and the recognition of cultural, natural, or arbitrary levels of deposition. Although suitable for archaeological applications, rigid adherence to methods taken from textbooks in forensic settings is not appropriate. Work on judicial exhumations should be modified with flexible excavation strategies developed for each case. In a mass grave, for example, the mandatory use of an excavation strategy based on a 1 m<sup>2</sup> grid and a depth range of 10 cm potentially introduces an artificial and arbitrary division of proof, space, and time and does not contribute to the interpretation of the clandestine burial. In this sense, the grid helps planimetric location of the remains in a criminal event scene sector. Only when there is convergence of objectives should archeology be considered forensic science. The collection of case studies in a forensic context is essential.

Both archaeological and forensic investigations require that excavations focus exclusively on the reconstruction and understanding and interpretation of human behavior in the past (and its impact on present and future societies). In the second case, the dynamics of the scene of a crime in the past is the main object. Both types of issues require accurate documentation of the location and relationship between the features, artifacts, and evidence. How these goals are met varies between forensic and archaeological contexts.

In the case of Brazil, the recent implementation of the Centro de Antropologia e Arqueologia Forense of the Universidade Federal de São Paulo and the studies developed at the Centro de Estudos de Medicina Legal of the Universidade de São Paulo in Ribeirão Preto are gradually enabling the practice of forensic anthropology in Brazil. The space of forensic anthropology—and

its osteological and genetic approach—is being (re)constructed in Brazil with these two research centers created in the last decade.

On the other hand, forensic archaeology—and its contextual, field-based approach to the excavation of bones and other evidence—has potential for development along with undergraduate archaeology courses at state and federal universities in Brazil and specialization courses and undergraduate and university extension courses at some universities and colleges. Examples include the Faculdades Oswaldo Cruz in São Paulo, the Departamento de Arqueologia and Curso de Graduação de Arqueologia of the Universidade Federal de Pernambuco in Recife, the Museu Nacional da Universidade Federal do Rio de Janeiro, the Fundação Oswaldo Cruz, the Museu Emilio Goeldi in Belém, and the Faculdade de Odontologia of the Universidade de São Paulo (FO-USP), as well as the activities of some laboratories, such as the Laboratório de Arqueologia Biológica e Forense of Universidade Federal de Pernambuco and the Laboratório de Antropologia e Odontologia Legal of FO-USP. These institutions have worked to develop teaching and basic research in archaeology and forensic anthropology in Brazil.

Participation of police professionals in developing and using forensic science, however, has not yet occurred effectively in Brazil, with the exception of the forensic anthropology team of the Polícia Federal, Brasília, and the special courses in forensic archaeology of the civil police of São Paulo between 2005 and 2010. Factors include the current lack of teaching of archaeology and forensic anthropology at police academies and chronic lack of communication among universities, researchers, and police institutions.

Solutions, in the case of Brazil, include production of basic and applied scientific research for the construction of standards in both forensic anthropology and forensic archaeology. These solutions recognize the justifiable demand for human rights in civil, criminal, political, and economic instances. They include development of police training in these forensic areas and expected interaction between archaeologists, anthropologists, and crime scene managers and investigators. The creation of positions or police career paths that include archaeologists is important, considering that anthropologists in police units are medical examiners and some categories of criminal experts. Finally, the political and economic incentive for the exchange of international forensic researchers in archaeology and forensic anthropology is needed, as well as the same incentive in the training of professionals in these areas in Brazil.

## NOTES

1. Monteiro da Silva and R. Oliveira (2005) and Monteiro da Silva (2009) indicated the lack of awareness of the field of forensic anthropology and the products of its researchers in government forensic institutions with coroners, forensic experts, and other professionals. A variety of published bibliographies, derived from official documents and bibliographies of universities, display this lack of unity in relation to the theoretical and methodological conformation of the forensic anthropology discipline.
2. José Bastos de Avila graduated in sciences and letters from the old Colégio de São Vicente de Paulo in Petropolis, Rio de Janeiro, in 1908. Later, he

graduated in medicine, entering the medical and hospital inspection staff of the Prefeitura do Distrito Federal, Brasília. His work in anthropology was characterized by collecting somatophyical data from school children. Later, he was appointed head of the Serviço de Antropometria do Instituto de Pesquisas Educacionais under the Ministério da Educação e Cultura. He performed research on the physical development of children at the Rio school. In the same period, he entered the Museu Nacional of Rio de Janeiro as a professor in the Seção de Antropologia, teaching the third course of anthropology in Brazil. He became a professor at the Faculdade Nacional de Medicina da Universidade do Brasil and a professor at the Faculdade Fluminense de Medicina. In 1958 he occupied the cadeira de antropologia física (chair of physical anthropology) in the then Faculdade de Filosofia da Pontifícia Universidade Católica and the Instituto Santa Úrsula. A summary of courses taught at these educational institutions can be found in Avila (1958).

3. Arthur Ramos (1903–1949) was a professor of anthropology and ethnology at the Universidade do Brasil and the head of the Department of Social Sciences of the United Nations Educational, Scientific and Cultural Organization. He served as organizer and head of Serviço de Neuropsiquiatria do Serviço Central de Escolas-Hospitais do Departamento de Educação do Rio de Janeiro. He taught as a professor of social psychology at the Universidade do Distrito Federal. He was the founder and head of the Serviço de Higiene Mental do Departamento de Educação do Rio de Janeiro. He also served as coroner for the Serviço Médico Legal do Estado da Bahia (Instituto Nina Rodrigues) and as a physician assistant at the Hospital São João de Deus in Bahia.
4. On 28 April 2009, during the first meeting of the working group of the Ministério da Justiça (MJ) of Brazil, established by Portaria Interministerial No. 187 of 9 February 2009, the main aspects related to effective contributions to the construction of a national unit of forensic anthropology and archaeology (Unidade Nacional de Antropologia e Arqueologia Forenses) from the perspective of a task force on a regional and state level were discussed. The shape and regulatory framework of the Anthropology and Archaeology Forensic Unit for Brazilian cases was the subject of the first meeting. This unit is linked to the federal police, civil police, military police, the Federal Public Ministry, Instituto Nacional de Metrologia, Qualidade e Tecnologia (INMETRO), Secretaria Nacional de Segurança Pública, the executive secretary of the MJ, the MJ Amnesty Commission, the Office of Legislative Affairs of the MJ, the Department of Legal Affairs of the Civil House of Presidency of the Republic, and the National Council of Justice in the context of decree 187 of 9 February 2009 (MJ). This multiplicity of links, a priori, indicates the complex character of the unit related to (1) natural events that cause considerable human casualties, identification of human remains, the lack of human capital (i.e., trained specialists), functional specialization, and organized structure in public bodies; (2) the need to adopt multidisciplinary measures in the area of forensic archeology and anthropology in order to research the causes and circumstances of these events; and (3) the need to promote multidisciplinary studies and research to promote functional specialization and complex methodology of application. Many of the recommendations studied come from Cox et al. (2008).
5. In 2012 the Centro de Filosofia e Ciências Humanas, Departamento de Arqueologia, Universidade Federal de Pernambuco, created the Laboratório de Arqueologia Biológica e Forense, coordinated by the author, with activities related to the Arqueologia da Morte e Forense, research group of Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

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# Biological Anthropology of Children's Growth in Amazonia

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**ABSTRACT.** It is well established that growth and health result from dynamic, multifactorial interactions that are sensitive to both genetic and environmental factors. In the Amazon, studies about the growth and health situation of traditional Caboclo and Quilombola (Afro-derived) populations, which compose most of the rural groups in the region, are still limited. We provide a brief overview of recent growth studies in Brazil, and as a case study, we describe and analyze a group of 431 children living in a wide range of environments, representing a large percentage of the vulnerable groups in the Amazon. The Caboclos are represented by individuals living in the Caxiuanã National Forest in Pará State and in the Mamirauá Sustainable Development Reserve in Amazonas State. The Quilombolas are represented by the communities of Santo Antônio, África, Laranjituba, Mangueiras, and Mola, all in Pará State. Both Caboclo and Quilombola children (0–10 years) generally exhibit levels of acute and chronic undernutrition above the national average, although current values are lower than those observed only a decade ago; yet there are also some cases of overweight children. The subsistence of many rural populations of Brazil is closely connected to the different natural ecosystems; as these ecosystems change, the populations become more economically and socially vulnerable, gradually transitioning from a mostly traditional to a more westernized lifestyle, thus leading to a nutritional and epidemiologic transition for which they are not prepared. As is the case for several Native American groups, unfortunately, the lack of more long-term investigations and the absence of public policies sensitive to their realities will likely make these groups continue to suffer for decades to come.

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

**RESUMEN.** Es bien conocido que el crecimiento y la salud son resultado de interacciones dinámicas, multifactoriales que responden tanto a factores genéticos como ambientales. En la Amazonia, son todavía escasos los estudios sobre el crecimiento y la situación de salud de las poblaciones Caboclas y Quilombolas (Afro-derivadas), que componen la mayor parte de los grupos rurales de la región. En este capítulo hacemos una revisión breve sobre los estudios recientes de crecimiento en Brasil, y seguidamente, como un estudio de caso, describimos y analizamos un grupo de 431 niños y niñas que viven en un rango amplio de ambientes, representativos de un porcentaje largo de los grupos más vulnerables de la Amazonia brasileña. Los Caboclos están representados por los grupos que viven en la Selva Nacional de Caxiuanã, en el estado de Pará, y en la Reserva de Desarrollo Sostenible Mamirauá, en el estado de Amazonas. Los Quilombolas están representados por las comunidades de Santo Antônio, África, Laranjituba, Mangueiras y Mola, todas en el estado de Pará. Aunque los valores actuales son menores que los observados hace una década, los niños y niñas (0-10 años) tanto Caboclos como Quilombolas muestran, en general, niveles de desnutrición crónica y aguda por encima de la media nacional, aunque también hay algunos casos de sobrepeso. Como muchas otras en Brasil estas son poblaciones en las que la subsistencia está inevitablemente conectada con los ecosistemas naturales y a medida que estos se alteran se vuelven más vulnerables económicamente y socialmente. Al involucrarse en un proceso de transición desde un estilo de vida principalmente tradicional a uno occidentalizado, esto conduce tanto a una transición nutricional

como epidemiológica para las cuales no están preparadas. Como en el caso de muchos grupos nativos americanos, desgraciadamente, la falta de más investigaciones a largo plazo y la ausencia de políticas públicas más sensibles a su realidad hará que estos grupos continúen sufriendo todavía en las décadas futuras.

**RESUMO.** Já é bem conhecido que crescimento e saúde resultam de interações dinâmicas, que são sensíveis tanto a fatores genéticos como ambientais. Na Amazônia, ainda há poucos estudos sobre as condições de crescimento e saúde de populações tradicionais Caboclas e Quilombolas (Afro-derivadas), que compõem a maioria dos grupos rurais na região. Neste capítulo descrevemos brevemente os principais estudos recentes sobre crescimento infantil realizados no Brasil e, em seguida, como um estudo de caso, analisamos um grupo de 431 crianças vivendo em uma ampla gama de ambientes, representando uma grande porcentagem dos grupos mais vulneráveis na Amazônia. Os Caboclos são representados pelos grupos da Floresta Nacional de Caxiuanã, no Estado do Pará, e pela Reserva de Desenvolvimento Sustentável Mamirauá, no Estado do Amazonas. Os Quilombolas são representados pelas comunidades de Santo Antônio, África, Laranjituba, Mangueiras e Mola, todas no Estado do Pará. Embora os valores atuais sejam mais baixos do que aqueles observados há apenas uma década, crianças (0-10 anos) Caboclas e Quilombolas apresentam, em geral, níveis de subnutrição aguda e crônica superiores a média nacional, ainda que haja também alguns casos de sobrepeso. Como muitas outras no Brasil, estas são populações para as quais a subsistência está inevitavelmente conectada com os ecossistemas naturais e na medida em que estes são alterados, elas se tornam socialmente e economicamente mais vulneráveis, envolvidas na transição de um estilo de vida mais tradicional para um mais modernizado, levando-as tanto a um processo de transição nutricional quanto epidemiológica para os quais não estão preparadas. Como tem sido o caso de muitas populações ameríndias, infelizmente, a falta de pesquisas de longa duração e a ausência de políticas públicas sensíveis à sua realidade, faz com que estes grupos continuem a sofrer por muitas décadas.

## INTRODUCTION

There are no long-term nationwide growth and development studies in Brazil. The longest ongoing project is the 1982 Pelotas Birth Cohort Study (Victora et al., 1985, 2003; Victora and Barros, 2006), which although large and scientifically validated, in our view, does not represent all the biological, social, and environmental diversity of the country because it is restricted to one city in Rio Grande do Sul, the southernmost state in Brazil. In this chapter a brief overview of recent growth studies from all the five regions of the country is presented; then, as the main focus of this review is the Amazon region, we present and discuss as a case study data from a group of 431 children living in a wide range of environments, representing a large percentage of the most vulnerable groups in the region, to demonstrate some of the complexities involved in conducting and comparing growth studies in the region.

Existing results of local and regional research indicate that all over Brazil, malnutrition has been decreasing in the past decades (Monteiro et al., 1997; Mondini and Monteiro, 1998; Monteiro, 1999; D. Silva and Nunes, 2015). Currently, it is easy to find both extreme situations: malnutrition and overweight/obesity in the same population. Nevertheless, this change is not

occurring in the same way and at the same pace in all Brazilian regions. In the North and Northeast regions such cases are more common. These two regions have shown the highest malnutrition rates for many decades as a result of Brazilian regional economic disparities. They have always been behind economically and present the weakest health conditions in general. In the following we present some studies by region to provide a brief overview of the current situation of Brazilian children's growth.

In southern Brazil, Lang et al. (2011) studied children of landless families in rural areas of Paraná State and found that 4.7% of the residents in the settlements and 10% in temporary camps were malnourished. While studying children from another southern state (Rio Grande do Sul) during National Children's Vaccination Day, Vitolo et al. (2008) found that wasting was observed in only 2.6% of them, stunting was seen in 9.1%, and 9.8% were overweight. In another study in Rio Grande do Sul, in one district of the capital, Porto Alegre, Cuervo et al. (2005) found that 58% of children had a nutritional deficit (38.1% were undernourished) and 61.9% were at nutritional risk (between percentiles 3 and 10). They pointed out that a height-for-age deficit was the most prevalent among those children.

In the largest state in the Southeast region, Minas Gerais, Castro et al. (2005), studying the situation of children in public preschools and kindergartens in the city of Viçosa, found that 13.6% had z-scores between -2 and -1, even though in general they had a satisfactory nutritional status when compared with children from other municipalities. In another study, also in Viçosa, Sant'anna et al. (2009) investigated 6- to 9-year-old children attending a family health program and found that 6.3% had low weight, whereas 7.3% were overweight and 11.2% were obese, with males presenting lower values than females. The authors attributed these low values of undernutrition to regular school meals, longer-duration educational activities, and leisure time, which contribute to the quality of children's growth in the region. Castro et al. (2004) studied children from rural settlements in the county of Tumiritinga, Vale do Rio Doce, Minas Gerais, and verified that 7.6% presented low weight-for-age and height-for-age values, especially the 1- to 2-year-olds.

In São Paulo, the richest state of Brazil, Guimarães and Barros (2001) studied public preschool children from Cosmópolis County and showed that 2.6% presented low height for age, 1.8% had low weight for age, and 1.2% presented low weight for height. However, 5.7% of the children measured were obese, especially those from downtown areas, with males presenting lower indices than females, like in Minas Gerais. In another county of the state of São Paulo (Vinhedo), Boccaletto (2005), also studying children from public schools, found that among girls, 8.4% had low weight and 13.5% were overweight and obesity among boys was 12.8% (Table 1).

In the Center-West region of Brazil, Tuma et al. (2005) studied children from three preschools in Brasília, the country's capital, and verified that 6.1% were overweight and 4.8% were stunted. The authors also attributed these findings to meals served in the schools. Silva and Nunes (2015) studied 5- to

TABLE 1. Selected growth studies of Brazilian children by region of the country, 2001–2014.

Population	Studied group	Study	Findings
<b>South Region</b>			
Paraná State	Children under 24 months from landless rural areas/temporary camps	Lang et al. (2011)	10.0% malnourished
Rio Grande do Sul State, city of São Leopoldo	Children 1 month to 5 years old	Vitolo et al. (2008)	Wasting, 2.6%; stunting, 9.1%; overweight, 9.8%
Rio Grande do Sul State, city of Porto Alegre	Children 6 to 59 months old	Cuervo et al. (2005)	38.1% undernourished (percentile <3); 61.9% between percentiles 3 and 10; most frequent deficit was height to age
<b>Southeast Region</b>			
Minas Gerais State, city of Viçosa	Children 6 to 9 years old	Sant'anna et al. (2009)	6.3% low weight, 7.3% overweight, 11.2% obese; males present lower values
Minas Gerais State, city of Viçosa	Children 24 to 72 months old from public preschools and kindergartens	Castro et al. (2005)	13.6% with z-scores between -2 and -1
Minas Gerais State, region of Vale do Rio Doce	Children 0 to 60 months old	Castro et al. (2004)	7.6% low weight to age and height to age
São Paulo State, city of Cosmópolis	Public preschool children 4 to 7 years old	Guimarães and Barros (2001)	2.6% low height to age, 1.8% low weight to age, 1.2% low weight to height, 5.7% obese
São Paulo State, city of Vinhedo	Public school children from 7 to 10 years old	Boccaletto (2005)	8.4% low weight, 13.55% of girls overweight, 12.8% of boys obese
<b>Center-West Region</b>			
Brasília, Distrito Federal	Children from three preschools, 7 to 71 months old	Tuma et al. (2005)	4.8% stunted, 6.1% overweight
Mato Grosso do Sul State (Datusus, Sisvan)	Children 5 to 10 years old	Silva and Nunes (2015)	Low weight in 4.8% of girls, 5.6% of boys; overweight/obese in 14.8% of girls, 11.9% of boys
<b>Northeast Region</b>			
Piauí State	Children 0 to 59 months old	Ramos et al. (2015)	10.9% low weight, 19.1% excess weight
Bahia State	Children under 5 years old	Assis et al. (2007)	11.11% malnourished
Paraíba State, city of João Pessoa	6 to 36-months old children from day care centers	Souza et al. (2012)	7.6% height deficit, 6.4% overweight
Paraíba State	0 to 60-months old children from day care centers	Pedraza et al. (2014)	6.2% low height, 2.1% weight deficit
Ceará State, city of Fortaleza	Children under 1 year of age	Soares et al. (2000)	10% low height to age; 8% overweight
<b>North Region</b>			
Acre State	Children under 5 years of age	Muniz et al. (2007)	3.7% low weight to height; 8.7% low weight to age; 7.5% low height to age; 2.8% overweight
Acre State	Children under 5 years of age	Araújo (2010)	35.8% low height to age; 7.3% low weight to age; 2.1% overweight; children with indigenous ancestry from rural areas had a 20.1% rate of malnutrition (Brazil average from 2006 = 7%)
Pará State	Riverine children under 2 years of age	Oliveira (2010)	35% malnutrition; 23.8% of mothers were overweight
Pará State	Riverine children under 2 years old from a protected area (Caxiuanã National Forest)	Piperata et al. (2011b)	36% stunted, 12% overweight/obese
Amazonas State	Children under 7 years old from public and private day care centers	Tavares et al. (2012)	15% low weight to age in public urban day care centers; 35.2% malnutrition in Amazonia rural ecosystems

10-year-old children whose families were classified as having low socioeconomic status from another Center-West state, Mato Grosso do Sul, and found that the prevalence of low weight was 4.8% for females and 5.6% for males. Overweight and obesity were 14.8% for females and 11.9% for males (Table 1).

In the Northeast region, Ramos et al. (2015) found a 10.9% rate of low height in a sample of 1,640 children from Piauí State, one of the poorest in the country, whereas 19.1% had excess weight, even in poor areas. Assis et al. (2007) indicated a high percentage of malnutrition in preschool children from 10 counties of Bahia State (11.11%). The authors identified higher deficits the further children were separated from the richest tertile. In Paraíba State, Souza et al. (2012) revealed that 7.6% of the studied children in public day care centers presented height deficits, whereas 6.4% were overweight. The authors say these results are linked to their poor socioeconomic situation. Pedraza et al. (2014) also studied preschool children attending day care centers in Paraíba State and reached similar results of 6.2% with low height. In the city of Fortaleza, the capital of Ceará State, Soares et al. (2000) found that 10% of the studied children from slum areas presented low height for age, but 8% were on the other extreme and presented overweight for their age (Table 1).

From the North of Brazil, Muniz et al. (2007) studied children under 5 years old from two counties in the state of Acre and identified prevalence rates of low weight for height of 3.7%, low weight for age of 8.7%, and low height for age of 7.5% for both counties, whereas the overweight prevalence was 2.8%, with no difference between genders. In another investigation, Araújo (2010) studied children under 5 years old from urban and rural areas in the state of Acre and showed important deficits: height for age was low in 35.8%, and weight for age was low in 7.3%, with only 2.1% being overweight. The author affirmed that children with indigenous ancestry from rural areas presented the highest malnutrition values (59.4%, of which 20.1% were severely malnourished; Table 1). The study confirms that these values were much higher than the Brazilian average of 7% in 2006 and close to values found in sub-Saharan Africa (38%).

In the state of Pará, the second largest of the region, Oliveira's (2010) study of riverine children under 2 years old from four counties found that malnutrition affected 35% of the studied population, whereas 23.8% of the mothers were overweight, showing a strong nutritional transition and high levels of food insecurity. Piperata et al. (2011b), studying another population of riverine children under 2 years old from a protected area (Caxiuanã National Forest), described that 36% of the infants were stunted, but there were no wasted/underweight children. However, 12% of the infants were considered overweight or obese (Table 1).

In the largest state of Brazil, Amazonas, Tavares et al. (2012) studied children under 7 years old in public and private day care centers and found that the children in private day care centers were more overweight, but more than 15% of children from the public day care centers still presented low weight for age. These values can be explained by the fact that the studied

children were from urban areas, with more favorable life conditions than the ones observed in different rural ecosystems of the Amazon region, where the rate of malnutrition can reach 35.2%, according to the authors.

In terms of indigenous populations, the largest study conducted so far, the First National Survey of Indigenous People's Health and Nutrition, identified that children under 5 years old presented an average height-for-age deficit for the five regions of 27.5%, but overweight and obesity were high among their mothers (30.3 and 15.8, respectively; Coimbra et al., 2013). Historically, indigenous children have presented the lowest growth status in the country.

In relation to Afro-derived traditional/rural (Quilombola) populations (O'Dwyer, 2002; Schmitt et al., 2002; Ministério do Desenvolvimento Social e Combate a Fome, 2007), the largest study, the *Chamada Nutricional Quilombola* (Ministério do Desenvolvimento Social e Combate a Fome, 2007), investigated 2,941 children under 5 years of age in 22 states and found that a height-for-age deficit was present in 11.6%, a weight-for-age deficit was present in 8.1%, overweight for age was found in only 2.4%, and overweight for height was found in 3.9% of the children. In a more recent study, Ferreira et al. (2011), investigating children from the state of Alagoas, described that 3.4% presented low weight for age, 2.0% had low weight for height, and 11.5% showed low height for age, but they also found 7.1% overweight children. These authors identified that 76% of the Quilombola population in Alagoas received governmental support in the form the Bolsa Família program but remained in the situation of food and nutrition insecurity. In the North region of Brazil, Guimarães and Silva (2015) investigated a group of Quilombola children between 0 and 5 years of age in Pará State and found that 29.9% were above a +1 z-score in terms of weight and body mass index (BMI); however, 31.1% of the children fell in the -2 z-score group in terms of stature for age. These samples show how complex the situation of these rural groups is. Nevertheless, it is clear that after Native Americans, the Quilombolas are considered the most vulnerable group in the country (Ministério do Desenvolvimento Social e Combate a Fome, 2007).

Overall, Brazil is going through a rapid nutritional transition, in which there is a decrease in the prevalence of malnutrition and an increase in overweight and obesity. This transition seems to be present among the majority of Brazilian social and age groups but has a special impact on those presenting higher social vulnerability. As an example, in a longitudinal study conducted in a voluntary sample of mainly urban children and adolescents (7 to 14 years) from different Brazilian regions included in the Brazil Sports Project (PROESP-Br) Data Bank between 2005 and 2011, Flores et al. (2013) found 2.11% underweight, 22.27% overweight, and 6.8% obesity and concluded that the prevalence of underweight was less than 5% in all categories of age and gender, but overweight and obesity had higher values, representing almost 30% of the young Brazilian population.

Although malnutrition is still high in some rural areas and particular groups, as seen above, many studies show a decline in

malnutrition in Brazil; however, specific differences concerning the different regions occur, particularly in relation to the North and Northeast, which continue to lag behind the other regions when it comes to children's health.

## THE DYNAMICS OF HUMAN GROWTH IN TROPICAL ENVIRONMENTS

It is well established that growth and development result from dynamic multifactorial interactions that are sensitive to both genetic and environmental factors (Frisancho, 1978; Ahn, 1986, 1990; Falkner and Tanner, 1986), in addition to social factors such as political instability, patterns of marriage, parity in the family, social status, psychological conditions, cultural norms, climate, and even the seasons of the year (Eveleth and Tanner, 1976; Bogin, 1999). The physiological, nutritional, and hormonal mechanisms responsible for growth and development are also affected differentially by interactions with variable environments (Baker, 1969, 1976; Argente and Chowen, 1994; Balam and Gurri, 1994; Crooks, 1995; Heinrichs et al., 1995; Lampl et al., 1995; Moore et al., 1999).

Traditional communities, such as Native Americans and some Caboclo and Quilombola populations in the Amazon and African agricultural groups, which depend on seasonal rainfall changes for their crops, domesticated animals, and availability of game for hunting, suffer during the rainy season because of the reduced availability of food sources. In the dry season, when more food is available, children grow faster (Cattle and Schwerin, 1985; Dufour, 1992; Ulijaszek and Strickland, 1993; United Nations Children's Fund [UNICEF], 2007).

On the other hand, as economic changes reach all corners of the world, higher socioeconomic status generally translates into better child and health care across countries and cultures. Higher socioeconomic status has been correlated with a reduction in family size, a reduction in children's workloads, a decrease in disease load, and a decline in infant mortality, which are also correlated with improved growth and development (Eveleth and Tanner, 1976; Glewwe, 1988; World Bank, 1993).

Caboclos and Quilombolas are traditional Amazonian populations in the process of rapid acculturation and modernization and under pressure from abrupt environmental changes and land conflicts. All these factors are likely causes of biopsychological stress, the effects of which are only starting to be investigated (Silva and Eckhardt, 1994; Silva and Crews, 1995; Silva, 1999, 2001, 2006a, 2011; Piperata, 2007; Piperata et al., 2011a, 2011b, 2013; Silva et al., 2016).

Among these stress factors, one of the most important for the Caboclo and Quilombolas groups has been diseases of several etiologies. In general, children will invariably reduce food intake and increase energy and electrolyte loss when ill. This combination of reduced intake and increased loss can cause significant reduction in rates of growth, in direct proportion to the duration and intensity of the disease episode (Santana, 1981;

Bogin, 1999). As the burden of disease varies greatly according to the seasons of the year, type of natural environment inhabited, level of dependency on cash, socioeconomic status, education, and access to environmental sanitation and primary health care services, it is necessary to acquire profound knowledge of the socioecological diversity of the region in order to be able to plan adequate public health policies for the overall population, particularly for the most vulnerable groups in Brazil and other tropical countries.

## TRANSDISCIPLINARY STUDIES, GROWTH, AND HEALTH IN THE AMAZON

According to Little and Haas (1989:3), transdisciplinary science is "one that crosscuts several traditional sciences, while at the same time providing synthesis, integration, and greater understanding of a body of knowledge." Our group has been conducting transdisciplinary research in Amazonia for the past 20 years, using concepts and methodologies from cultural and physical/biological anthropology, from medicine and epidemiology, and from ecology, among others, to explore the mechanisms of adaptation of rural, riverine populations in Brazil to their native environments (Silva, 2001, 2006a, 2009, 2011; Silva and Padez, 2006; Guimarães and Silva, 2015; Silva et al., 2016; Guimarães et al., 2018).

This continuing research program addresses issues of great relevance to biological anthropology, such as physiological acclimatization to different ecosystems, growth plasticity, the effects of rapid ecological and environmental changes on traditional peasant groups, and the impacts of socioeconomic changes on the health and growth of vulnerable populations. Such research improves our overall understanding of how humans biologically and culturally adapt to rapidly changing ecological circumstances (Baker and Little, 1976; Dressler, 1993; Santos and Coimbra, 1994; Silva and Crews, 1995). Because Caboclo and Quilombola populations have a close relationship with and interdependency on their environment, as well as a predominantly rural lifestyle, they offer a natural "experimental" setting in which to examine mechanisms of human adaptation to shifting environments. A case study on the impact of ongoing socioecological changes on some traditional Amazonian groups follows.

## THE CONTEXT OF DEVELOPMENT IN AMAZONIA: CABOCLOS AND QUILOMBOLAS

During the past 50 years, especially in the latter half of the twentieth century and the first decade of the twenty-first century, the Brazilian Amazon has been under intense pressure from the federal government to "integrate" with the rest of the country. The idea was to develop "megaprojects" as an effort to improve the economy and limit threats from neighboring countries

wishing to control the isolated and sparse native population and the rich natural resources (Morán, 1981, 1983; Schmink and Wood, 1984; Sponsel, 1986; Nugent, 1993; Stewart, 1994; Pichón, 1996). The main outcome of this and other government efforts to “colonize” and “develop” the Amazon basin has been environmental degradation, increased population densities in peri-urban areas and shantytowns, and alterations of traditional socioeconomic relationships among resident human populations (Morán, 1983, 1993; Schmink and Wood, 1984; Nugent, 1993; Silva, 1997b, 2011).

There has been a considerable amount of work on the growth and health of Brazilian indigenous populations (Santos, 1993; Coimbra, 2005; Coimbra and Santos, 2001; Coimbra et al., 2013; Garnelo and Pontes, 2012). However, there is still limited information about other traditional populations, particularly about the peasant groups of Amazonia. For this reason, our research concentrates on the less studied groups, the Caboclos and Quilombolas.

The term *Caboclo* still generates intense debate among anthropologists. Some view it as a derogatory term for poor, exploited, illiterate, rural, and disenfranchised populations (Parker, 1985; Lima-Ayres, 1992). Others suggest it defines large segments of Amazonian peasantry and their social and economic characteristics (Nugent, 1980, 1993; Silva et al., 1995b; Harris, 1998; Rodrigues, 2006).

Lima-Ayres (1992) indicates that Costa Pereira and Teodoro da Silva have identified the roots of the term *Caboclo* as deriving from the Tupi *caa-boc*, meaning “that which comes from the woods.” Parker (1985: xix), describes another etymology found in Aurélio B. Ferreira’s dictionary (Ferreira, 1971), suggesting that the name comes from the Tupi *Kari'boka*, meaning “child of the white man.” Regardless of the meaning attributed or the origin of the term, historically, what have come to be known as *Caboclo* populations developed in the Amazon basin beginning in the late eighteenth century (Wagley, 1963; Morán, 1974; Parker, 1985; Lima-Ayres, 1992; Siqueira, 1997). They have been characterized as sharing a common environment and similar genetic backgrounds (Santos et al., 1987, 1996; Silva, 2001), as well as numerous sociocultural characteristics such as subsistence activities, household structure, marriage and relationship patterns, dietary habits, knowledge and use of ethnomedicine, and folk Judeo-Christian traditions, representing a combination of a number of sociocultural traits of their ancestors (Buchillet, 1991; Lima-Ayres, 1992; Neves, 1992; Nugent, 1993; Silva, 1995, 2009, 2011; Murrieta, 1996, 1998b; Benchimol, 1998; Rodrigues, 2006; Amazonas, 2007).

Currently, the majority of the riverine peasant populations in the North of Brazil can be considered under the term *Caboclo* (Morán, 1983; Parker, 1985). Even though they compose the largest segment among the Amazonian rural populations (Instituto Brasileiro de Geografia e Estatística [IBGE], 1991; Silva et al., 1995b; Murrieta, 1998a; Silva, 2001), they have received very limited attention from the scientific community because of their characteristic admixed heritage (Nugent, 1980, 1993;

Chibnik, 1991; Neves, 1992). Hence, little is known still about many aspects of their life, health, and modes of interaction with the complex natural ecosystem of the Amazon.

Quilombolas are also part of the Amazonian traditional peasantry. The term *Quilombo* was first used to represent a physical space and a resistance movement against the slave system in Brazil (Salles, 2005). Groups, composed mostly of black runaways from the farms and plantations, formed parallel centers of power, production and social organization that even after the end of slavery in the country in 1888, continued to hold opposition against the oppressive practices related to the black population. Later, indigenous and other populations became incorporated into the Quilombos, and their land rights were granted by the law, acquiring the term *remnant* in addition to Quilombola. Nowadays, they are present in all regions of the country, especially, but not limited to, rural areas, and many still maintain some degree of geographic isolation, leading to high levels of socioeconomic inequalities and restricted access to health services (O’Dwyer, 2002; Ferreira et al., 2011; Gomes et al., 2013; Melo and Silva, 2015; Pereira et al., 2015).

Despite its constitutional mandate, Brazil is still struggling to provide adequate health to its citizens. Particularly in rural areas of the Amazon basin, access to health care is still very limited (Confalonieri, 2005; Silva, 2006a, 2011; Cavalcante, 2011; Ministério da Saúde, 2013). In general, the level of involvement of rural populations with the market economy and the differences in the environments in which they live are associated with diverse influences on the health and growth of their children, but no large-scale, longitudinal study addressing the issues related to growth and health in the region exist. Hence, what is known comes from cross-sectional data such as the studies conducted by Giugliano et al. (1981), Silva and Crews (1995) Silva (1999, 2001, 2006b, 2011), Piperata (2007), Piperata et al. (2011a, 2011b), Murrieta et al. (1998), Guerrero (2010), and Guimarães and Silva (2015).

In the following we present as a case study data from some long-term projects conducted with traditional rural groups in Pará and Amazonas, the two largest states of Brazil, to give the reader a perspective of the challenges of conducting growth and epidemiologic studies in the region. The results of these studies are then analyzed in relation to other data available for the north of the country.

## CONDUCTING GROWTH AND EPIDEMIOLOGIC STUDIES IN THE AMAZON

The Amazon Basin encompasses one of the last and most diverse tropical rain forests in the world, covering an area of 3.5 million square kilometers. Over 40% of all plants and animals alive today inhabit this area (Wolf, 1987; Macedo and Castelo, 2015). As a tropical ecosystem, the Brazilian Amazon is dominated by two annual cycles. The rainy season is from December to mid-July and the dry season from July to November (Murrieta,

1998a; Morán, 1993; Murrieta et al., 1999). These two seasons have a profound impact on the environments and lives of local populations (Morán, 1974, 1993; Silva, 1999, 2001; H. Silva et al., 2010).

As a result of the extended and disorganized pattern of human occupation of the Amazon basin and the logistical constraints of conducting research in the area, only rarely are major studies conducted in the most isolated and pristine regions of the Amazon basin.

The groups of populations described herein are located in the states of Pará and Amazonas (Figure 1). The total population of Pará was 8,073,924 inhabitants in 2014, and in Amazonas it was 3,873,743 inhabitants (IBGE, 2015). Official records report that most of the Amazon is sparsely populated, with a density of only 4.12 inhabitants per square kilometer (IBGE, 2015). Currently, the majority of the people live in urban or peri-urban areas, but large portions of the population, especially the

traditional groups, such as Caboclos, Quilombolas, and the Native Americans, still remain in the rural areas.

The research presented here was conducted between 2009 and 2014. The houses of Caboclos and Quilombolas are generally located near the main rivers; settlements can be a few meters from the edge of the river or several kilometers inland (Parker, 1985; Morán, 1993; Salles, 2005). Houses are built on stilts and made from a wide range of materials such as thatch, wood, clay bricks, and combinations thereof. Most have no internal showers or toilets, and many still do not have access to electricity. Traditionally, the houses do not have piped water or sewage because there are no water and sewage treatment systems in most of the rural areas of the Brazilian Amazon (Wagley, 1963; Morán, 1974; Silva, 1997a, 1997b, 1999, 2006a, 2011; Silveira et al., 1997; Siqueira, 1997). Housing units can have one or more families living under the same roof, or the families may live and work as an extended unit, with two or more houses

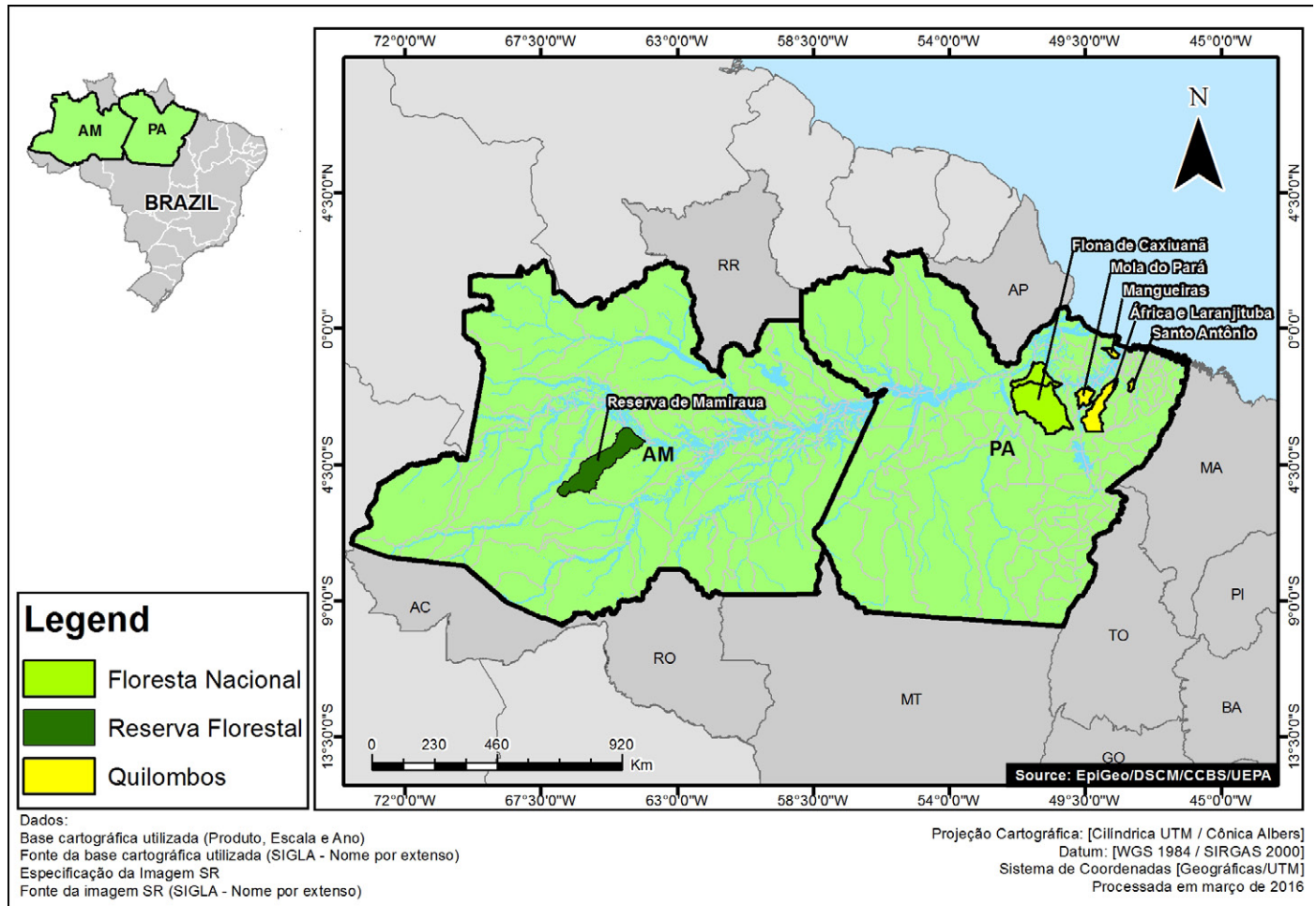


FIGURE 1. The states of Pará (PA) and Amazonas (AM) with the indicated study areas in Brazil. Translation of legend: light green, Caxiuana National Forest; dark green, Mamirauá Forest Reserve; yellow, Quilombola areas. Source: EpiGeo/DSCM/CCBS/UEPA, 2016.

occupying a contiguous area (Siqueira, 1997; Murrieta, 1998a; Murrieta et al., 1999).

The environments considered in this study are representative of the majority of the ecosystems inhabited by the Caboclos and Quilombolas in the Brazilian Amazon. They include floodplain (*várzea*), represented by the Mamirauá communities, and upland (*terra firme*), represented by the Caxiuanã and the Quilombola groups. In general, floodplains experience seasonal floods over several months of the year, and upland are areas traditionally occupied by forests and never flooded (Morán, 1981, 1983). Also considered in this study are the major river systems in the Amazon, the white water rivers (*rios de águas claras*) and the black water rivers (*rios de águas pretas*). The black water rivers are poor in nutrients, whereas the white water rivers traditionally have more nutrients and support a much higher biomass (Morán, 1974, 1991).

## BLACK WATER AND THE CAXIUANÃ NATIONAL FOREST

The Caxiuanã National Forest (FLONA) is a protected area of 330,000 ha covered mainly by primary tropical rain forest (85%), along with flooded forests (12%) and secondary vegetation and nonforested areas (3%). The forest is situated in the county of Portel in the state of Pará, at approximately 400 km southwest of Belém, the state capital (Museu Paraense Emílio Goeldi [MPEG], 1993, 1994; Silva et al., 1995a; Silva, 2001; see Figure 1).

In Caxiuanã during the dry season, rainfall is less than 60 mm per month in some months (October and November), and in the wet season the rainfall can be above 1,000 mm per month (February and March). The average temperature is 26°C, and the relative humidity is about 85%, with little variation during the year (MPEG, 1993, 1994). The black water system, also known as the “system of hunger,” is characteristically poor in both animal and vegetable biomass for consumption, and its exploitation for subsistence is difficult since both soils and rivers are poor in nutrients (Morán, 1974, 1991). Nevertheless, there are also some advantages of living in a black water ecosystem. Insects, major vectors of diseases such as malaria, yellow fever, dengue fever, and leishmaniosis and a considerable source of discomfort throughout the year because of their constant attacks, are much less prevalent in these areas than in other regions of the Amazon, such as Mamirauá and Santarém (Morán, 1993; Moura, 2007; Silva, 2011).

The Museu Paraense Emílio Goeldi (MPEG) and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) decided to establish the Ferreira Penna Research Station (FPRS) in the Caxiuanã National Forest in the early 1990s as a field station for long-term research on biodiversity. The FPRS encompasses 10% of the FLONA, corresponding to an area of 33,100 ha. In its physical facilities, the station has a resident nursing assistant and a health post and is the only source of

western emergency medical attention in the FLONA (MPEG, 1994; Silva, 2001). The local population of the FLONA is represented by approximately 413 people (207 men, 206 women), of which approximately 60% are children and adolescents aged 0 to 19 years (Lisboa et al., 2013).

Because of the isolation of the FLONA, electricity is available only by using diesel power generators whose services are shared between neighboring houses or photovoltaic cells installed on the rooftop or near individual residences. Most of the population uses water for drinking, washing, and cleaning directly from rivers or untreated open wells (Piperata et al., 2011a; Lisboa et al., 2013). Ramos (2001) reports that the wells began to emerge after 1999, when the Goeldi Museum encouraged their construction because of the indication that most of the communities had worms. But only a few houses have them; most people still use the river.

In general, the livelihood in these communities is based on slash-and-burn agriculture, fishing, hunting, extraction of natural products such as açai (*Euterpe oleracea*) and Brazil nuts (*Bertholletia excelsia*), and subsistence agriculture of manioc, corn (*Zea mays*), tobacco (*Nicotiana tabacum*), bananas (*Musa* sp.), and other edible fruit trees (Silva et al., 1995a; Silveira et al., 1997; Silva, 2001). Although there are legal restrictions, hunting is still an important source of protein. Animals hunted include agouti (*Dasyprocta* sp.), paca (*Agouti paca*), freshwater turtles (several species), armadillos (*Dasyurus* sp.), peccary (*Peccary peccary*), crocodiles (unknown species), and monkeys (mainly *Alouatta* sp.). The diet is based on manioc flour, fish, hunted game, and, during the dry season, açai. The daily diet is sometimes complemented with industrialized products such as coffee, sugar, crackers, canned meats, rice, and free-range chicken, duck, or pig. In recent years, the proportion of industrialized foods has been growing. All houses have a small, usually suspended, garden with medicinal plants tended by the mother or grandmother. From these plants traditional remedies such as teas and infusions are made and used for fever, cough, cold, diarrhea, vomiting, and other ailments. Most diseases are treated with local remedies, although those with more complicated cases are sent to the city.

## THE MAMIRAUÁ SUSTAINABLE DEVELOPMENT RESERVE AND THE FLOODPLAINS

The Mamirauá Sustainable Development Reserve covers an area of 1,124,000 ha, located at the confluence of the Solimões and Japurá Rivers and adjacent to the Amanã Sustainable Development Reserve in Middle Solimões, a region of Tefé in the state of Amazonas (Figure 1). It is known as the largest *várzea* protected reserve in the world (Moura, 2007). It is considered the first protected area for sustainable use created in Brazil (1990), encompassing the idea of environmental protection and shared management of natural resources with local populations (Moura, 2007), and is therefore a key area for studying the



relationship between human populations and the environment in the Amazon.

The Mamirauá Sustainable Development Reserve encompasses areas of seasonally flooded forests, where the waters from the Amazon River bring rich sediments from the Andes. During the dry season, the sediments are used for planting crops on the margin of the river and cattle raising in the grassland and the inland savanna. During the wet season, the floods form internal lakes, attracting a variety of fish that come to breed and find food away from the main river canal. In these lakes, fish are easily caught with traditional nets (Júnior, 1996). The annual flooding level varies from 10 to 15 m. The river movement and seasonal floods have a strong impact on the landscape, which changes from year to year (Júnior, 1996). According to the Mamirauá Institute, the total population was estimated to be around 2,720 individuals in 2011, but it is, in fact, very difficult to keep an accurate census because of an intense inflow and outflow of families to the area because of the constant shifting of the rivers and areas available for agriculture and the need for children and adolescents to go to school (Moura et al., 2015).

### **QUILOMBOLA COMMUNITIES AND THE SOCIOECOLOGY OF AFRO-DERIVED GROUPS IN AMAZONIA**

The Quilombola communities have been living with a history of discrimination and exclusion, struggling arduously for their rights to be politically recognized, including their rights to land, health, and education. Like other invisible and vulnerable populations of the Amazon, their conditions of life in general have been little studied, contributing to the ignorance about their health status and quality of life.

In this case study we analyzed five groups of Quilombola communities in Pará State: Santo Antônio (county of Concórdia,  $n = 300$  individuals), África and Laranjituba (county of Moju,  $n = 350$  individuals), Mangueiras (county of Salvaterra, Marajó Island,  $n = 1,200$  individuals), and Mola (county of Cametá,  $n = 900$  individuals). These groups represent approximately 500 families living in a wide range of ecosystems in the region (Silva, 2015; Figure 1).

It is not the purpose of this chapter to describe all the details of the Quilombola communities discussed because that has been done elsewhere (Leão, 2005; Costa, 2008; Borges, 2011; Cavalcante, 2011; Oliveira, 2011; Santos, 2013; Silva, 2015). For that reason, only a general characterization of the study groups will be presented.

Overall, the Quilombo remnants investigated have several common traits such as strong ties to their ancestral territory and long-term links of consanguinity to a small number of ancestors, usually runaway slaves; a mix of Catholic and African traditions; low literacy rates; and a lack of access to basic sanitation, health, and education infrastructure. Generally, Quilombo communities are places difficult to access because the intention of their past

inhabitants was not to be found by slave hunters (Salles, 2005). In our sample, some communities such as África, Laranjituba, and Santo Antonio are located in upland forest and accessible nowadays by roads, even though they are often precarious, dirty roads, taking anywhere from 3 to 8 hours of travel from Belém, the state's capital, during the dry season. The houses are usually built of wood and near each other, with distances varying from 20 to 100 m, and constructed, like the Caboclos', near the river's edges or inland.

Other Quilombola communities such as Mola and Mangueiras are accessible only by boat throughout most of the year. These areas are on floodplain environments and suffer greatly the effects of seasonality. In these areas the houses are more disperse, up to 500 m or more distant from each other. Mangueiras is demographically the largest of the areas studied and is divided into several smaller localities known as São João, Vila Pereira, da Trindade, and da Divindade e de Mucajá. The houses in Mola and Mangueiras are built of bricks or wood and covered with thatch or clay tiles; some families share outside bathrooms with neighbors and relatives.

All communities investigated had access to electricity, but none had water, sewage, or trash collection systems. As in the Caboclo settlements, water for all purposes comes from the rivers and from wells excavated near the houses. In general, environmental sanitation is precarious in the Quilombola communities. Also like the Caboclos, all the Quilombolas investigated survive by practicing subsistence agriculture; fishing; hunting; and selling farinha (manioc flour), corn, beans, and other agricultural products and extracted forest products such as castanha (local name for Brazil nuts *Bertholletia excelsa*) and açaí. Some families also rely on government cash transfer programs such as Bolsa Família, retirement pensions, and local government donations of basic foods. There is a strong network of exchange of food items among neighbors and relatives, which reinforces social relations.

### **THE GROWTH AND HEALTH OF CABOCLOS AND QUILOMBOLAS**

To investigate the growth and health of Caboclos and Quilombolas, anthropometric data were collected in agreement with the internationally accepted procedures described by Weiner and Lourie (1981), Frisancho (1993, 2008), the World Health Organization (WHO, 2006), and Brazilian norms. Anthropometric variables were used because they are simple to collect in the field and because they are reliable indicators of nutritional status (Silva, 2001; Frisancho, 2008). All of the anthropometric measurements were taken by the same individuals in each community to avoid interobserver errors. Validated anthropometers and scales were used to perform these measures. We converted age (in years), heights (in centimeters), and weights (in kilograms) to z-scores to evaluate levels of chronic growth deficit, acute growth deficit, and combined acute and chronic nutritional stress.

The researchers first visited the communities and explained the details of the projects at a general assembly. Then at each

house visited during data collection, the researchers explained the project again to the potential participants. During these visits, all questions were answered, and possible benefits to the community and the individuals were discussed. Verbal consent to participate was requested and confirmed in writing or by fingerprinting and registered through an informed consent form, following the parameters of Resolutions 196/96 and 466/12 of the National Health Council and international standards of ethics in research. The projects were approved by the Ethics in Research Committee of the Federal University of Pará.

A detailed epidemiologic and alimentary census of each house and of the individuals gave the necessary data to evaluate the general characteristics of health and nutritional status of the studied populations following protocols already tested in the Amazon and internationally (Frisancho, 1990, 1993, 2008; Dufour and Teuffel, 1995; Silva, 2001; Silva and Padez, 2006). Questionnaires and detailed observations about environmental risk, education, labor activities, land use, subsistence strategies, home conditions, and available consumer goods in the home provided the comparative qualitative elements for the analysis.

Descriptive statistics for all variables by age group, sex, and community were determined to characterize each segment of the populations studied. The raw means and the means stratified by age group, sex, and communities were determined for all quantitative data and compared across the different stratification levels using *t*-tests.

The analysis of z-scores for weight for age (WAZ), height for age (HAZ), weight for height (WHZ), and BMI for age (BAZ), which are based on the standard deviation of the means, provided a comparison between data for the children investigated and international reference data used by the WHO (1997) and also with other samples from around the country and the world. The most commonly used cutoff point was adopted for z-scores of -2 for short and low-weight individuals (WHO, 1995, 1997; Monteiro, 1999).

Cut points for age groups were established following the most common ranges found in the biomedical and anthropological literature (Baumgartner et al., 1986; Melton, 1991; Monteiro et al., 1992, 1997; Monteiro, 1999; WHO, 2006). The investigated sample is composed of 431 children (207 girls and 224 boys) between 0 and 9.9 years of age (Table 2).

**TABLE 2.** Comparison of Height for Age z-score (HAZ), Weight for Age z-score (WAZ), Weight for Height z-score (WHZ), and Body Mass Index for Age z-score (BAZ) means, standard deviation (SD), and t-test of the analyzed parameters for children aged 0–4.9 and 5–9.9 years old (431 total, 207 girls, 224 boys) of the three studied populations (Caxiuanã, Mamirauá, and Quilombolas) in Amazonia, Brazil.

Age group (y) and sex	n	HAZ			WAZ			WHZ			BAZ		
		Mean	SD	<i>p</i>	Mean	SD	<i>p</i>	Mean	SD	<i>p</i>	Mean	SD	<i>p</i>
<b>Caxiuanã</b>													
0–4.9				0.039*			0.071			0.677			0.971
Girls	35	-1.48	1.73		-1.24	1.52		-0.04	2.90		-0.19	1.91	
Boys	32	-2.36	1.70		-1.84	1.13		0.22	2.18		-1.75	2.18	
5–9.9				0.780			0.960			0.840			0.949
Girls	39	-1.73	0.99		-1.12	0.59		-0.36	0.59		-0.43	0.53	
Boys	25	-1.66	0.73		-1.13	0.47		-0.39	0.68		-0.42	0.55	
<b>Mamirauá</b>													
0–4.9				0.585			0.842			0.686			0.475
Girls	35	-1.46	1.51		-1.05	1.43		0.57	2.80		0.12	1.55	
Boys	45	-1.62	1.05		-1.00	0.93		0.77	1.56		0.31	0.76	
5–9.9				0.752			0.680			0.714			0.210
Girls	39	-1.21	1.11		-0.67	0.74		0.06	0.91		-0.08	0.77	
Boys	55	-1.28	0.96		-0.61	0.65		0.13	0.93		0.12	0.77	
<b>Quilombolas</b>													
0–4.9				0.228			0.251			0.516			0.792
Girls	30	-1.05	1.26		-0.74	1.41		0.78	2.59		0.47	1.50	
Boys	23	-1.51	1.51		-1.17	1.24		0.35	2.11		-0.63	1.49	
5–9.9				0.660			0.972			0.865			0.665
Girls	29	-0.91	0.63		-0.63	0.69		-0.12	0.98		-0.30	0.86	
Boys	44	-1.01	1.10		-0.62	1.10		-0.17	1.40		-0.18	1.23	

\**p* > 0.05.

The parameters investigated present, in general, negative means for Caxiuanã children from 0 to 9.9 years old, except WHZ for boys 0–4.9 years of age, and these boys are shorter than the girls. In Mamirauá there was no significant difference between boys and girls, but all children were shorter and lighter than the WHO means. Girls 5 to 9.9 years old presented a small negative z-score for BAZ.

In Quilombola children there were no significant differences between boys and girls, but they were also, on average, shorter and lighter than the WHO reference groups. Boys from 0 to 9.9 years presented slightly negative values for BAZ (Table 2).

Comparing all communities, it is possible to identify that children from Caxiuanã, in general, are shorter and lighter than children from Mamirauá and Quilombola communities. The parameters HAZ, WHZ, and BAZ showed no significant differences among the communities using ANOVA (HAZ,  $p = 0.056$ ; WHZ,  $p = 0.280$ ; and BAZ,  $p = 0.214$ ). WAZ was the only parameter that presented a clear significant difference among the communities ( $p = 0.018$ ). The Tukey test was used and showed that Caxiuanã children were the smallest of the three populations (Figure 2).

In a previous study, Silva (2001) described that 79.6% of the children from 0 to 10 years old from Caxiuanã were below  $-2$  z-scores in terms of height for age, and 34.8% were below  $-2$  z-scores in relation to weight for age in a sample for 1996–1997. Our study from 2009 shows that this number has been reduced to almost half: 36.64% of the children are still negative for height for age, and 12.98% are negative for weight for age.

Piperata et al. (2011b) studied a sample of communities from Caxiuanã on two occasions: In 2002 they pointed out modest improvements in HAZ for children, especially for girls, although the girls still had negative means and the younger ones had significantly lower BMI compared with the adolescents. In 2009 they found 36% of the infants ( $<2$  years old) were stunted, but none were wasted/underweight; however, 12% of the children were overweight or obese. Similarly, we found 9.16% of children were overweight or obese in a different sample from Caxiuanã. In Mamirauá we found 23.7% mildly to moderately stunted.

According to the National Survey of Quilombola Children under 5 years old (Ministério do Desenvolvimento Social e Combate a Fome, 2007), 11.6% of the rural Afro-Brazilian children presented a deficit in terms of height for age, 8.1% presented low weight for age, and 2% presented low weight for height. In our study 22.64% of the children under 5 years of age presented some level of stunting, 13.21% presented wasting, and 5.66% of the children showed negative weight-for-height values, indicating that these Quilombola children from Pará are worse than the national average.

Guimarães and Barros (2001) studied 1,200 preschoolers in the public education system in Cosmópolis, São Paulo, southwest Brazil, comparing downtown and rural areas, and observed that boys had lower values than the girls in all three anthropometric indices. The prevalence of anthropometric deficit ( $z$ -score  $\leq -2$ ) in general was 2.6% in relation to height for age, 1.8% in weight for age, and 1.2% in weight for height. Even though they did not register important nutritional deficiencies, 5.7% of the

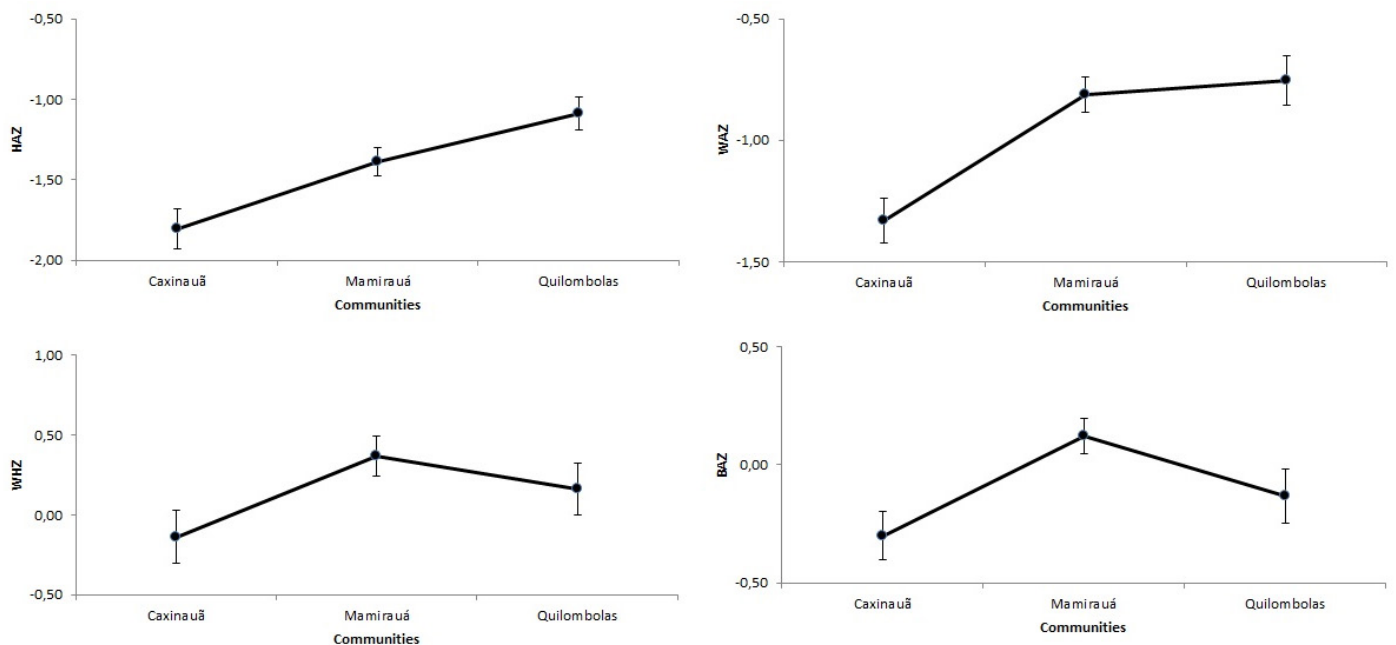


FIGURE 2. Comparison of growth parameters among the studied communities. HAZ - Height for Age Z-score; WAZ - Weight for Age Z-score; WHZ - Weight for Height Z-score and BAZ - BMI for Age Z-score.

children in the downtown area had a z-score greater than 2 in weight for height, whereas children in the rural area presented a negative z-score.

Silveira et al. (2010) investigated the association of malnutrition in children who lived in substandard settlements (*favelas*) of Maceió, northwest Brazil, with maternal nutritional status and environmental conditions. They showed that 8.6% of the children presented moderate and high malnutrition, whereas 11.3% were overweight/obese. In relation to the mothers, 38.8% of them had low stature (>1.55–1.60 m), whereas 45.6% were overweight/obese. They also found that the lower the school level of the mother was, less attention she gave to the personal and environmental hygiene habits of the infant, and the less capable she was of providing more appropriate food for the growth and development of the child. Also, 70.2% of the sample had a monthly income lower than the national minimum wage, which strongly influenced the nutritional status of the children.

According to the latest report of the Food and Agriculture Organization on food insecurity in the world (Food and Agriculture Organization of the United Nations et al., 2012), Brazil had a decrease in the number of undernourished people from 14.9% to 6.9%. Even though there are many limitations related to methodological and age range differences when trying to compare growth studies across the country, the samples presented here are, in general, still above this percentage, but the trend is in the right direction of a reduction in undernutrition in recent decades.

## CONCLUSIONS

Some recent studies have discussed the reasons for the decrease in undernutrition in Brazilian children and called attention especially to the Bolsa Família Program (BFP), a monthly income conditional cash transfer program from the federal government that began in 2003 and has been considered a successful model (Piperata et al., 2011a, 2013; Food and Agriculture Organization of the United Nations et al., 2012).

The Bolsa Família is the social program in which the greatest amount of public resources has been invested in the past decade. Jaime et al. (2014) affirmed that children participating in the BFP from 2008 to 2012 presented considerable improvements in their nutritional status. According to them, in this period, the overall height deficit prevalence in Brazil was reduced to 9%. The height and weight deficits were reduced 3.3% and 0.5%, respectively, in the Northeast, reaching a prevalence similar to the national data in 2012. However, the North region, despite presenting a reduction in the prevalence of poor nutritional indicators, still has greater height (19.2%) and weight (7.2%) deficits when compared with the national data, reinforcing the need for more studies about food security, the nutritional situation, and public policies of this region.

In general, the BFP has positively affected food acquisition, education, and health care assistance. Paes-Sousa et al. (2011), analyzing data collected during the Health and Nutrition Days in 2005–2006, mentioned that children from families participating in the BFP were 26% more likely to have normal height for age as well as weight for age than the ones who did not participate and affirmed that the program could lead to better nutritional outcomes since the number of undernourished children decreased in all social groups and there is a greater effort by the families to provide food for the children. The authors also showed greater access to goods and services, which ends up improving nutrition and health.

Conde et al. (2007) studied the child population of the Brazilian semiarid region by using data from the 2005 Health and Nutrition Day report, and they related that children younger than 5 years old who participated in the BFP showed a reduction of almost 30% in the frequency of stunting. The main benefits were for children between the ages of 6 and 11 months, who showed a 62.3% reduction in stunting that was attributed to the program.

However, Vega et al. (2014), who analyzed a nationwide sample of Brazilian children under 2 years old whose families were receiving Bolsa Família, showed that they could still be considered food insecure. They found erroneous introduction of food at a premature age, excessive weight in adults, and continued occurrence of health problems such as diarrhea and respiratory diseases. The Bolsa Família transfer program aims to guarantee food security, and what the authors observed was the opposite. They suggested that the program should be followed by serious educational interventions related to health and efficient eating habits. Our studies corroborate their perspective. Additionally, in another study, Pereira et al. (2008) analyzed anthropometric data of preschool children from families in the five regions of Brazil who received Bolsa Família and found that 17.6% of them still had low height for age.

In the past decade, many rural families started receiving this income (in our sample, 70% among the Quilombola, 30% in Mimirauá, and 71% in Caxiuanã), which has influenced their lifestyle as well as their health and nutrition in positive and negative ways, as shown. Over the past two decades there have been improvements in transportation and access to electricity. Some communities have received closed wells and hydraulic pumps. And there has been more access to consumer goods. The situation regarding vaccination of children has improved, and their access to schools has increased, associated with the implementation of the Bolsa Família and its predecessor programs (Bolsa Escola, Bolsa Alimentação, and Auxílio Gás, which were unified in the Bolsa Família in 2004). Throughout the country there has been a noticeable change in many rural households, with more appliances such as TVs, DVDs, sound systems, gas stoves, furniture, refrigerators, and washing machines, as well as some physical improvements in the houses. Many families who used to make farinha, have small food gardens, fish, and hunt are now

buying processed foods and trying to control the cash so that it will last for the entire month. Then, when it is gone, some have little or nothing to eat as they no longer plant or fish regularly. This insecurity can affect the long-term health and physical status of the children, who remain, in general, shorter and lighter than the national average. Piperata et al. (2011b) and Guimarães and Silva (2015) assert that among Caboclos and Quilombolas children's growth does not seem to be improving at the same rate as the economic indicators, calling attention to the need for a more detailed evaluation of the BFP.

Many studies link nutritional status and economic condition, indicating possible severe consequences for the future of children (Crooks, 1995; Bogin, 1999; Assis et al., 2007). Victora et al. (2008) analyzed associations between maternal and child undernutrition with human capital and risk of adult diseases in five low- and middle-income countries (Brazil, Guatemala, India, the Philippines, and South Africa) and found strong evidence that adequate nutrition in utero and up to the first 2 years of life is essential for the formation of human capital and is also associated with economic status in adulthood. Children facing malnutrition are more likely to become short adults, to have lower educational achievement, and to give birth to smaller infants. This is still the current situation faced by most of the Caboclos, Quilombolas, and Native Americans of the Amazon.

Although a certain effort has been made by the governments, the situation of Amazonian rural populations remains critical. As the available data show a slow pace of change, it is necessary to develop firmer and continuous interventions at the municipal, state, and federal government levels and the planning and implementation of long-term public policies designed to effectively deliver improvements in the quality of life and health of these populations.

The growth and health situation of Amazonian rural populations is a combination of a complex set of factors involving their geographic and environmental diversity and each one's particular socioeconomic situation and history, but as shown here, these populations also present commonalities with other regional and Brazilian populations. Overall, the Quilombola children are relatively short and light for their age; as in the Caboclo populations, the rates of undernutrition have fallen, and there are already some cases of overnutrition.

Naturally, the particularities of being Caboclos and Quilombolas cannot be forgotten. The latter face the added impact of racism and the constant struggle for their territory, factors that are often difficult to assess in terms of health impacts; in regard to the former they remain politically invisible, and many, such as those in our study samples, live in protected areas and are severely constrained in terms of subsistence activities (Silva, 2006b).

Quilombolas and Caboclos are among the most numerous Amazonian rural groups. They represent economically and socially vulnerable populations that are in the process of a forced transition from a more traditional to a more westernized lifestyle, leading to both a nutritional and epidemiologic transition

and resulting in some specific characteristics regarding their morbidity and mortality profiles. Unfortunately, the lack of more long term investigations and the absence of public policies more sensitive to their reality will make them continue to suffer for the decades to come.

## ACKNOWLEDGMENTS

This research was financed by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Departamento de Ciência e Tecnologia do Ministério da Saúde (DECIT/MS), and Fundação de Amparo à Pesquisa do Estado do Pará (FAPESPA). We also received support from UNICEF, from Instituto Saber Ser Amazônia Ribeirinha (ISSAR), from Instituto Mamirauá, and from the Universidade Federal do Pará. We thank the Museu Paraense Emílio Goeldi (MPEG), Prof. Dr. Edila Moura from the Mamirauá Sustainable Development Institute (IDSM) and Graduate Program in Anthropology-Federal University of Pará (PPGA-UFA), Prof. Dr. Graça Ferraz from the MPEG, and the Caboclo and Quilombola communities of Pará and Amazonas.

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# 6

## Osteological Research Development in Mexico

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**ABSTRACT.** This chapter presents a historical sketch outlining the development of scientific research regarding ancient human remains from Mexico, from discoveries in the nineteenth century excavations up to the present day, and the founding of various institutions charged with the study, preservation, and custody of those remains. A section of this chapter focuses on the explanation and discussion of the main theoretical and methodological paradigms used in the study of ancient populations, giving rise to different theoretical approaches that currently predominate in this discipline as well as the various issues that prevail today. Paleodemography as a specific subdiscipline in such studies—and its major contributions to understanding demographic dynamics of past populations—is another topic developed in this chapter.

**RESUMEN.** Se presenta un bosquejo histórico del desarrollo de la investigación en restos humanos esqueléticos de poblaciones antiguas de México, desde los primeros hallazgos en las excavaciones del siglo XIX hasta nuestros días, así como la fundación de distintas instituciones que tuvieron en su momento la encomienda de su estudio, conservación y custodia. Un apartado de este capítulo se destinó a la explicación y discusión de los principales paradigmas teóricos metodológicos utilizados en el estudio de las poblaciones antiguas, que originaron las diferentes corrientes teóricas que predominan actualmente en esta disciplina así como las distintas temáticas que prevalecen hoy en día. La paleodemografía como campo específico de este tipo de estudios es otro apartado que se desarrolla en este capítulo, así como sus principales contribuciones al conocimiento de la dinámica demográfica de las poblaciones del pasado.

**RESUMO.** Um esboço histórico do desenvolvimento de pesquisas em restos humanos de populações antigas do México, desde as primeiras descobertas nas escavações do século XIX aos dias de hoje, e da fundação de várias instituições tinha na época a carga dos presentes estudo, preservação e custódia. A seção deste capítulo dedicado à explicação e discussão dos principais paradigmas teóricos e metodológicos utilizados no estudo de populações antigas, dando origem a diferentes abordagens teóricas que atualmente predominam nesta disciplina, bem como as várias questões que prevalecem hoje. O paleodemography como um campo específico tais estudos é outra seção que é desenvolvido neste capítulo e suas principais contribuições para a compreensão da dinâmica populacional das populações do passado.

### INTRODUCTION

The discipline of anthropological osteology studies the physical variability of ancient human populations and their causes based on the analysis of skeletal remains. Its purpose is to discern physical features, living conditions and the way skeletons were influenced by

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

the physical–biological environment, due either to a developed occupational activity or cultural patterns prevailing at each stage of its evolution.

Based on extensive knowledge of skeletal biology, physical anthropologists in Mexico have gathered a large amount of information to build the complex biological and cultural mosaic formed by human groups that inhabited the present territory, evidence which can be found in thousands of archaeological sites scattered across the country from different eras and cultures. The development of skeletal biology studies in physical anthropology therefore demonstrates a theoretical and methodological process of maturity spanning more than a century of history.

With the founding of the Museo Nacional [National Museum] in 1825, the first collections of objects assembled from “ruins” of the great pre-Hispanic cities—such as Alta Vista, in Zacatecas, Teotihuacan in the state of México, Monte Alban in Oaxaca, and Palenque in Chiapas—were initiated. Several foreign expeditions arrived in Mexico throughout the nineteenth century. Notable was the French Mission sponsored by Joseph Bonaparte in 1864 and which included the first social scientists who studied mainly archaeological sites in La Huasteca region as well as sites in western and central Mexico to discover the roots of the Mexican people. Many of the objects and skulls recovered from excavations were sent to the countries that had financed the expeditions, so no craniological studies from that period were published in Mexico (Comas, 1970). Excavations were not continuous, and recovered skeletal remains were abandoned in the National Museum basement. Francisco Martínez Calleja created the physical anthropology department at the museum in 1887, but after only a few months it was replaced by the zoology department at the request of the museum director, Jesús Sánchez. Mexico participated in the scientific exposition of Madrid in the 400th-anniversary celebration of America’s discovery in 1892, which included skeletal remains collected for display from the Tarahumara in Chihuahua, Guadalupe in San Luis Potosí (SLP), and Santiago de Tlaltelolco in Mexico City. Alfonso L. Herrera and Ricardo Cicero restored the anthropology department in 1895 for the Eleventh International Congress of Americanists. Both also continued as well with excavation works in Tlaltelolco (Comas, 1970:13–14). In a first attempt to stop the looting and destruction of archaeological evidence, the government of Porfirio Díaz declared in 1897 that monuments and archaeological objects were to be considered as objects of national heritage (Márquez Morfín and González Licón, 2011).

## TWENTIETH CENTURY FOREFATHERS

Nicolas Leon was appointed in 1900 as assistant naturalist in the anthropology department. Through his research with Tarascos and studies in the museum’s anthropological collection, the first physical anthropology research was published in Mexico. The anthropology department was abandoned and activities stopped after Leon’s death in 1929. In 1931 Daniel Rubin de la

Borbolla and Javier Romero resumed activities. Excavations at that time in Monte Alban provided bone material, which was analyzed by Romero. These studies generated data about some cultural practices like dental mutilation, trepanation, and cranial modification. Analyses were started with Romero’s work on evident cranial modification in pre-Hispanic Mesoamerican bones, traits that had only been reported by Hrdlička (1908) for native groups of the American Southwest.

In 1940 Eusebio Dávalos Hurtado was the first student to graduate with a degree in physical anthropology from the Escuela Nacional de Antropología (National Anthropology School) at the National Museum. Dávalos Hurtado later became a medical surgeon who, along with his student, María Teresa Jaén Esquivel, encouraged studies of the presence of disease traces in human bones. They are both considered pioneers of osteopathological studies in Mexico, and their research is a collection of data that documents the most common diseases in pre-Hispanic remains (Dávalos Hurtado and Romano Pacheco, 1965; Dávalos Hurtado, 1970; Jaén Esquivel, 1978; Jaén Esquivel et al., 1990).

The decade of the 1960s represents a methodological breakthrough in osteological studies. Influenced by the student political movement of 1968, the curricula of physical anthropological studies at the Escuela Nacional de Antropología e Historia (ENAH [National School of Anthropology and History]) changed, adopting Marxist philosophy as a theoretical model to study social reality. This theoretical influence led some colleagues to propose the use of historical materialism as an analytical method. This prevailing school of thought at the ENAH during the 1960s and 1970s proposed a total shift towards comprehensive approaches that would not fragment the reality to be studied, which allowed understanding of the multiple causes of biological variability in human populations during each particular historical period (Dickinson and Murguía, 1982). The influence of Marxism in osteological work had little impact, and Arturo Romano Pacheco taught extra-curricular osteology courses. There were faint attempts to apply historical materialism in some osteological research, most of them resulting in overlapping adaptations of a series of statements that tried to integrate social-economic, political, ideological, and cultural factors with biological analysis results, but without being able to correlate scientific results (Márquez Morfín, 1996).

During the development of the field of osteology, researchers had adopted different methodological approaches in an attempt to find answers about migration and biological distance issues among human groups, or within groups. Hypotheses included “What type of relationship was there among groups?”, “Where did they come from?”, and “What was the genetic admixture process?” (Vargas Guadarrama, 1973; Pijoan Aguadé and Salas Cuesta, 1984). Sometimes epigenetic characters were addressed in a given population, but the issue or query that could be answered using this technique was not clear.

Osteopathological studies for disease classification, aetiology description, distribution and age are plentiful and considered as an inseparable part of skeletal monographs (Salas

Cuesta, 1977; Bautista Martínez, 1986; Crespo Torres, 1989). These monographs spread the practice of incorporating descriptions of specimens with pathological alterations as an appendix in the study of physical traits, mainly clinical and aetiology disease issues, from the history of medicine and disease perspective (Jaén Esquivel, 1996). Overall, the study advances involved positivist thought, hence the interest in long and detailed descriptions of techniques used. New techniques were automatically used in Mexican research as they emerged abroad just for the use of the technique itself rather than implementing its use as a means of testing a hypothesis.

The bioarchaeology concept, coined by Jane Buikstra in the late 1970s (Buikstra, 1977), was introduced in Mexico during this period in order to name a comprehensive methodology for the interpretation of finds during excavation, including all kind of materials. However, the purpose was neither the analysis of cultural remains by the archaeologist, nor of human skeletons by the physical anthropologist for an osteological report, which most often became part of an appendix in the archaeologist's publication. The bioarchaeological proposal involved coordinating ideas, assumptions, scenarios and discussions among peers that address a topic from different approaches in order to find an answer to questions previously posed in a research protocol.

The development of bioarchaeological studies under this approach has had a number of obstacles that have limited its development, such as few physical anthropologists specializing in osteology, or the poor condition of bone preservation due to taphonomic causes. The leading factor in the lack of development of integrated projects is based on the regulations of the Instituto Nacional de Antropología e Historia (INAH). The physical anthropologist was not authorized to perform archaeological excavations for the recovery of skeletal series, and the archaeologist seldom submitted documentation about the context (Hernández, 2011). Thus, bone material usually was analyzed with no contextual data for each individual skeleton. In rare cases, some bioarchaeological studies were performed in which physical anthropology and archaeology were integrated to interpret findings based on a solid research approach with defined questions and specific methodology (e.g., those bioarchaeological works done in Monte Albán by Márquez Morfín and González Licón (2006); in Xcambó, Yucatán, by Tiesler Bloss et al. (2005); in Tamtoc, San Luis Potosí, by Córdova Tello et al. (2012)).

## PARADIGMS IN SKELETAL BIOLOGY RESEARCH

### OSTEOBIOGRAPHICAL ANALYSIS

Osteological research since the 1970s, influenced by research on adaptation processes of human populations, addressed the matter of “living conditions” of ancient populations by identifying injuries related to health and nutritional aspects of individuals. Spongy hyperostosis and *cribra orbitalia* were the

most common injuries identified in bone material, both being associated with iron deficiency anaemia (Pijoan Aguadé and Salas Cuesta, 1984). Other examples include: infections and malnutrition identified by growth arrest lines or Harris Lines in long bones and enamel hypoplasia (Mansilla Lory, 1980; Mansilla Lory and Villegas Alcantara, 1995); as well as occurrence of periostitis as non-specific signs of infectious disease and frequency of osteoarthritis in pre-Hispanic human remains (Serrano Sánchez, 1966).

Frank Saul (1972) developed the first comprehensive approach using the presence of pathological processes as indicators of disease, such as spongy hyperostosis and *cribra orbitalia* as iron deficiency anaemia indicators. Also, he used osteometric techniques to physically characterise individuals and calculate their height in order to record changes within this parameter and find an interpretation in biosocial terms. Morphoscopic analysis on cultural body changes such as cranial deformation and dental filing, among other factors, were associated with social status of the individual as well as evidence of their geographic origins. Saul's osteobiographic analysis had an impact on osteological research carried out in Mexico in the late 1970s. The osteobiographic model prevailed at the beginning of the 1980s in the study of several pre-Hispanic Mayan collections (Márquez Morfín, 1982, 1984, 1987). Currently, some research designs are based on Saul's osteobiographic model, demonstrating the continued importance of his research.

### THE HEALTH-SOCIETY PARADIGM

Under the influence of Marxism, the osteobiographic approach and the Goodman et al. proposal (1984) led to the implementation of a systematic methodology and specific research questions in the late 1990s. An interest developed in Mexico within the anthropological osteology field in leaving behind the biological conceptual structure, to find new analytical approaches to understanding humans as social beings. The acceptance that the biological phenomenon is determined by multiple factors led to a search for interpretive approaches to osteological studies using a theoretical framework that recognizes social, economic, political, and ideological aspects of the biological phenomenon and the way in which these aspects are interrelated.

The health-society paradigm would later arise, focused on micro-adaptation processes of human populations through the comprehensive assessment of physical and cultural characteristics, and health and living conditions of ancient groups. The study of these processes has evolved from a change in the theoretical approach and systematic methodology. This change consisted in analysing the epidemiological and demographic pattern as the research center line instead of descriptive results for taxonomic purposes, or the identification, from the clinical point of view, of any disease as a paleopathological appendix of osteometric monographs. Research in Mexico, derived from the Goodman and Martin model (2002), was developed by Lourdes Márquez Morfín as part of the “Health and Nutrition in the Western Hemisphere” project coordinated by Steckel

**TABLE 1.** Health and nutrition indicators for La Ventilla and Tlajinga 33 in Teotihuacán; Monte Albán, Oaxaca; Jaina, Campeche; and Palenque, Chiapas. The *n* represents number of cases with indicator / total number in the sample; % is the percentage of cases with an indicator; a dash (—) indicates data not available.

Indicator	La Ventilla		Tlajinga 33		Monte Albán		Jaina		Palenque	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Spongy hyperostosis	17/68	25	2/34	2.9	3/81	3.7	17/62	27	62/69	89.9
<i>Cribra orbitalia</i>	—	—	4/31	12.9	3/81	3.7	20/60	33	23/28	82.1
Enamel hypoplasia – incisor	10/59*	17	—	4.5	3/39	7.7	—	—	24/47	51
Enamel hypoplasia – canine	10/59*	17	—	55.2	1/38	2.6	13/25	52	35/50	70
Tibiae periostitis	10/69	15	17/46	36.9	12/70	17.1	37/75	49	118/121	97.5
All skeletal periostitis	2/57	4	25/50	50	11/87	12.6	46/22	38	163/170	95.8

\* Values for incisors and canines.

and Rose (2002). Osteological series analyzed under this new approach came from the Valley of Mexico Basin, Monte Alban in Oaxaca and the Maya area, in particular Palenque, Chiapas; ChacMool, Quintana Roo; Jaina, Campeche; Xcaret, Quintana Roo; and Copan, Honduras. Health and nutrition as well as the mortality profile make up the main results of this research to date (Table 1).

However, this line of osteological research has been criticized mainly by physicians involved in osteological research, as well as by demographers and other physical anthropologists who support the traditional lines of descriptive and classifying research. Reviews varied, some suggesting that physical anthropology was unable to correctly determine the age of a skeleton since assessment parameters are based on reference series biologically distant to the series being studied, or that using these standards would replicate the age structure of the reference population. Furthermore, these reviews posed the question about the ability to know if past growth and attrition processes were similar to present ones (Bocquet-Appel and Masset, 1982; Bocquet-Appel, 1985, 1996), which misrepresents the paleodemographic work to be detailed later.

Most studies on health and living conditions are based on the health-society paradigm, which arises from a scheme where population and environment are bound through two large bridges: (1) the social organization through which human beings develop the structures and processes required to transform nature, and (2) the genome, which transforms the deepest constitution of human populations. It is therefore essential for the health and nutrition study of ancient populations to contain archaeological data of human skeletal remains so the level of cultural development of these societies can be considered during the interpretation of results. These data will also demonstrate the multiplicity of causes of biological variability, primary and secondary determinants of health changes, demographic profiles, and the way these factors affect the social and economic organization.

## PALEODEMOGRAPHY

Paleodemography is a physical anthropological approach developed throughout the twentieth century, influenced by the development of life condition studies in ancient populations based on the health-society paradigm. One of the most sensitive indicators within this paradigm is precisely the analysis of mortality profiles, their determinants, and impact in life span. Paleodemography became a basic methodological tool in these types of studies and among the most important research fields in the twenty-first century.

Mexican paleodemography was originated from Douglas Ubelaker's work (1974), which built a life table from an age-at-death distribution of individuals represented in an ossuary excavated near a tributary of the Potomac River. The methodology used by the author was based on the Swedlund and Armelagos (1969) and Acsádi and Nemeskéri (1970) proposals to build a life table, which required ages-at-death to be grouped into discrete age categories. This involved leaving behind the traditional way anthropologists grouped individuals into broad age groups according to Hooton's classification (1947), and included the accurate application of new standards for age-at-death estimates. Several researchers used this methodology to develop the life table, including the work of Civera Cerecedo and Marquez Morfín (1985) who analyzed one of the largest Mexican bone collections consisting of six tons of skeletal remains from the basement of the Metropolitan Cathedral in Mexico City, dated from the seventeenth to the mid-nineteenth centuries. Mario Ceja Moreno's research (1987) on the pre-Hispanic population of Azcapotzalco produced the first figures on the demographics of a Tepaneca group related to the period prior to the arrival of the Spanish; Hernandez Espinoza's work (1991) was the third effort based on Ubelaker's methodology of another colonial sample in the cathedral with primary burials from the sixteenth to the nineteenth centuries, unlike skeletons excavated in 1976 that

were mixed when extracted by a backhoe and had to be analyzed as an ossuary (Márquez Morfín, 1984).

From Janus Nemeskéri's visit to Mexico and the course taught to some interested physical anthropologists, the methodology used in paleodemographic work was the one proposed by Acsádi and Nemeskéri (1970). The first research performed under this new methodology was on an osteological series from an ancient village of the pre-Classic period (2,000 BC–AD 200) in the Basin of Mexico, Tlatilco, consisting of over 400 skeletons of all ages and both sexes from which the first reliable mortality table was obtained for a group that lived 4,000 years ago (Civera Cerecedo and Márquez Morfín, 1998). Paleodemography, however, was not well received in anthropological circles. The reluctance of anthropologists to venture into paleodemography relates to bioanthropological education, which involves specialization in social and cultural as well as medical and biological areas, leaving aside statistical and mathematical data, combined with the lack of paleodemography courses. Regarding demography, poor data on cultural, social and even political and ideological issues often prevented demographers from correctly interpreting statistical results, even though demographic techniques are reliable. In light of a new scenario, these circumstances may have generated an atmosphere of uncertainty in those fellow anthropologists and demographers who attempted to break into paleodemography, very few of whom continue research on this issue.

DEMOGRAPHIC DYNAMIC OF SOME PRE-HISPANIC GROUPS

Paleodemographic works developed during the past 15 years can be grouped into two research trends.

1. *Obtaining and interpreting paleodemographic profiles*

As indicated previously, one indicator of the Goodman and Martin (2002) model is the paleodemographic profile of an osteological series. Most of the series so far analyzed are related to research in the health of prehistoric peoples. Tables 2, 3, and 4 show some of the results obtained from Mesoamerican osteological series.

These results are can be generalized neither for Mesoamerica nor for the rest of Mexico, since they are reconstructed based upon samples recovered from archaeological sites that had a specific development in a determined time and whose mortality is the result of variable historical circumstances. For example, Table 2 shows some of our results obtained in several osteological series studied in the last 15 years, which come from populations that lived in different periods and that had different forms of social organization, hence the results of the indicators are not homogeneous, as they respond to factors such as social stratification and unequal access to resources, among others.

Table 3 depicts samples of population excavated in Mexico City and who lived during XVIII and XIX centuries. The differences obtained are due to the social sector to which they belong. Finally, Table 4 shows the paleodemographic profile of some Mayan populations of the Classic and Postclassic periods, highly stratified societies that according to archaeological data had different rates of growth. What they share are deplorable hygienic conditions that shortened their life span.

2. *New techniques and methodologies*

One of the limitations of paleodemography is that sex of those under age fifteen is not represented in osteological series. Skeletal biology studies question the identification of this

**TABLE 2.** Survival indicators for different Mesoamerican osteological series.  $E_{(0)}$  = mean expectancy of life at birth;  $E_{(30)}$  = expectancy of life at age 30;  $l_{(15)}$  = survival probability at age 15; AA = average age of population over 15 years old; S = survival percentage over age 50. A dash (—) indicates data not available.

Series	Chronology	$E_{(0)}$	$E_{(30)}$	$l_{(15)}$	AA	S (%)
Tlatilco	(1300–0 BC)	20.7	10.8	0.366	29.6	10.7
Cuicuilco	(1300–0 BC)	25.9	10.5	0.550	29.9	6.3
Monte Alban	(300–900 BC)	23.4	8.1	0.476	28.6	6.2
Tlajinga 33	(300–900 BC)	24.8	27.4	0.345	29.3	7.7
Jaina	(300–900 BC)	17.4	18.3	0.320	28	13.0
Xcambó	(300–900 BC)	25.7	17.1	0.5979	—	—
Palenque	(300–900 BC)	25.1	8.77	0.466	26.8	3.4
Chac Mool	(300–900 BC)	20.2	16.0	0.524	33.6	24.3
Chac Mool	(1200–1521 BC)	20.6	—	—	31.6	19.9
Xcaret	(1200–1521 BC)	15.4	6.4	0.361	31.6	19.0
El Meco	(1200–1521 BC)	26.8	—	—	—	—
Cholula	(1200–1521 BC)	23.9	9.8	0.480	29.3	7.7

**TABLE 3.** Paleodemographic indicators for the Colonial period in Mexico City and in a rural area (San Gregorio Atlapulco, Xochimilco).  $E_0$  = mean expectancy of life at birth;  $E_{15}$  = expectancy of life at age 15;  ${}_1q_0$  = Infant mortality rate; A = Average age of all once-living population; AA = average age of population over 15 years old.

Series	$E_0$	$E_{15}$	${}_1q_0^*$	A	AA
Cathedral	23.9	26.7	225	21.1	33.1
Soledad	30.1	26.5	166.7	23.5	31.9
San José	22.3	16.3	180	17.1	27.2
Santa Paula**	23.7	24.0	180	26.1	28.7
San Gregorio	15.6	18.1	213	18.0	28.6

\* For every 1,000 births. Source: Márquez Morfín and Hernández Espinoza (2016).

\*\* Source: Ortega Muñoz (2004: 198–201).

**TABLE 4.** Fertility and survival indicators for Mayan coastal settlements.  $r$  = annual intrinsic rate of increase;  $E_0$  = expectancy of life at birth;  ${}_1q_0$  = infant mortality rate; A = Average age of all once-living population; AA = average age of population over 15 years old; TFR = total fertility rate; F = mean family size. A dash (—) indicates data not available.

Indicator	Jaina	Terminal	Post-	El	Xcambó
		classic	classic		
		Chac	Chac	Meco	
		Mool	Mool		
$r$	1.5%	2%	1.5%	1.5%	2.6%
$E_0$	15.9	21.3	20.1	26.8	37.6
${}_1q_0$	33.3%	23%	26%	70%	—
A	19.4	21.3	20.1	—	—
AA	30.7	33.1	33.6	—	—
TFR	6.4	6.4	6.6	4.3	6.0
F	3.9	3.7	4	—	—

Sources: Márquez Morfín and Hernández Espinoza (in press), Ortega Muñoz (2007), and Tiesler Bloss et al. (2005).

parameter through traditional methods. Hernández Espinoza (Hernández Espinoza and Peña Reyes, 2010; Hernández Espinoza and López Mendiola, 2010) developed a technique for sex identification in infant skeletons, and results were compared with those obtained by nuclear DNA identification with an accurate ratio of 80% (De la Cruz Laina et al., 2008). This changed the perspective of these studies. Hernández Espinoza and Márquez Morfín's (2010) research on children represented in the San Gregorio osteological series is a sample of this change in a mortality profile interpretation. Results show a high mortality

of girls between three and four years old; their skeletons have malnutrition injuries due to the inequity displayed towards them since boys in pre-Hispanic societies had greater social status, so the latter were better cared for and better nourished (Figure 1).

A meeting in Rockstock, Germany was held at the beginning of the twenty-first century with European and American paleodemographers. These “hardliners” of paleodemography believe that this specialty should be based more on the application of mathematical models to eliminate imperfections of the distribution by age groups. Results of this meeting were published in the book *Paleodemography: Age Distribution for Skeletal Samples* (Hoppa and Vaupel, 2002), which criticizes the traditional methodological standards used by physical anthropologists to estimate age-at-death in individuals over fifty years due to the lack of accuracy of age estimation of the elderly. This work discloses the *transitional analysis* (Boldsen et al., 2002), a method for age-at-death estimation based on information obtained from three indicators: cranial sutures, pubic symphysis and auricular surface of the ilium, using the coding system established by the authors. According to the authors, an advantage of transitional analysis is the ability to improve age estimations of older adults, which has been and is a troublesome issue in paleodemography since many estimation methods in adulthood have an open terminal age category, such as 55 years or more. However, by applying this method to the San Gregorio osteological series, ideal for paleodemographic work due to its composition, distribution reaches 115 years, which is not consistent with data on aging and life expectancy obtained for European, Asian, Caribbean and Mesoamerican series (Bullcock et al., 2013; Hernández Espinoza et al., 2013) (Figure 2). Paleodemographers and their colleagues therefore need to keep working on these matters.

Finally, despite all criticism and controversy, the paleodemographic approach remains the primary way physical anthropologists and demographers can learn about ancient population dynamics. Paleodemography is considered a “bridge” to articulate biological data with cultural data, which is ultimately our task as social scientists.

## TRENDS IN OSTEOLOGICAL RESEARCH

In summary, three trends in the research of skeletal remains can be distinguished currently in Mexico:

1. Osteological research based on physical anthropology research classics that have been innovated with new research questions and new methodologies, including those related to the characterization of populations and their variation through the geometric morphometric technique. Research on taphonomic processes and identification of cut marks according to Pijoán Aguadé's technique (1997) is another line that has shown efficacy in the study of skeletal remains presenting evidence of ritual treatment. Work on cultural practices such as intentional cranial modification and its association with social organization is another matter that has been widely developed in the last decade



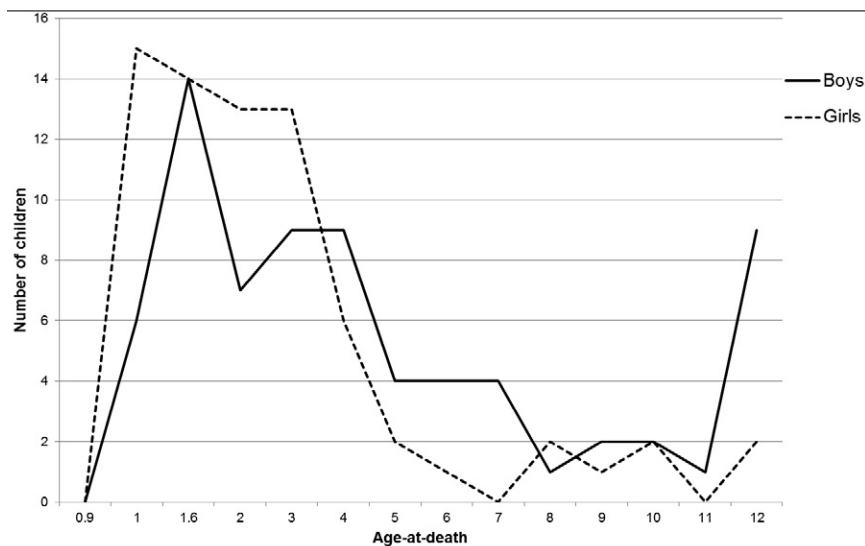


FIGURE 1. San Gregorio, Atlapulco-Xochimilco, México. Subadult series: sex and age at death distribution.

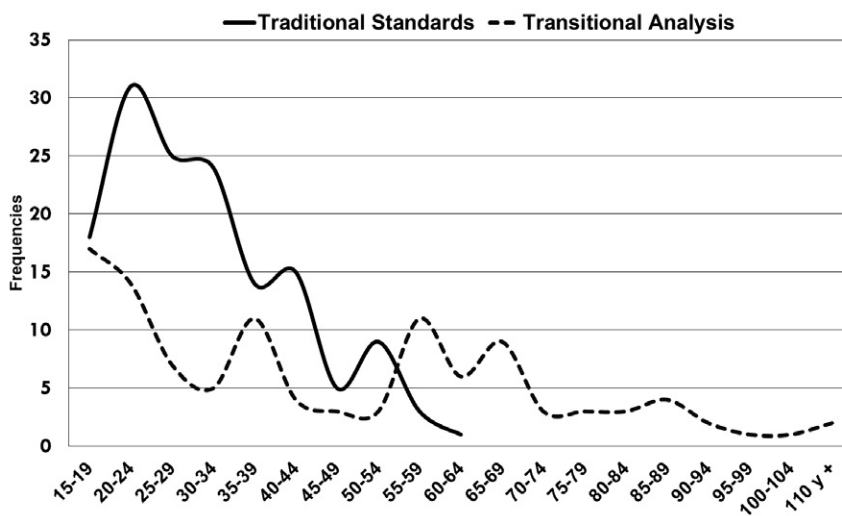


FIGURE 2. San Gregorio, Atlapulco-Xochimilco, México. Age at death distribution: comparison between two methods.

(Tiesler Bloss, 2012). This cultural practice has also been used as a good indicator of population mobility as shown by the research of Sierra Sosa et al. (2014), results of which shall be presented in paragraph 3, below. A typical subject is burial patterns, which has been included in social stratification and inequality studies, providing new interpretations of the funerary patterns and mortuary practices.

2. The second trend consists of studies on health and nutrition based on the health-society paradigm. This trend includes

paleodemographic research and issues related to specific living conditions of populations, such as research on child growth looking for trends in the past regarding their lifestyles. Examples of this type of research are available in Márquez Morfín et al. (1998); Peña Reyes et al. (2007); Peña Reyes and Hernández Espinoza (2008); and Peña Reyes et al. (2010). Gender studies in ancient populations are another line included in this trend, which focus on two issues: the role of women in prehistory and the presence of children in the archaeological record. These two

strands are synthesized in the work coordinated by Marquez Morfín (2010), one of the first academic works in Mexico in this type of research. Reconstruction of physical activity through markers caused by work and daily activities reflected in the skeleton is another line of research developed within this trend, based on the identification of musculoskeletal indicators. This line can be used to explain how populations adapted or adjusted to different livelihoods from a biological and cultural view, as well as economic, ecological, and political factors, among others (Alfaro Castro, 2002; García Maya, 2001; Giannisis, 2004; Medrano Enríquez, 1999).

3. The third trend was developed by the application of new techniques derived from biological and chemical sciences to osteological work, as with DNA recovery and identification, which has positively impacted the study of ancient populations. This trend is also characterized by interdisciplinary research, e.g., biochemical analyses of carbon and nitrogen. After identifying the type of artificial cranial modification of individuals making up the osteological series of Xcambó, Yucatán, and ceramic analysis of offerings, Sierra Sosa et al. (2014) proposed that there was great mobility among exchange centers of the Yucatan peninsula coast and in southern Mayan area settlements during the Post-classic period.

One of the questions physical anthropologists constantly have is the sex identification of children's remains recovered from offerings related to the rites and ceremonies devoted to the pantheon of Mesoamerican gods. The identification of ancient DNA has provided an answer to some of these questions. We now know that offering 48 at the Templo Mayor, devoted to Tlaloc, was made up of three-year-old boys (De la Cruz Laina et al., 2006). The mixing process from identification of mitochondrial DNA helps to find an answer to questions about American settlement. The research of Gonzalez Oliver et al. (2001) on haplogroups present in Mayan populations provides an answer to questions about the origin of this group. Research to discover kinship from the analysis of skeletal remains from graves is a prolific field with good results. Dietary composition and its impact in health is another line of osteological research through the analysis of trace elements and stable isotopes. This type of research is included in social inequality studies in order to interpret the results from some series where men have access to animal protein, while the diet of women was based on corn collection and its derivatives (Berriel, 2002; Brito, 2000; Rodríguez, 2004).

Despite these achievements, physical anthropology in Mexico has a long road ahead. However, osteological studies present several challenges that must be overcome by the next generations in the search for new paradigms to solve the research questions that concern young researchers today. The development and implementation of new technologies to enhance osteological studies is perhaps their most promising avenue for new advances.

One of the most important challenges is to overcome the differences between different specialties that converge in an excavation. Archaeologists and physical anthropologists need to

look for integral planning studies focused on populations and find new ways to interpret the past of the Mexicans.

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# Paleopathology in Mexico

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**ABSTRACT.** Paleopathology, the study of disease in ancient populations through the examination of human remains, is a recognized field of knowledge in the scientific world. Its contributions to anthropology, archaeology, and medicine have earned it a relevant place because it has enhanced the knowledge of vital phenomena and of health-related biocultural processes in human populations worldwide (Buikstra and Roberts, 2012). Research in the Americas provides a general overview of disease in the past, with emphasis on some regions such as North America or the Andes (Verano and Ubelaker, 1992; Steckel and Rose, 2002). A regional review with a historical perspective is the main focus of this chapter, which presents the origins and development of paleopathology in Mexico. Discussion includes a review of osteopathological studies and reflection on the current state of the field, including future perspectives.

**RESUMEN.** La paleopatología, el estudio de la enfermedad en poblaciones del pasado por medio del examen de restos humanos, constituye un campo de conocimiento reconocido en el ámbito científico. Sus aportes, en la antropología, la arqueología, la medicina, le han ganado un lugar relevante por su contribución a un mejor conocimiento de los fenómenos vitales y los procesos bioculturales relacionados a la salud en las poblaciones humanas alrededor del mundo (Buikstra y Roberts, 2012). Si enfocamos nuestro interés al continente americano podremos encontrar contribuciones que nos dan una perspectiva general de la enfermedad en el pasado, con énfasis en algunas regiones como Norteamérica o la región Andina (Verano y Ubelaker, 1992; Steckel y Rose, 2002). Una revisión a nivel regional, que sustente una perspectiva histórica de las aportaciones efectuadas, es sin duda conveniente. Nuestro interés principal en este trabajo es revisar los inicios y desarrollo de la Paleopatología en México; mostraremos enseguida su contribución al conocimiento de las afecciones osteopatológicas entre los antiguos habitantes del actual territorio mexicano. Finalmente, formularemos una reflexión sobre el estado actual de este campo de estudio y sus perspectivas a futuro.

**RESUMO.** A paleopatologia, o estudo da doença em populações do passado por meio dos remanescentes humanos, constitui um campo de reconhecido conhecimento na esfera científica. Suas contribuições, na antropologia, arqueologia e medicina, lhe renderam um lugar de destaque por sua contribuição para uma melhor compreensão dos fenômenos vitais e processos bioculturais relacionados à saúde em populações humanas ao redor do mundo (Buikstra e Roberts, 2012). Se nos concentrarmos nosso interesse no continente americano encontramos contribuições que nos dão uma visão geral da doença no passado, com ênfase em algumas regiões, como América do Norte e da região andina (Verano e Ubelaker, 1992; Steckel e Rose, 2002). A revisão a nível regional, que suporta uma perspectiva histórica das contribuições feitas, é certamente conveniente. Nosso principal interesse neste artigo é revisar o início e desenvolvimento da paleopatologia no México; logo mostrar sua contribuição para o conhecimento das condições osteopatológicas entre os antigos habitantes do atual território mexicano. Finalmente, iremos desenvolver uma reflexão sobre o estado atual deste campo de estudo e as perspectivas futuras.

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*Manuscript received 28 April 2016; accepted  
10 November 2017.*

## **HISTORICAL DEVELOPMENT OF PALEOPATHOLOGY IN MEXICO**

The study of skeletal remains of ancient populations has been a goal of anthropology in Mexico since the country's formal constitution in the last third of the nineteenth

century. Instructions for anthropological research in Mexico, put together by the Société d'Anthropologie de Paris, advocated compiling skeletal collections that accounted for the origin and diversity of the country's pre-Hispanic indigenous population. At that time, several pre-Hispanic osteological materials arrived in France from Mexico, and they are currently part of the anthropological heritage of the Museum of Man in Paris. Collections now kept at the National Anthropology Museum in Mexico were also begun during this time. While registering and cataloging these collections, the presence of pathological alterations was noted. Aleš Hrdlička, who published an initial study in this field (Hrdlička, 1899), visited Mexico at the end of the nineteenth century. His visit was an incentive for Nicolás León, a trained physician and an undisputed pioneer of Mexican physical anthropology, to establish the recording system for pathological conditions that the museum used in the management of its bone collections. León himself recovered, at this early stage, pathological cranial specimens that are still recognized as crucial museum pieces and that were studied much later, including one case of leontiasis ossea (Dávalos Hurtado, 1953; Mansilla Lory et al., 2007) and one of oxycephaly (Romano, 1991).

Formal research in the field of paleopathology in Mexico began in the late 1950s under Eusebio Dávalos Hurtado, who trained as a homeopathic physician and was the first student to graduate from the recently established National School of Anthropology (Escuela Nacional de Antropología). He authored several papers, mainly case studies, that were gathered in a book integrating his contributions on the subject (Dávalos Hurtado, 1964, 1965). These studies, which he referred to in subsequent publications, allowed him to convey a general appreciation of health- and disease-related phenomena among the ancient peoples of Mexico (Dávalos Hurtado, 1967, 1970). Dávalos Hurtado introduced paleopathology as a subject in the curriculum of physical anthropology at the National School of Anthropology and History (Escuela Nacional de Antropología e Historia, or ENAH). Thus he contributed to a new stage in the development of paleopathology in the country, under the framework of the also recently established National Institute of Anthropology and History (Instituto Nacional de Antropología e Historia, INAH).

In 1953, the first National Congress on Radiology, Physical Medicine, and Rehabilitation took place in Mexico City. With support from INAH, Luis Vargas y Vargas, an expert radiologist, orchestrated an exhibition of pathological pieces from several archaeological sites accompanied by radiographic images. With the collaboration of Dávalos Hurtado, a series of research projects followed that incorporated the use of x-rays in osteopathological research (Dávalos Hurtado and Vargas y Vargas, 1956).

Presentation of a thesis by Serrano Sánchez (1966) on the frequency of osteoarthritis among several pre-Hispanic populations of Mexico can be taken as the beginning of the use of population analysis that attempted to link expression of illness with the physical environment and life conditions among those groups studied. At the time, this approach already had been used

for several years by renowned researchers working with skeletal collections in different regions worldwide (Hootton, 1930; Snow, 1948; Angel, 1955; Nemeskeri and Harsanyi, 1959; Brothwell and Sandison, 1967).

The increase of research on ancient skeletal remains undertaken by a new generation of physical anthropologists has also created a broader paleopathological record, including skeletal samples from different places and chronological periods. This information is scattered among several archeological texts, in the form of appendices, as part of the osteological record.

Saul's (1972) methodological proposal on an osteobiographical analysis represented a qualitative boost to paleopathological work in Mexico. It established questions that have been integrated into the study of ancient populations' vital phenomena and life conditions. Saul's work in the Mayan region resulted in valuable contributions to knowledge of the role(s) that sickness played on the population dynamics of peoples from this region (Saul, 1973; Saul and Saul, 1984).

The first attempts to establish a view of pre-Hispanic osteopathological conditions, presented in a systematized way date to the early 1970s (e.g., Jaén and Serrano, 1974). They were later extended in several publications, taking into account the identification of large categories of pathological conditions or their progression in different moments of pre-Hispanic chronology, even including the colonial period (Jaén, 1977; Jaén and Márquez, 1985; Jaén Esquivel et al., 1991; Jaén Esquivel, 1996; Márquez Morfín et al., 2002).

In the 1980s further work to gather this information was assumed by the National Academy of Medicine (Academia Nacional de Medicina) as part of a project titled *General History of Medicine in Mexico (Historia General de la Medicina en México)* (Martínez Cortés, 1984). Several authors reviewed the presence and frequency of pathological alterations in skeletal remains, taking into account different regions and chronological stages. These papers appeared in *México Antiguo* (Martínez Cortés, 1984). The issue includes essays on prehistoric settlers (Serrano Sánchez and Castillo, 1984a), agricultural peoples of the Village period (Serrano Sánchez, 1984), settlers of the Teotihuacan metropolis in the Classic period (Serrano Sánchez and Castillo, 1984b; Somolinos, 1984), pathology of the peoples of central Mexico in the Postclassic period (Civera Cerecedo, 1984; Salas and Serrano Sánchez, 1984; Viesca Treviño, 1984), and osteopathology of ancient Mayans (Saul and Saul, 1984). Papers focused on medical treatments described in ethnohistorical sources, and ethnographical documentation was also included.

In the same decade, works of North American authors such as Goodman et al. (1984) and Hodges (1989)—and a later proposal of biocultural synthesis advocated by Goodman and Leatherman (1998)—had strong influence on the academic programs established to train new researchers. An increasing number of archeological explorations in the country have yielded several skeletal series, allowing researchers to undertake broad analyses of the health and biological conditions exhibited.

## RECENT PALEOPATHOLOGICAL RESEARCH

### INSTITUTIONAL FRAMEWORK

The Department of Physical Anthropology was established in 1877 as part of the former National Museum (Museo Nacional), where Nicolás León carried out fruitful work at the start of the twentieth century. He forged an anthropological research tradition that has been carried on in the new National Museum of Anthropology (Museo Nacional de Antropología) affiliated with INAH. The Department of Physical Anthropology is headquartered there, where it maintains Mexico's pre-Hispanic and colonial period skeletal collections.

Human osteological materials are kept also by regional offices of INAH throughout the country, although the number of physical anthropologists working in those locations is small. Within INAH, its school, ENAH, preserves several osteological collections and has the support of an academic group of physical anthropologists who have contributed greatly to the field of paleopathology.

The School of Anthropology and History of Northern Mexico (Escuela de Antropología e Historia del Norte de México) was established more recently. It also is overseen by INAH and carries out work related to paleopathology.

Another institution focused on physical anthropology where paleopathological topics are studied is the Institute of Anthropological Research (Instituto de Investigaciones Antropológicas, or IIA), housed at the National Autonomous University of Mexico (Universidad Nacional Autónoma de México, or UNAM). The IIA was formally established in 1973, but its history began ten years before in the anthropology section of the Institute of Historical Research (Instituto de Investigaciones Históricas) within the same university.

A project to exhume human remains was conducted by IIA in recent years in the graveyards of ancient churches located in the state of Hidalgo, Mexico. Led by María Villanueva and Lilia Escorcia, this project yielded a small, contemporary skeletal collection that includes identification data from the exhumed individuals. Several mummified corpses were also studied. The results include pathological data that were reported mainly in undergraduate and master theses on physical anthropology (López Juárez 2007, Menendez Taboada 2009, Sánchez Crispin 2009, Ugalde Bravo 2009).

The School of Medicine at UNAM has established a contemporary skeletal collection with biological profiles. The collection is still growing, and it includes specimens exhibiting pathological diseases that constitute valuable referents for paleopathological research (Huicochea, 2003; Báez Molgado and Herrera Saint-Leu, 2007; Báez Molgado et al., 2009).

Another project with positive impact is FOROST (forensic osteology; Gilbert et al., 2011), an online metadatabase of images of skeletal trauma. The project was designed for free dissemination of standardized traumatic injury data provided by

several institutions and countries worldwide. It was established through collaboration of UNAM's School of Medicine and IIA with California State University, East Bay.

Other initiatives promoting paleopathological studies in recent years include the osteopathology seminars launched by IIA in collaboration with the School of Medicine (UNAM). Frank Saul and C. E. Merbs are renowned scholars in this field who have participated in these events.

Some state universities in Mexico employ physical anthropologists or bioarcheologists in their academic departments (e.g., Zacatecas, San Luis Potosí), but in particular, the Autonomous University of Yucatán (Universidad Autónoma de Yucatán) has developed a very successful concentration and postgraduate program on skeletal anthropology. The program has been highly successful and has promoted bioarcheological research focused on the Mayan culture (Cucina and Tiesler, 2003).

Since its foundation in 1981, activities carried out by the Mexican Association of Biological Anthropology (Asociación Mexicana de Antropología Biológica) have stimulated paleopathology as well as other lines of research. A significant number of talks have been given at the "Juan Comas" Colloquiums of Physical Anthropology (Coloquios de Antropología Física "Juan Comas"). These talks were published thereafter in the journal *Estudios de Antropología Biológica* (<http://www.revistas.unam.mx/index.php/eab>), and they show the contemporary tendencies regarding the theoretical-methodological approach of several ongoing research projects.

## THEMATIC TOPICS

### CASE STUDIES

Several examples of case studies referring to conditions that display a striking appearance, such as the previously mentioned skulls with leontiasis or oxycephaly, can be found in the literature over time. Specific infections such as treponematosi and tuberculosis have attracted great attention. This information, however, must be integrated into the debate regarding the geography of these diseases and their spread through time from the pre-Hispanic era to the colonial period (Mansilla and Pijoán, 1995, 1998, 2005; Mansilla and Pijoán Aguadé, 2003).

Some papers describe prominent pathological cases such as syphilis (Mansilla and Pijoán, 1995), hydrocephalus (Karam Tapia, 2005), scaphocephaly (Comas Camps, 1966; Vera and Serrano Sánchez, 1993; Hernández Flores et al., 2001), a case of hydatid cyst (Talavera et al., 1991), dwarfism (Báez Molgado, 1995; Bautista Martínez and Romano Pacheco, 2003), and other conditions (Bautista Martínez et al., 2005).

### STUDIES OF TRAUMA INJURY

A research topic of special significance is that of occupational trauma injuries or those related to the way of life, such

as injuries involving interpersonal violence (Jaén Esquivel et al., 1995). This subject is closely related to forensic and taphonomic analyses, including ritual violence, with many examples across the indigenous cultures of Mesoamerica (Cid Beziez and Torres Sanders, 2004; Pijoán and Mansilla, 2004, 2008; Pijoán and Mansilla Lory, 2007; Tiesler, 2007). Various types of human sacrifice and corpse manipulation have been recognized within these cultures.

#### STUDIES ON TREPANATIONS

The topic of trepanation has piqued the interest of researchers from the first cases reported by Lumholtz and Hrdlička (1897) to the more recent reports by Romero Molina (1970, 1974). Romero Molina determined areas of concentration where this practice was carried out in Oaxaca and Sierra Tarahumara (Northern Mexico) and also documented some cases dating back to the Middle Formative Stage in the center of the country. Scraping and drilling are noted as the techniques used. Cases in which the subjects survived after the operation were also reported. Other notable studies, which examine trepanation in Oaxaca, were conducted by Wilkinson and Winter (1975a, 1975b), Winter (1984), and Márquez Morfín and González (1992).

#### STUDIES ON MUMMIES

An important element of the most recent stage of paleopathological development in Mexico has been the technological enhancements to research projects on mummified tissues. The first papers published on mummies were written at the end of the nineteenth century (Batres, 1889; Lumholtz, 1891). However studies on this topic were not avidly pursued until the last third of the twentieth century, when large numbers of mainly colonial period discoveries occurred inside temples and convents. These specimens were preserved as part of Mexico's cultural heritage, the study of which has been increasingly addressed from inter- and multi-disciplinary perspectives (Márquez Morfín and González Crespo, 1985; Medina Monzón, 1993; Báez Molgado and Meza Peñaloza, 1994; Mejía Pérez et al., 2009). In northern Mexico, mummies have also been recovered in archeological contexts and used as objects of specialized research (Mejía Pérez et al., 2009; Ramírez Castilla, 2014).

This field of study, developed in relatively recent years, illustrates the diversification of techniques and methods that both facilitate accumulation of data and expand categories of information collected about the ancient population history of the country. Not only the classical morphological techniques, but also medical imaging, biochemistry, histopathology, and toxicology procedures have been applied to anthropology, forensic medicine, conservation, and museology, depending on the different research goals being pursued. Recent thesis work by Ruiz González (2014) reviews these aspects of mummy research in Mexico, and active research on the subject has been furthered by Josefina Mansilla Lory (2002) in INAH's Department of Physical Anthropology (Dirección de Antropología Física).

#### HEALTH AND NUTRITION STUDIES

Another field of study that has seen a surge in development is research that integrates evidence of pathological alterations with health and nutritional conditions. Specific and nonspecific stress markers are analyzed using methodology established by Goodman et al. (1984) within a paleodemographic and paleoepidemiological framework and in relation to social organization, gender, and ecological context (Mansilla, 1994; Márquez Morfín and Jaén, 1997; Cucina and Tiesler, 2003).

In particular, Lourdes Márquez Morfín and Patricia Hernández Espinoza (2006a) have promoted osteological analyses in studies of health conditions by using Goodman and Martin's model (2002), which consists of standardized indicators relating to other biological and archeological data. This model has been widely implemented in ENAH's research program on "Society and Health in Ancient Populations," which has generated a great number of theses and publications.

#### ARCHEOPATHOLOGY

Numerous studies have examined plastic representations of pathological conditions in the past. At least we can take into account those diseases that are depicted in an easily recognizable and more realistic fashion (Nettleship 1954) and which cannot be considered only as stylistic expressions of artists. These studies are worth mentioning as contributions to our knowledge of disease among the indigenous peoples of Mexico.

Studies of ceramic figurines, sculptures, and paintings from various archeological sites have revealed a variety of pathological alterations such as dorsolumbar kyphosis (Ramos Meza, 1960), clubfoot (Matos Moctezuma and Vargas, 1972), and facial paralysis (Matos Moctezuma, 1970), among many other conditions.

#### PALEOPATHOLOGY IN COLONIAL TIMES

Starting in the 1980s, activities related to archeological salvage and rescue operations have enabled recovery of bone remains dating back to the colonial period, thus the study of skeletal remains from this period of Mexican history is being addressed more frequently. In many cases, the remains come from sites inhabited by indigenous people. Paleopathological reports allow assessment of changes in disease patterns that took place during the colonial period in comparison to those diseases present in the pre-Hispanic era, as well as assessment of effects from the admixture of current populations in Mexico (Meza-Peñaloza and Báez-Molgado, 1994; Meza-Peñaloza and Ortuño, 1995; Llamosas, 1998; Bernal Felipe and Castrejón Caballero, 2003; Meza Manzanilla, 2003; Moncada González and Mansilla Lory, 2005).

In addition, relevant papers analyzing skeletal remains recovered from colonial era cemeteries have also been published. These include numerous series on which life statistics are based. They also provide historical documentation, which gives context



for the osteological data. In this way, results with the highest significance can be achieved (Márquez Morfín, 1984; Mansilla and Pompa, 1992; Hernández Espinoza, 1991; Meza-Peñaloza and Báez-Molgado, 1994; Tiesler et al., 2010). Moreover, a great number of undergraduate and master's theses, as well as doctoral dissertations, have resulted from the examination and maintenance of skeletal collections, which has in turn increased the understanding of health and nutrition in indigenous populations during the colonial period. Of particular interest is research on the appearance of infectious diseases in the population (Del Castillo Chávez, 2000; Almady Sánchez, 2007).

### **OSTEOPATHOLOGICAL EVIDENCE IN THE ANCIENT POPULATION OF MEXICO**

Study of the evidence of disease in bone remains from the most ancient stages of settlement of the Americas can facilitate identification of an osteopathological pattern. Furthermore, this pattern can then be contrasted with that of the Old World Upper Paleolithic populations, and thus it can enhance understanding of changes in the morbidity profile, which will constitute a distinctive trait in later stages of cultural development throughout the Americas. Study of the various skeletal remains of ancient hunter-gatherers in Mexico help establish a general overview of health and disease during the Archaic period of 4500–1200 B.P.

The known osteopathological information can be summarized as follows: The morbidity pattern recognized in Mexican samples is no different from that present in Old World Upper Paleolithic populations. Degenerative diseases (such as osteoarthritis or osteophytosis) and trauma injuries were the main ailments among the first settlers.

Infections are not observed in the skeleton or the teeth. Periodontal swelling is frequently associated with pronounced dental wear, but dental caries are not a prominent phenomenon. Pathological manifestations of nutritional issues also are not present.

The osteopathological pattern changes with the rise of agricultural societies. The Neolithic revolution, in both the Americas and the Old World, meant a profound transformation expressed in many ways through the biology of the population. One of them, the proliferation of diseases, particularly infectious ones, has been outlined by de Aguirre (1970:16) as “the pathological explosion of the productive sedentary man.” A sedentary lifestyle and population growth were conditions that maintained diseases at an endemic level. Social differentiation and certain contingencies germane to agricultural production favored nutritional ailments.

Although pre-Columbian populations on either side of the Atlantic had many pathological similarities, especially those stemming from the common heritage of ancestral hominids, the manifestation of specific infectious diseases contrasted significantly in both hemispheres. Before the arrival of Europeans, the New World was characterized by the absence of massive infections capable of causing severe epidemics (Merbs, 1992).

At the time of the Spanish conquest, indigenous peoples of the Americas suffered much less from contagious diseases. Instead, degenerative injuries, nutritional and metabolic disturbances, and nonspecific trauma-related infections prevailed (St. Hoyme, 1969). This lack of disease can be accounted for by the “cold filter” of the circumpolar regions during pre-Hispanic migrations to the Americas, as well as the subsequent isolation of the Amerindian populations for many millennia. Apart from that, many specific infectious diseases are of very recent origin.

Low population density in prehistoric hunter-gatherer groups made infectious disease a relatively minor problem. The osteopathological evidence shows only a limited number of diseases in relation to later periods.

In the past ten thousand years, human communities have often experienced periods of quick transition that have had severe impacts on health- and disease-related patterns (Armélagos, 1990). Nevertheless, new data are needed to achieve a better understanding of the population history of Mesoamerica, particularly regarding the most ancient stages of settlement in Mexico and the transition period between hunter-gatherers and farmers.

### **PERSPECTIVES ON PALEOPATHOLOGY IN MEXICO**

Paleopathology has been integral to prehistoric osteological studies in Mexico since the second half of the twentieth century. However, the research is scattered across monographic papers on osteological collections or, as previously mentioned, appears as appendices attached to papers on the archaeological analyses of specific sites.

The nature of these paleopathological reports is rather descriptive, but they have helped to build data collections that contribute to analytical reviews. More recently, paleopathological research has advanced through the use of more elaborate theoretical or methodological approaches, thereby yielding an abundant bibliography.

Hence, data on health conditions can be recounted under regional or chronological criteria: information can be used to explain perspectives by period or cultural area, such as the paleopathology of preceramic populations (Serrano Sánchez, 1984, 1998), the population of the great metropolis at Teotihuacan (Serrano Sánchez, 1984; Rojas Lugo and Serrano Sánchez, 2011), Cholula (Serrano Sánchez, 1989; Mansilla Lory, 1994), or other ancient Mesoamerican centers (Márquez Morfín et al., 2001; Márquez Morfín and Hernández Espinoza, 2006b).

People of the Mayan region have attracted scholarly attention over the past decades. This interest has resulted in abundant research, which can be consulted in the bibliography compiled by Danforth et al. (1997) on human osteology in the Mayan area covering the period from 1839 to 1994. Notable papers published more recently include Danforth (1997), Gómez (2001), Storey et al. (2002), Cucina and Tiesler (2003), Cetina Bastida and Sivera Sosa (2005), Ortega Muñoz (2005), Márquez Morfín and

Hernández Espinoza (2006b), and Montero López and Núñez Enríquez (2011), among others.

Methodological approaches have also been postulated. Studies by Jaén and Márquez (1985) and Márquez Morfín and Jaén (1997) posited an osteological analysis model that relates paleoepidemiology with paleonutrition and paleodemography, emphasizing the need to apply radiological and biochemical analyses along with macroscopic analyses to achieve a thorough osteopathological diagnosis.

Despite the progress accomplished to date, it must be noted that research to synthesize existing information from several publications is needed. This does not exclude or downplay the need for descriptive papers on case studies and skeletal collections that could add new information.

Theoretical formulations are necessary in order to explain processes linked to the evolution of prehistoric populations, ranging from the preceramic dwellers and the rise of agriculture to the emergence of major cities and the complex societies that flourished up to the time of the Spanish conquest. Likewise, it is necessary to study the changes in disease patterns that arose during the colonial period.

Investigation of health and disease in colonial period populations is relatively new, and thus there is little consistency in the presentation of results. Although historical documentation provides information on the topic, data derived from skeletal studies offer valuable new perspectives on what is known from other sources.

We anticipate that within Mexican paleopathology the study of mummies will be encouraged. Especially those of the colonial period.

Another goal we must achieve is to incorporate molecular biology techniques and cutting-edge medical images that will improve and enrich current and future efforts, granting Mexican paleopathology the place it deserves along with other leading studies in our region.

The multi- and interdisciplinary nature of paleopathology is an obvious benefit to research being carried out at present. Incorporating progress in molecular biology and cutting-edge medical imaging will enhance and enrich current and future efforts and grant paleopathology the place it deserves alongside other leading studies in Mexico.

It is necessary to encourage the application of histomorphological analyses. Initiatives employing histomorphological techniques for osteopathologic diagnosis were published by Romano (1974) and Tiesler et al. (2006), but these studies represented isolated efforts. Such techniques should be regularly included in paleopathological investigations carried out throughout the country.

The need to study large and well-documented skeletal collections upon which detailed paleoepidemiological analyses can be performed is evident. To accomplish this, it is essential to have a standardized information record that facilitates and validates comparisons between regions and chronological periods on an intrapopulation level. Likewise, it is necessary to implement theoretical and methodological approaches with a

more solid foundation of medical knowledge of diseases and diagnoses. Examples of diagnoses performed on contemporary collections serving as comparative material were published by Báez-Molgado et al. (2009, 2013), Menéndez Taboada (2009), and Meza-Peñaloza et al. (2012). Another innovative area of research has to do with implementation of diagnostic techniques in paleopathology and their applications in forensic anthropology (Meza-Peñaloza et al., 2012; Báez-Molgado et al., 2013, 2015).

Collaboration and communication at national and international levels must be encouraged in order to integrate the results of research into a wide geographic and cultural view that strengthens the impact of that research. It is also essential to rely on an evolutionary perspective to understand health-related changes according to demographic transitions. Discussion of differences during the demographic transition between Europe and the Americas is still pending. It has been posited that main factors in the proliferation of epidemic outbreaks in the Old World and endemic diseases in the New World were determined to be fewer domesticated species, lower population density, and overcrowding among pre-Hispanic societies (Barnes, 2005; Barrett and Armelagos, 2013). Although there is little information on the presence of tuberculosis before the arrival of Europeans in the New World (Hernández Espinoza et al., 2014), research into the impact of zoonoses on the health of indigenous populations before and during the conquest is virtually nonexistent.

Current trends in epidemiology emphasize the need to expand real knowledge about transitional stages with comparative diachronic and synchronic perspectives (Muehlenbein, 2010). Although social, political, economic, and cultural experiences vary within each society through time, it is possible to define the main health-related risk factors. Knowledge of health conditions within ancient populations can be enhanced through attainment of historical and archeological information. In this way, paleopathology will cease to be solely about the death counts of children, women, and men of the past; instead it can contribute critically to research on the epidemiological changes. The majority of the Mexican population is living in an advanced epidemiological transition period, simultaneously facing the challenging burdens of chronic disease, the lags of infectious diseases, and diseases related to nutritional deficiencies, which are characteristic of demographic and epidemiologic dynamics.

Finally, we must emphasize that in Mexico, paleopathological research can contribute to a better understanding of population dynamics (Tiesler and Jaén, 2012), rather than being simply a privileged way to study the past. This should be achieved through comparative studies of ancient and contemporary populations within their own historical and sociocultural frameworks, including the derived implications in terms of health policy management.

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# 8

## Forensic Anthropology in Mexico

*Lourdes Márquez Morfín*

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**ABSTRACT.** Forensic anthropology in Mexico and Latin America has experienced exponential development since the 1980s due to violence associated with government by military regimes. Although phenomena of this nature have always existed, for more than half a century those related with kidnappings, disappearances, and homicides have become more relevant in the developing field of forensic anthropology. This chapter aims to describe and analyze the current state of forensic anthropology in the academic, social, and political context of contemporary Mexico. This short survey is divided into four sections: (1) introduction; (2) a brief history about the origin and development of the field; (3) the formation of the forensic anthropologist; and (4) the updating and professionalization of forensic anthropologists. From these, the last two were developed more fully, since they are intrinsic to the growth of forensic anthropology in current-day Mexico.

**RESUMEN.** La antropología física forense en México y América Latina ha experimentado un desarrollo exponencial desde la década de los 80 a causa de regímenes de gobierno castrense, aunado al fenómeno de la violencia. Si bien siempre han existido eventos de esta naturaleza, por más de medio siglo han cobrado relevancia los relacionados con secuestros, desapariciones forzadas y los homicidios. En el capítulo el objetivo es describir y analizar la situación actual de esta disciplina en el contexto académico, social y político del México contemporáneo, para lo cual dividimos la exposición en cuatro secciones: (1) Introducción (2) breves antecedentes sobre su origen y desarrollo; (3) la formación del antropólogo forense; y (4) actualización y profesionalización de los antropólogos forenses. De éstas desarrollamos más ampliamente las dos últimas ya que considero que son fundamentales en el balance de la antropología forense en el México actual.

**RESUMO.** A antropologia forense no México e na América Latina experimentaram um desenvolvimento exponencial a partir da década de 80 devido aos regimes de governos militares e aumento da violência. Embora sempre tenham existido eventos de esta natureza, se observa que por mais de meio século adquiriram relevância os relacionados com sequestros, desaparecimentos forçados e os homicídios. Este capítulo tem como objetivo descrever e analisar a situação atual da disciplina no contexto acadêmico, social e político do México contemporâneo, para o qual dividimos a exposição em quatro seções: (1) introdução; (2) breves antecedentes sobre sua origem e desenvolvimento; (3) formação do antropólogo forense; (4) atualização e profissionalização dos antropólogos forenses. Desenvolvemos mais amplamente as duas últimas seções, pois considero que são fundamentais para o balanço da antropologia forense no México atual.

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

### INTRODUCTION

According to reports by Amnesty International, accounts of abuse and human rights violation cases within the jurisdiction of International Humanitarian Law have increased since the late 1990s. However, Mexican government strategies of controlling and dismantling organized crime groups officially began with President Felipe Calderón Hinojosa in 2006 (Mastrogiovanni, 2014).

Mexico is enveloped in a wave of insecurity, violence, and abuse by criminals and military institutions in the wake of ever-increasing abductions and homicides resulting in a surfeit of unidentified bodies, skeletons, or human remains. In 2011, official figures from Campaña Nacional Contra la Desaparición Forzada (National Campaign Against Forced Disappearances) estimated there were more than 22,000 missing persons under these conditions (National Campaign Against Forced disappearances 2011). Missing individuals need to be located and identified. Therefore, the forensic anthropologist has gained importance and relevance as a fundamental specialist not only for the advancement of justice in legal cases related to human rights, but also for the positive identification of the victims—essential concerns for both the authorities and society as a whole.

Nonetheless, by 2015, Mexico barely had twenty professionals devoted to forensic anthropology, including physical anthropologists, social anthropologists, and archaeologists. Most of them worked in government areas such as the Procuraduría General de la República (PGR), Procuraduría General de Justicia (PGJ) of each state, the state forensic medical services (SEMFO), the Instituto de Ciencias Forenses del Distrito Federal (INCIFO), as well as in research centers such as the Instituto de Investigaciones Antropológicas (IIA) of the Universidad Nacional Autónoma de México (UNAM) and the Instituto Nacional de Antropología e Historia (INAH) and its school, the Escuela Nacional de Antropología e Historia (ENAH).

Most Mexican forensic anthropologists are trained professionals who graduated from the ENAH with a degree in physical anthropology. Other experts working in Mexico were trained at UNAM; others in forensic sciences schools, such as the Institute of Forensic Sciences of Puebla or the Instituto Nacional de Ciencias Penales (INACIPE); and yet others yet others earned a master's degree in criminology from the Instituto de Formación Profesional (IFP) from the Procuraduría general de Justicia del Distrito Federal (PGJDF). Levels of training in each case are different: UNAM is postgraduate, ENAH is undergraduate and postgraduate, and INACIPE offers only certification renewals with no postgraduate studies or programs of specialization.

## FORENSIC PHYSICAL ANTHROPOLOGY IN MEXICO: ITS FIRST STEPS

An interest in the history and development of forensic anthropology has motivated several physical anthropologists to create compilations on the history of this discipline and its current status in Mexico. Some of the most relevant authors include Zaid Lagunas (Lagunas Rodríguez, 1975; Lagunas Rodríguez and Reyez Vasquez, 2009), Jesús Luy (Luy, 1998), Arturo Romano (Romano Pacheco, 1999), Arturo Talavera (Talavera et al., 1999; Talavera and Rojas, 2006), Lorena Valencia (Valencia-Caballero and Methadzovic, 2009), and María Villanueva (Villanueva et al., 2003, 2006; Villanueva, 2007). Their works have categorized the origins and development of this discipline into

three time stages: before the 1970s, the years 1972–1996, and from 1996 until today. These authors agree that any anthropological investigations of crimes (for the purposes of this chapter, “criminal anthropology”) or any work produced during the first stage cannot be considered true forensic anthropology, but rather forensic criminology.

The field of criminal anthropology began during the last third of the twentieth century when various physical anthropologists were in one way or another incorporated into the legal field. Arturo Romano Pacheco, head of the Department of Anthropology of the INAH was one of the experts with the greatest recognition in our country. José María Luján, who studied at the ENAH, joined the Mexico City medical forensic service, where he had a long tenure working on the identification of individual victims of large-scale disasters in Mexico (Luján, 1975). Luis Alberto Vargas, a physician and physical anthropologist, alongside Mario Alba Rodríguez, assisted Moreno and his team in the Procuraduría General de Justicia del Distrito Federal (PGJDF). Vargas also worked for four years in a master's degree program in criminology at the institute of vocational training, from the Procuraduría general de Justicia del Distrito Federal (PGJDF). Jesús Luy Quijada, one of Romano's students, joined the PGJDF where he currently works and is one of the pillars in the training of new staff (Vargas and Alba, 1973). Alberto Pardo and Luis Valencia are two other anthropologists who have a long history as experts in the field; the former in the Estado de México, and the latter at the SEMFO in the Estado de México and in the city of Morelos (Valencia, 2004).

Traditional participation by physical anthropologists, as in other countries, consisted of identifications of iconic historical figures, such as the Aztec Emperor Cuauhtémoc, the poet Sor Juana Inés de la Cruz, and some prestigious servicemen, among many others. The sporadic or permanent collaboration with forensic experts in the area of human identification has become more crucial in recent years.

At the end of 2012, there were more than 22,000 missing persons, 15,921 unidentified bodies, and 1,400 sets of human remains from clandestine graves, as reported by the PGR. The field continues to expand and provide job opportunities in law enforcement institutions for forensic anthropologists, social anthropologists, and archaeologists. The practice of forensic anthropology in academic institutions, nongovernmental organizations, or government agencies is carried out in collaboration with experts in the field of forensic science. A multidisciplinary team includes the coroner, the criminalist, photographer, chemist, toxicologist, pathologist, and the entomologist among other experts involved with laboratory testing. Each of these professionals has a clearly defined field of action and liability according to the legal system of each country.

The forensic teams of Latin America, in countries such as Argentina, Peru, Guatemala, and Chile, are actively involved in the tasks of human identification, both locally and internationally. They have taken on this role in response to organizations created by the victims' families to protect and defend against human



rights violations. The region's clearest example is the Madres de la Plaza de Mayo in Argentina. Other organizations that have worked closely with the victims' families include Equipo de Antropología Forense de Argentina, the Peruvian Team of Forensic Anthropology, the Colombian Interdisciplinary Team of Forensic Work and Psychosocial Assistance (EQUITAS), the research group of forensic anthropology of Uruguay, and the Foundation of Forensic Anthropology of Guatemala, among many others. To make a proper intervention, there are several protocols—such as that of Istanbul, the International Police (INTERPOL), the International Committee of the Red Cross—and various procedures and manuals from PGR on the handling of torture, disappearances, etc., that guide forensic work in Latin America. In Mexico, although various organizations have demanded respect and vindication for the rights of women, indigenous groups, and peasant communities, these organizations are not exclusively devoted to the application of forensic anthropology. Recently the Mexican forensic anthropology team (EMAF) was created with participation of an enthusiastic group of physical anthropologists from different institutions (Lizbeth García, Lilia Escorcía, Jorge Gómez, Zaid Lagunas Rodríguez, Lorena Valencia, Luis Valencia, and María Villanueva, among others) and sponsored by the International Committee of the Red Cross in collaboration with José Pablo Baraybar from Peru.

Human identification for legal purposes is the responsibility of the government. However, under special circumstances, such as the large number of missing women in the state of Chihuahua, collaboration of the Argentine forensic anthropology team (EFA) has been requested. In 2014 the EFA participated again in the search for the human remains related to the students who disappeared from Ayotzinapa, Guerrero. The latter case involved certain discrepancies due Political matters and nuances in the protocols of action used by the local authorities.

## REFERENCE STANDARDS

Physical anthropological research has been the basis of the forensic anthropology field through the elaboration of reference standards to estimate data that are used to construct either individual biological profiles or those from a community at a population level. Most of the standards used in the applied field of forensic anthropology are derived from anthropological research whose aim is to develop reference standards for the estimation of age at death, sex, ancestry, physical characteristics, height, facial reconstruction, etc. These results are applied to multiple problems in everyday practice. Books on osteology and forensics, to mention a few specific treatments on the subject, present and analyze the techniques used and allow for a quick reference of physical characteristic estimation methods (Buikstra and Ubelaker, 1994). Only two books about physical anthropology have been written in Mexico, but they are essential in forensic work. Juan Comas' manual (1983) is still widely used. An osteology manual edited by Zaid Lagunas and Patricia Hernández

(Lagunas and Hernández, 2006) offers basic human identification techniques and even integrates a specific section on forensic anthropology by Edwin Crespo, a physical anthropologist who has taught forensic anthropology courses in Mexico.

Osteological investigations have a long-standing tradition in Mexico. I will mention only those studies whose results have been applied to forensic cases, or pre-Hispanic individual identification research, such as Santiago Genovés' study on height calculation (1967), based on the length of long bones. It is used as an international standard level for both pre-Hispanic and contemporary groups (Ramey Burns, 2007, 2008). Later on, Andrés Del Angel and Hector Cisneros made some statistical corrections to the formula proposed by Genovés. In 2014 Antinea Menéndez developed a new formula based on a contemporary Mexican series integrated by cadavers sent to the anatomy department of the UNAM. This research was presented as a master's thesis at the ENAH and recently published (Menendez Garmendia et al., 2014). For studies related to sex and age we have traditionally used North American textbooks as mentioned before. Some investigations based on Mexican contemporary groups include Vargas and Alva (1973), Márquez Morfín (1985), Escorcía Hernández and Valencia (2000, 2003), Regalado Ruiz (2005), Villanueva (2007), Regalado Ruiz and Del Angel (2008), and Valencia Pavon et al. (2010). Other contributions were developed about sexual dimorphism, such as Santiago Genovés (1959), Sergio López (1971), and Zaid Lagunas Rodríguez (1975). Jorge Gómez-Valdés (Gómez-Valdés et al., 2011) made a contribution to the topic of sexual dimorphism by using the morphometry of the sciatic notch and cranial morphometrics; and some of his colleagues in the Department of Anatomy at the Faculty of Medicine, UNAM, have made studies for sex estimation based on the jaw, scapula, and carpus (Gomez-Valdes et al., 2011). The use of histomorphology was accomplished for age estimation in pre-Hispanic Maya groups, like with Pakal, King of Palenque during the Classic period (Tiesler and Cucina, 2003).

Research to create a computerized system of facial reconstruction for personal identification, called the face of the Mexican (CARAMEX), was based on the study of facial variability of the Mexican population and is one of the most frequently cited works in legal circumstances. It is an interagency project initiated in 1993 between the UNAM and the PGJDF, directed by Arturo Romano, Carlos Serrano, María Villanueva, Jesús Luy, and Karl Link (Serrano Sánchez et al., 2000). The first version of this study was offered to the PGR in 1996 and adjusted in 2002. In 2004 a forensic anthropology laboratory was established at the UNAM, where investigations were conducted based on a series of skeletons of known age and sex from Zimapan, México. The aim was to obtain biological standard references for contemporary Mexican populations. Lilia Escorcía Hernández and Lorena Valencia (2003), graduate students at the IIA, UNAM, developed a study on facial reconstruction and the thickness of facial tissue in a Mexican series as part of their thesis. Erick Gaytán (2004) analyzed different methods and techniques for facial reconstruction (Table 1).

**TABLE 1.** Physical and forensic anthropological theses accepted, during 1997–2014 at Universidad Autónoma de Yucatán and the Escuela Nacional de Antropología e Historia, Instituto Nacional de Antropología e Historia (ENAH-INAH). A dash (—) indicates information is unknown.

	<b>Title</b>	<b>Author</b>	<b>Degree</b>	<b>Institution</b>	<b>Director</b>
1997	Anthroposcopic age discrimination in male and female over and under 18 years of age. A problem of physical forensic anthropology	Benítez A., José C.	Bachelor's	ENAH-INAH	Luis Alberto Vargas Guadarrama
1998	The estimation of age in Mesoamerican subadult skeletal remains. Osteological collection of San Gregorio Atlapulco, Xochimilco.	Ortega, Allan	Bachelor's	ENAH-INAH	Lourdes Márquez Morfín
2000	The use of computed tomography to obtain data on facial soft tissue thickness and its applications in facial reconstruction	Escorcía Hernández, Lilia; Valencia Caballero, Lorena	Bachelor's	ENAH-INAH	Edwin Crespo Torres
2003	Comparative study of three bone collections of different strata and their application in forensic anthropology	Olvera, Ruth R.	Bachelor's	ENAH-INAH	Arturo Talavera González
2004	Analysis of facial reconstruction methods and techniques for application in Mexican populations	Gaytán R., Edgar	Bachelor's	ENAH-INAH	María Villanueva
2004	Issues in estimating age using the sternal extremity of the first four ribs	Cerezo Román, Jessica	Master's	ENAH-INAH	Patricia Olga Hernandez Espinoza
2004	Creation and consolidation of the human identification department in the Estado de Morelos	Valencia Rodríguez, Jose Luis	Bachelor's	ENAH-INAH	Zaid Lagunas Rodríguez
2007	Indicators of age standards based on micromorphological analysis of the fourth rib developed in forensic samples from the state of Yucatan, Mexico. Merida	Valencia Pavón, Margarita	Master's	Universidad Autónoma de Yucatán	—
2009	Foundations of forensic anthropology, techniques and prospection, exhumation and analysis of bone remains in forensic cases	Lara B. Israel D.	Bachelor's	ENAH-INAH	Arturo Talavera González
2012	Methodological proposal for the identification of child physical abuse in skeletal remains: considerations from forensic physical anthropology	García Barzola, Bárbara Lizbeth	Master's	ENAH-INAH	Lourdes Márquez Morfín
2012	Analysis of the face region as a method of forensic identification	Espejel Santillan, Eduardo	Bachelor's	ENAH-INAH	Lorena Valencia-Caballero
2013	Estimation of height in the process of human identification	Sedano Rios, Sandra Ivette	Master's	ENAH-INAH	Lourdes Márquez Morfín
2013	Estimation of soft tissue thickness and its relation to the dimensions in the face region during growth between 10 and 20 years	Consejo Dueñas, Carlos Alejandro	Doctorate	ENAH-INAH	María Eugenia Peña Reyes
2013	Forensic anthropological analysis of skeletal remains and identification of victims of organized crime in Mexico. An anthropological proposa	Jiménez Baltazar, Carlos Alberto	Doctorate	ENAH-INAH	Lourdes Márquez Morfín
2014	Why and why measure someone? Dissertation and proposal of formulas to estimate height in in contemporary Mexican population	Menéndez Garmendia, Guillermina Antinea	Master's	ENAH-INAH	Lourdes Márquez Morfín

## TRAINING FORENSIC ANTHROPOLOGISTS IN MEXICO

Forensic anthropology is a subdiscipline of physical anthropology that specializes in the reconstruction of the biological profile of an individual (age, sex, height, biological affiliation, markers of skeletal muscular stress, trauma, and pathology) through the study and analysis of human biology, either from comprehensive examination of the skeleton or some of its parts. The work of the specialists must be performed within each particular context, be it biological, social, and/or cultural, and then their knowledge is applied in the legal sphere of justice procurement and the defense of human rights. The academic training of the forensic anthropologist can take place in institutions, universities, or research centers. The central purpose of this subdiscipline is to provide the theoretical and methodological tools necessary to collaborate in tasks such as individual human identification and the recovery, analysis, and study of cadavers or skeletons that have been mutilated, burned, segmented, and fragmented, among other tasks (Schmidt and Symes, 2008). The purpose is to offer their knowledge and methodologies, as well as proper techniques, to give reliable evidence to the medical–legal judicial system in criminal or civilian cases, as well as to victims of human rights violations. Specialists also participate in investigations related to relevant historical persons and in cases of accidents or massive disasters to contribute to the positive identification of individuals (Brickley and Ferllini, 2007; Nafté, 2007).

Academic instruction in forensic anthropology has as its goal the preparation of specialists proficient in biological, social, and cultural knowledge. This makes it an activity particularly well suited for physical anthropologists, archaeologists, and social anthropologists, as well as those trained in the health sciences. It is constructed for those who wish to take part in the development of research in the field of human identification, injuries, fractures, contusions (ante-peri / post-mortem) (Kimmerle and Baraybar, 2008, 2011), estimation of the time of death, and the circumstances of death. When ante-mortem records such as photographs exist, cranial–facial superimposition can be done. Every necessary technique in the investigation ought to be handled under strict ethical criteria, as well as with professionalism, considering the degree of statistical reliability of the reference standards used for evaluation. Not all criteria for estimation of age or sex or biological affiliation have the same degree of statistical confidence. For example, trials in the United States do not accept facial reconstruction as proof since it has a wide margin of error; it simply does not meet the criteria used in courtrooms (Komar and Buikstra, 2008:233). In Mexico, although not explicitly stated, it is considered necessary to accept only data obtained through scientific methods applicable to Mexican populations.

In the current international scene, a wide range of programs in physical anthropology, bioarchaeology, and forensic science exists that include specific training in the field of human identification. Formation and training in forensic anthropology

internationally is actually quite variable, depending on developmental status of the discipline in each country and that country's own problems and issues. Educational programs vary in content; some offer graduate programs, certification courses, workshops, and courses to attain diplomas. The content and objectives of courses cover specific topics depending on the academic level of the program.

The United States is without doubt the most important center of formation for forensic anthropologists. It is requisite to be a graduate student, and work is regulated through annual certification by the forensic association, which extends diplomas only to those professionals who have taken and passed both written and practical examinations where their level of commitment is established along with their expertise in forensic cases, teaching, and research (Komar and Buikstra, 2008).

Each country has its own particular problems as well as regulations regarding teaching and professional performance. In Europe, the academic syllabus was developed from the field of legal medicine (Schmitt et al., 2006). Problematic issues in Spain, for example, are related to identification of renowned historic persons or are focused on human rights issues. These areas of concern can include recovery of people from clandestine graves resulting from civil war—interests circumstantially shared with Columbia, Argentina, Chile, Guatemala, and now Mexico. In England there are private companies focused on the professional practice of forensic sciences, including physical anthropology and archaeology (Márquez-Grant and Roberts, 2012). The University of Lancashire, through its School of Forensic and Investigative Sciences, offers a master's degree in forensic anthropology. The University of Granada, Spain, has a master's program in forensic and physical anthropology that offers a specialization in physical anthropology and the possibility of professional employment in the areas of human growth and development, forensic anthropology, the assessment of physical condition and nutritional state, osteology, paleopathology, human population biology, and biodemography, among others.

In the case of Latin American programs, the relevance of contextualizing social, cultural, and political problems surrounding the exercise of forensic anthropology is clear in terms of the significance of considering human rights issues, the committees of truth, criminal law, and other issues related to forensic science in general. Proposals in Colombia, Peru, Spain, and England have assisted in shaping the curricular map of the graduate program offered at the ENAH, as has a wide array of published texts on forensic anthropology, specifically those related to osteology, which focus on the assessment of physical characteristics including age, sex, biological affiliation, height, trauma, and pathologies (Márquez Morfín, 2003).

Academic instruction in forensic anthropology in Mexico did not acquire broad recognition until recently, when growing insecurity and violence in the country induced scholars to intervene from their trenches of teaching to prepare professionals capable of addressing the pressing problems of missing people and victim identification. Several institutions have become involved.

The academic sector has a commitment in this regard, given the need to face the responsibility of training specialists and professionals able to confront the circumstances (Márquez Morfín, 2013). Training programs have been developed under the auspices of two institutions in particular, INAH (and its school, the ENAH) and the IIA of UNAM.

For decades, the ENAH has offered a bachelor's degree program in physical anthropology. Student instruction includes extensive study of anatomy, osteology, growth and development, physical characterization of contemporary and ancient populations, cultural practices, and pre-Hispanic mortuary patterns, among other topics of anthropological relevance. Given the growing interest of new anthropology students in the area, the ENAH offers a training program in forensic anthropology, which for the last five years has been taught by professors Luis Valencia and Jorge Gómez-Valdés. Formation in the undergraduate degree involves students training for as long as eight semesters to acquire the basic knowledge necessary for human identification in terms of justice or of a legal nature. The degree also trains students to work in human rights cases, including providing the competence to participate in the identification of victims from mass disasters, accidents, and other large-scale traumatic events (Márquez Morfín 2013).

A new diplomate program in forensic anthropology began at ENAH in August 2014 aimed at graduates with bachelor's degrees in physical anthropology and other related sciences. The main objective of this specialized training is to consolidate professionals in the field of forensic anthropology who possess the knowledge, skills, abilities, and temperament essential to contribute to human identification within the Mexican legal system. In particular, the curriculum aims to train professionals and develop their research skills for three semesters in the areas of legal, anthropological, and medical forensics. Upon successful completion, the ENAH grants the student a diploma and professional document that enables them to work in the field.

In 2010, the ENAH opened tracks in bioarchaeology and forensic anthropology that offer master's and doctorate degrees in physical anthropology to train experts further in human identification (Márquez Morfín, 2013). Students can develop a place in this field, with a capacity to integrate basic research with practice. Enrolled students choose one of the two tracks. Some courses are common to both and others are specific to the chosen area. The graduate school offers a space where students of physical anthropology or a related scientific field can acquire enough knowledge to carry out essential ethical commitments with quality training. The master's degree is planned to last four semesters, during which students study various subjects relevant to their chosen track and then they design and execute a timely research project relating to their area of interest. The doctorate program is mainly oriented towards research in physical anthropology, and it involves the planning and development of an investigation to be accomplished during the course of six semesters. Within this program emphasis is placed on research theses aimed at developing Mexican population reference standards to estimate age, sex, stature, biological

affiliations, or ancestry, because one of the central problems for positive human identification is the lack of specific studies on Mexican physical characteristics. In this way, the research of graduate students provides indispensable knowledge for the practical application of this discipline. Curricular maps and minimum content for courses were developed in consultation with forensic anthropology programs from different countries, especially Colombia, Peru, Spain, and England. Books and manuals on forensic anthropology served as guides to define essential concepts and techniques of adequate methodology and scientific standards. The first generation of students in this program matriculated during 2010–2012. Of five enrolled students, three completed their master's degree during the 2012–2013 academic year.

The first diplomate qualification in forensic anthropology was carried out in 1993, thanks to the initiative of Luis Vargas, in collaboration with Lourdes Márquez the Director of the DAF of INAH, who invited a number of experts led by Frank Saul. A new different program in forensic anthropology also has been accessible for some time, directed by the Coordinación Nacional de Antropología from INAH. These efforts are not isolated; other educational institutions have also addressed the problem. The IIA of UNAM has a forensic anthropology track within its graduate anthropology program. It has also made an agreement with the University of Granada, Spain, to confer a master's degree with a specialization in forensic anthropology. In addition to these, in 2012 UNAM approved the bachelor degree in forensic science, to deal with the problems surrounding human identification due to the growing number of unidentified individuals and others who have disappeared. The UNAM also created a laboratory to specialize in forensic anthropology. The anatomy department in the Faculty of Medicine oversees the creation of reference series from cadavers and skeletons, which has served as the foundation for basic research standards for the contemporary Mexican population.

There has been a proliferation of other institutions teaching and training through specialized courses. For example, the Centro de Investigación y Formación Forense, Distrito Federal, offers a course in forensic anthropology. The agenda includes aspects such as human anatomy, history of forensic anthropology, physical anthropology, forensic ballistics, forensic osteology, traumatology, pathology, criminal anthropology, dental anthropology, burials and exhumations, crime scene anthropology, anthropology in human rights, and molecular analysis. Other courses were developed with various associations such as the Mexican Forensic Society (SOMEFODESC). The Instituto de Ciencias Forenses y Periciales in the state of Puebla offers a master's degree in forensic medicine integrated in four semesters. The Centro Minimalista de Ciencias Penales, also in Puebla, provides a specialization in forensic anthropology. The program is divided into six topic modules: (1) introduction to crime; (2) general foundations of anthropology; (3) forensic anthropology basics (osteology and forensic dentistry); (4) methods and techniques in human identification; (5) human and nonhuman differentiation; (6) praxis in forensic anthropology, thanatology, and forensic

taphonomy; (7) contents form, development, and relief before judicial tribunals; and (8) rights and obligations of experts.

## UPDATING AND PROFESSIONALIZATION

To provide better training in this field, the authorities of ENAH and UNAM invited some well-known experts: José Vicente Rodríguez Cuenca from Colombia, dictate some workshops in 2004 and 2010; Vicente Campillo from Spain, and Edwin Crespo from Puerto Rico are all forensic experts taught intensive courses in forensic anthropology at both Institutions (the ENAH and the UNAM). Tatiana Balueva and Elizaveta Veselovskaya dictated a course on facial reconstruction at ENAH in 2010. In the last five years the greatest impact on professionalization of forensic staff, especially anthropologists, has been the priceless work of the Comité Internacional de la Cruz Roja (CICR) Forensic advisor for Mexico, Alejandra Jiménez, who has worked tirelessly since 2009. She conducted meetings with law enforcement officials to review and discuss the international forensic protocols for human identification. Jiménez has also organized updated workshops in Ciudad Juárez, Xalapa, Chiapas, and Mexico City. In June 2012, the CICR led and founded the Third Meeting of Forensic Medical Services: Standardization of criteria in complex cases. To lead the meeting, Alejandra Jiménez from the CICR, invited Jose Pablo Baraybar of the Peruvian forensic anthropology team (EPAF) to train Mexican forensic anthropologists in the newest methods and techniques available.

The relationship between ENAH and the CICR began when Lourdes Márquez was invited to participate in CICR workshop organized by Alejandra Jiménez in Xalapa in December of 2011, where I was involved in forensic identification of four individuals. From that moment on, collaboration concerning graduate physical anthropologists from the ENAH and the CICR allowed us to design various workshops at the ENAH laboratory, in which we had a chance to revise and extend the use of the most appropriate techniques in human identification. The first workshop took place in 2012 with the collaboration of Jorge Gómez Valdés, a physical anthropologist in the Department of Anatomy of the UNAM, who provided us with skeletons of known age and sex to be used in the course. The authorities of the CICR were responsible for coordinating and sponsoring participation by the majority of Mexico's forensic anthropologists who were working in various institutions (PGR, PGJ, SEMEFOS). Participants received a diploma at the end of the course.

In April 2013, CICR sponsored a second event, with a program designed for 23 forensic anthropologists, again organized by Jiménez. We organized the workshop: Actualization Journeys, as the course was titled, was again taught by José Pablo Baraybar. Participants included some ENAH professors and graduate physical anthropologists along with some students. The objective was to achieve further knowledge of human identification and to review the most suitable techniques and standards. In addition,

some guidelines and protocols for identification were developed, along with homogeneous and standardized procedures for all governmental institutions associated with legal procedures. The training had excellent results and very satisfactory effects.

In December 2013, a forensic archaeology workshop: Strengthening Workshop in Forensic Anthropology was planned; Three mass graves were prepared for this purpose, with fake skeletons and mannequins in a suitable area at the ENAH. To lead this workshop the CICR invited José Samuel Suasnavar, a forensic anthropology advisor and physical anthropologist of the Guatemalan forensic team with extensive experience in the excavation and recovery of remains in his country. Since 2014 we have continued to update the courses and workshops offered at ENAH.

During the last decade the core of continual efforts to achieve professionalization of forensic anthropologists who can work in human identification in Mexico has been the training of experts at all levels—undergraduate, specialty, and graduate. This has been accomplished by providing courses and workshops (and communicating updated laboratory practices) that allow professionals to stay up-to-date in essential knowledge as well as to share experiences they face daily at work.

## CONSIDERATIONS

The paths that have led to formation of the forensic anthropology groups in Latin America have followed two phenomena. The most important is the demands for justice made by relatives of victims of human rights violations, whose voices have arisen at the international level looking to end the impunity surrounding the disappearance of their loved ones. This is done through international treaties as well as local initiatives that require creation of truth commissions to ensure justice, reparation, and non-repetition.

In Mexico as well as other countries in Latin America, certain facts deserve to be clarified, and this will require the more active involvement of forensic anthropologists. Therefore, training programs offered by the relevant educational institutions must promote and lead the development of disciplines not only in research, but also be oriented to determining the biological variability of the contemporary Mexican population. These programs must be involved in the knowledge of Mexico's legal parameters, development of information systems, and records of missing people, in either catastrophic or violent contexts. This work should include epidemiological and socio-anthropological studies that contribute to the construction of profiles that facilitate identification of persons who have lost their identity through the circumstances of their disappearance and death.

## ACKNOWLEDGMENTS

I express gratitude to my colleagues from the ENAH—for their comments, suggestions, and support—especially to Lizbeth

García Barzola, Bibiana Cadena, Montserrat Méndez, Adriana Zamora, and Julia Perez.

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# Biological Anthropology in Mexico: Biodemography and Epidemiology

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**ABSTRACT.** This chapter presents a general overview, from the perspectiva of physical anthropology, of theoretical studies and methodological approaches to the interpretation and multicausal analysis of biodemographic and epidemiological problems in ancient and contemporary populations, exemplified by particular cases. Hence, we describe the converge and complementary between Anthropology, Demography, Genetics and Epidemiology through the review of the last 85 years of research in Mexico. This allow us to establish the historical development and main research topics to understand diversification of the field, as wells as traditions, discrepancies and the approaches of the ne contributions.

**RESUMEN.** Este capítulo presenta un panorama general, desde una perspectiva antropofísica, de los estudios y planteamientos teórico-metodológicos para la interpretación y análisis multicausal de problemas biodemográficos y epidemiológicos de poblaciones antiguas y contemporáneas, ejemplificadas en circunstancias concretas. Por lo que se describe la convergencia y complementariedad entre Antropología, Demografía, Genética y Epidemiología para lo cual se llevó a cabo una revisión de investigaciones que abordan estos estudios en los últimos ochenta y cinco años en México. Ello con el fin de establecer el desarrollo histórico, principales tópicos de investigación y diversificación disciplinar, así como tradiciones, discrepancias y aportaciones de los nuevos abordajes.

**RESUMO.** Neste trabalho é apresentada uma visão geral de uma perspectiva antropofísica, estudos e abordagens teóricas e metodológicas para a interpretação e análise das causas múltiplas biodemográficas e problemas epidemiológicos de populações antigas e contemporâneas, exemplificado com circunstâncias específicas. Então eu descrição de convergência e complementaridade entre a Antropologia, Demografia, Genética e Epidemiologia, para o qual realiza uma revisão de pesquisas abordando esses estudos no passado na América Latina e no últimos ochenta cinco anos no México, para estabelecer o desenvolvimento histórico, principais tópicos de diversificação e disciplina de investigação. Bem como as tradições, as discrepâncias, contribuições e novas abordagens.

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

## INTRODUCTION

The relationships between demography, genetics, epidemiology, and anthropology are established through approaches that seek to combine the biological and social sciences. These approaches focus on the structure of populations, the mechanisms that influence their preservation, continuity, and development, as related to vital processes (e.g., mortality, fecundity, migration), as well as those that can modify them (genetics) in interaction with geographical, ecological, socioeconomic, and technological components.

Research over the past 85 years in Mexico has sought to establish causal explanations of human origins, the variation of growth patterns and population development, and the coevolution of genes and culture in specific environments where processes of selective adaptation influence population health patterns.

As Camargo and Sandoval (1991: 11) point out, “population studies are highly compatible with biological thought in anthropology,” thus demography, genetics and epidemiology have complemented each other with socio-cultural contributions (Spuhler 1975; Weiss, 1976; Howell, 1986). Learning the patterns of populations in general, as well as their genetic, environmental, socioeconomic, and historical causes, allows a deeper understanding of population growth, underemployment, unemployment, birth control, parental structures, fertility, mortality, birth, migration, nutrition, health, sexuality, breastfeeding and consanguinity, among other factors. Such research facilitates the construction of broader explanatory frameworks that relate evolutionary biology to socio-cultural factors in history, bearing in mind that there are significant biological aspects in human populations reflected in demographic and epidemiological variables.

The research carried out is documentary and has been developed from different books, journals, and recent databases in Mexico in the last 85 years. This research involves the convergence of the fields of demography, genetics, epidemiology, and anthropology (Comas, 1973; Leguina, 1973; Spuhler, 1975; Henry, 1976; Johnston and Selby, 1978; Roberts, 1980; Poole and Rothman, 1990; Terris, 1992; Krieger and Zierler, 1996; McMichael, 1999; Den Broeck and Brestoff, 2013; Lisker et al., 2013).

### **INFLUENCE OF BIOCULTURAL INFORMATION ON DIVERSIFICATION OF BIODEMOGRAPHY**

Biocultural data give rise to biological, sociocultural, and mixed interpretations that are transformed and used by anthropology. Johnston and Selby (1978) examine the human experience based on the presupposition that each individual forms part of an ecological context as a member of a population group, and is a product of the interactions between the biological, environmental, psychosocial, social, cultural, and historical conditions that influence the adaptability and survival of both the individual and the group (Goodman and Leatherman, 1998). In the United States, physical anthropology offered an approach that reflected an anti-racist and indigenous vision that would contribute to the recognition of genetic admixture as the basis of nationalist discourses, such as that which occurred in Mexico (Peña, 2012).

### **HISTORICAL DEVELOPMENT**

In the middle of the nineteenth century, evolutionary theory emerged alongside a Eurocentric scientific racism that gave rise to the identification of race with nationality, integrating the sense

of the “mestizo” (a person of mixed race) in Mexico as the basis and destiny of the so-called “Indian,” therefore justifying the attempts to erase biological, ethnic, and cultural differences. At the same time, the State developed its own concern regarding the disadvantageous situation of the native peoples, producing indigenous public policies influenced by the culturist theory of Franz Boas. These policies questioned the dominant racist demographic and eugenic vision and argued in favor of an applied anthropology on the basis of respect for the existence of all cultural types (Rutsch, et al. 2004). This posture was contrary to that imposed by the European colonizers who sought a functionalist anthropology “interested in providing efficient tools for the control and good governance of the subjugated peoples” which would in turn entail controlled changes (Díaz-Polanco, 1983: 94).

At the same time the anthropological discipline was instituted, its scholars, including physical anthropologists, began working to apply these public policies to the indigenous population. They articulated both the anti-racist discourse and that of the indigenous movement under the ideal of genetic admixture, denying the existence of pure races and the impossibility of the degeneration of any sort of mixture. The Indians should become mestizos, not only through the mixing of the three racial branches (mongoloid, Caucasoid, and negroid) but also through language, education and the access to land (Molina, 1909).

Comas et al. (1976) referred to physical anthropology in the twentieth century as “the new physical anthropology.” The field was focused on the study of the human being, integrating demography, human genetics, and epidemiology in an attempt to reorient study problems and analysis from other theoretical visions. It is worth noting that the scientific approaches or focuses were a result of not only theoretical-methodological models, but also sociohistorical and political contexts. Such is the case of Mexican anthropology, which at one point considered physical anthropology to be related to racial discrimination, the influence of eugenic and phrenological theories, and focused on criminological anthropology due to its applied research. Over time physical anthropology was type casted as:

Auxiliary to archeology, it specialized in excavations and the study of osteological material, although its relationship with ethnology made it focus on the approaches of somatometry, nutrition and growth for indigenous groups (Litvak, 1998: 31).

Physical anthropology in Mexico has had to revindicate the importance of the study of diversity and biological variability across different contexts and time periods. This allowed the perceived overspecialization of the field to recover scientific validity by relying on and producing interdisciplinary connections with biology or expanding anthropological (sociocultural) models that only recognize biology as another variable of interaction rather than an axis of analysis.

One of these interdisciplinary connections that has developed around population dynamics is biodemography. Biodemography

explores the relationship between anthropology and genetics through the study of the variability and dynamics of current and past populations. Research reconstructs the genetic structure developed within a population, with statistical data providing a biological and historical explanation in this context. Valls (1985: 46–47) mentions that from a genetic point of view, evolution consists of alterations of the allelic frequencies whose processes can be of three types and that such processes lead to the genetic variability of population importance in the long term. These approaches have facilitated the construction of genetic models and population references, such as life tables (Cavalli-Sforza and Bodmer, 1971; Luna, 1989). However, Sauvain-Dugerdil (1991: 14) warns that the more powerful the techniques, the greater the risk of replacing the object of study with the measurement. Astorga mentions in this regard that the unity of diversity will find its representation in the number (1988: 146). Thus, it is thought that a biocultural approach might correct this problem. This allows a sampling of the population, previously defined by traits or sociocultural characteristics, which is focused on the variation of the statistical norm. In other words, biodemography is not limited to the use of such models, but it also seeks to associate any such information with the social organization of populations in order to recognize certain genetic patterns. This association with social anthropology seeks to understand the structure and social organization that exists in a certain population. An association with historical demography based on parochial, civil, and vital statistics allows micro-demographic studies of contemporary groups. Aside from skeletal remains, archaeological evidence and genetic markers provide information from different perspectives of the structure and social organization within certain populations, allowing to understand them as a more complex process. Therefore, we are aware that our species is the only one capable of self-transformation. As Titiev puts it:

The law of growing dependence on culture -indicates that- when hominids first appeared they used many biological mechanisms and very little culture. As time went by they increased their dependence on culture and decreased their dependence on biology. Despite this fact, *Homo sapiens* can never completely depend on culture, nor can it completely eliminate biology (Titiev, 2000: 167).

This approach, applied to the reconstruction of populations and the analysis of their structure and indicators, bring us to understanding the mechanisms that influence the transmission and variability of genes and the construction of a biological history (Colantonio et al., 2007). This goes hand in hand with the proposal of “the law of biocultural evolution”, that points out that as culture evolves, biological variability within population increases and decreases among human groups or populations (Kelso, 1974); thus, research focuses on how the biosocial and biocultural history of populations became on the mechanisms that influenced their preservation or modification over time.

Biodemography includes several avenues of study such as human origins, the dispersion of populations, and the adaptive relationship populations have with their environment. Applications in demographic anthropology involve the study of genetic variation of the patterns of growth and development of populations and individuals. Applications in epidemiology establish relations of coevolution and biocultural adaptation in the patterns of health and nutrition in such populations. Biodemography also relates to the field of forensic sciences regarding the identification of individuals, although more often it pertains to the study of past demographic phenomena associated with the relationships between paleodemography, epidemiology, and nutrition. Biodemography studies have been on the rise since the 1950s, including research pertaining to biodemographic markers of prehistoric populations (structure, size, density, the rate of mortality, birth, fecundity, migration, and genetic variation) (Dahlberg, 1943). This research has led to the consideration of individual cases and population projections depending on their context and period (prehistoric, historical, or contemporary). In addition to the population characterization (hunter-gatherers and farmers, urban and rural, or local and global) research establishes material living conditions under contexts of interaction and relates them to population structure and dynamics.

Through this research, the need for an understanding of the population genetic structure and its interrelations became evident. Such an understanding includes the component of socio-cultural organization, which is required for the recognition of certain genetic patterns (Harrison, 1977). According to Dike (1984), these genetic patterns are most easily recognized through the analysis of a socioculturally defined and reproductively isolated micro-population. This work utilizes a subdivision of alleles or genotypes (autosomal markers—DNA and protein, mtDNA and Y-chromosome lineages, among others), which make up the genetic structure differentiated by demographic structure (age and sex), kinship structure (hereditary or family relations), socioeconomic structure (social status), and environmental or geographic structure (residence). Goals include establishment of the internal genetic structure of a micropopulation complex. Crawford (2000) indicates that the work of bioanthropology should include an approach which allows the selection and interaction of components and co-determinants (biological-genetic, environmental, population, socioeconomic, technological, and others), as well as the selection of a multiorganizational methodological strategy (that includes the gene, population, and individual levels to measure heritability). He also encourages the use of statistical packages for the representative sampling that accounts for population variation. This process becomes relevant since the majority of studies are either local or regional, particularly in societies which are considered rural in Europe and North America. Also included are those hunter-gatherer societies of South America and Africa that have been classified as “tribes” with technological processes and the social organization of “primitive agriculture” (Cavalli-Sforza 1966, 1969; Cavalli-Sforza et al., 1994; Howell, 1979, Zubrow, 1986). There is also evolutionary studies

focused on the micro-adaptations presents in South American “tribes” that allow, from the genetic perspective, to establish a projection of how the future evolutionary strategy of our species might work. This is supported on four principles, already present on genetic variability and adaptability, that will allow humans to continue the process of biosocial evolution:

Numerical stabilization of our demography, protection against mutagens (especially chemical and of radiation), qualitative improvement of hereditary heritage (conjugal selection, genetic counseling, prenatal diagnosis) and improvement or correction of the phenotypic expression of individual genotypes (eugenics- eyeglasses, hormonal treatments and organ transplants-) (Valls, 1985: 70).

Since the human genome is only variable in a small fraction at a quantitative level, it is necessary to study human beings as parts of whole populations and not only as individual organisms. That implies an expansion of evolutionary theory to consider the environmental context and the currency of coevolution and its functional implications, which due to their relation with pathogens and the presence of culture (Freeman and Herron, 2002), could influence phenotypic differences in individuals and among populations. This can be observed in the relationship between biodemography and epidemiology, which seeks to understand the role of genetic polymorphisms in the susceptibility, expression, and progression of diseases, thus generating strategic responses focused on the prevention and treatment of the diseases, as well as the development of drugs. Undoubtedly, the evolutionary history of our species is being transformed by advances in the study of molecular genetics on the presence of microbacteria in contemporary human remains and in ancient DNA found in skeletal remains and mummy tissues. One of the emblematic cases of the coevolution of humans with pathogenic agents, tuberculosis is considered one of the diseases that has mutated and produced new strains so far back into prehistory that it may have affected the first hominids. In fact, its expansion might match the migration patterns of *Homo sapiens* in Africa (Zink et al., 2001; Brosch et al., 2002; Gutiérrez et al., 2005; Mokrousov et al., 2005).

The presence of culture in coevolution influences the genetic structure of our species and groups through a set of behaviors and strategies that are developed throughout their history and in their coexistence with their environment or exposure to the agent. An example of this is observed in the metabolism of the intestinal enzyme lactate dehydrogenase (LDH or LD) found in dairy products derived from cows, and active in humans during the first years of life. It is thought that the domestication of livestock began in the Neolithic period and that, over time, exposure to consumption produced the capacity to degrade lactose through the development of LDH in populations that consumed milk products from their livestock. This is a characteristic that is distinct among populations, depending on how strong the genetic links are with their ancestral groups, as in groups with

Asian ancestry in which the majority are lactose intolerant due to traditional lifestyles that did not include consumption of milk products (Beja-Pereira et al., 2004).

In summary, the fields of biodemography and epidemiology in Mexico have evolved dramatically in the past 85 years. Research investigations in these areas today address key issues of Mexican populations using methodology well established in the international scholarly community.

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# History of Growth and Nutrition Studies in Mexico

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**ABSTRACT.** Growth studies in México have been conducted to a large extent in association with the nutritional and health status of children and adolescents. Potentially related information includes several social, political, and economic factors which influence living conditions and, in turn, the growth and maturation of children and youth from early in the twentieth century to the present. An exhaustive description of all growth studies conducted in Mexico was not feasible; rather, this survey focuses on selected studies which considered potentially important factors affecting the transformation of the population over time. The review includes three sections. The first focuses on the social and economic context across time and considers growth studies in relation to anthropology, health and nutrition, and the observations from several national surveys. The second section considers studies of indigenous groups in different parts of the country. And the third section reviews the relatively limited data base concerned with the biological maturation of children and adolescents.

**RESUMEN.** Los estudios de crecimiento en México se han realizado en su mayoría en relación a la estimación del estado nutricional y de salud de los niños y adolescentes. Se ha considerado incluir información sobre diversos factores de tipo social, económico y político de relevancia por su influencia en las condiciones de vida y por tanto en el crecimiento y la maduración de los niños y adolescentes desde principios del siglo XX hasta la actualidad. Es difícil hacer una descripción exhaustiva de todos los estudios de crecimiento realizados en México, por lo que para este trabajo se seleccionaron algunos estudios que consideran esos factores que han influido en la población a través del tiempo. Esta revisión incluye tres secciones. La primera considera el contexto social y económico a través del tiempo incluyendo estudios realizados desde la antropología, salud y nutrición, así como los resultados de algunas de las encuestas nacionales. La segunda comprende estudios realizados en poblaciones indígenas en distintas partes del país. La tercera hace una revisión de una limitada base de datos que considera la maduración biológica de niños y adolescentes.

**RESUMO.** Os estudos de crescimento no México foram conduzidos, em grande parte, em associação ao estado de saúde de crianças e jovens. A informação potencialmente inclui diversos fatores sociais, políticos e econômicos que influenciaram as condições de vida da população e por sua vez o crescimento e a maturação de crianças e jovens do início do século 20 até o presente. Uma descrição exaustiva de todos os estudos de crescimento realizados no México não é possível; assim, este levantamento enfatiza estudos selecionados que consideraram os fatores potenciais e mais importantes que afetam a transformação da população ao longo do tempo. Esta revisão inclui três seções: a primeira aborda o contexto social e econômico no tempo e considera estudos de crescimento das áreas de Antropologia, Saúde e Nutrição e além da observação de vários levantamentos nacionais. A segunda seção considerou a população indígena de diferentes partes do país. A última seção revisou bases de dados relativamente limitadas considerando a maturação biológica de crianças e adolescentes.

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

## INTRODUCTION

The growth status of children is an indicator of general health, nutrition, and overall well-being of a community or population (Tanner, 1992). This generalization, however, does not apply to individuals, as factors which affect individual growth are multiple and complex (Malina et al., 2004a). From a population perspective, surveys of growth status over time are important in understanding the impact of change or lack of change in societal conditions, specifically the potential role of health, nutritional, social, and economic conditions, among others, on well-being and biological variation (Malina, 1979; Bielicki, 1999).

Observations of the growth status of children in many countries are largely limited to height and weight. Historically, attention was focused on linear growth, specifically of preschool children exposed to marginal nutritional conditions in many developing areas of the world. Notably, the prevalence of growth stunting among preschool children is widely accepted as an indicator of chronic undernutrition in a community. Circumstances underlying these conditions are rooted in the chronically poor in nutritional, health, and living conditions, which are associated with inequalities in access to resources and services (Bielicki, 1986, 1999; Martorell and Habicht, 1986; Malina et al., 2004a). Although the inequalities are rooted in social, economic and political complexities in a region or country, the negative consequences are evident in the growth status of children born and raised in such conditions.

More recently, attention has shifted to the other extreme of the nutritional spectrum. Current worldwide concern for the epidemic of childhood obesity, which often begins in early childhood, has shifted attention to the potentially negative consequences reported on excess weight-to-height indexes. In contrast to nutritional deficiencies, energy or caloric excess is a major factor underlying the increasing prevalence of overweight and obese children throughout the world. Of course, a related factor is a reduction in habitual energy expenditure associated to a large extent with reductions in regular physical activity.

With the preceding background in mind, this chapter reviews growth studies of children residing in Mexico, while taking into account the demographic, social, and political conditions in the country beginning early in the twentieth century. Throughout the first half of the twentieth century, studies were focused primarily on the growth of children per se (essentially height and weight), in a clinical and to a lesser extent in an anthropological context. Beginning in the 1960s and 1970s, emphasis shifted to regional and national surveys of health and nutritional status which included measures of height and weight.

Indigenous populations are central to, and have an important place in, the history of Mexico. Although early studies focused on variation in the physical characteristics among adults in different indigenous groups (Faulhaber, 1970), more recent studies have focused on the growth and nutritional status of indigenous children. To this end, separate consideration is given to the growth studies of indigenous children.

## GROWTH STUDIES AND THE CHANGING SOCIAL AND ECONOMIC CONTEXT IN MEXICO

The expansion of urban communities early in the twentieth century presented many challenges associated with marginal health conditions and inadequate services which contributed to elevated mortality. Mexico City, for example, had an estimated mortality rate of 57.4/1000 in 1901 which was three times that of London and New York (Chaoul, 2012). Poverty and crowding were major limitations to providing services, specifically sanitation programs, in rapidly developing urban centers. Nevertheless, hygienists working within the framework of the “germ theory” (which was popular in the late nineteenth century) focused attention on underprivileged urban sectors and schools. Schools were run by municipal authorities, but lacked suitable facilities—buildings, equipment, and basic sanitary installations. Given the concern for conditions in schools, and to record actual conditions, medical examinations of schoolchildren were initiated in 1902 at the *Escuela Normal para Profesores*. This marked a more systematic approach, including assessment of the growth status of schoolchildren, which was occurring in several sectors.

From an anthropological perspective, initial efforts were undertaken by Nicolas León who trained under Aleš Hrdlička. León established courses in physical anthropology and anthropometry. Around the same time, the *Sección de Higiene y Antropometría Escolar*, under the *Dirección General de Educación Primaria e Instrucción Pública*, was initiated by the *Secretaría de Instrucción Pública y Bellas Artes* in 1906; and the *Instituto Médico Nacional* developed a comprehensive survey of Mexican children residing in an orphanage in Mexico City. This survey included anthropometric, postural, physiological (vision, visual and tactile sensitivity, pulse frequency, several blood characteristics, and respiratory frequency and capacity), as well as functional characteristics (muscular strength). Physicians developed anthropometric equipment for a detailed anthropometric battery. Initial observations were limited to several variables in 14 children, who were 6–14 years old (Vergara Lope, 1910; León, 1919).

Emerging interest in the development of a health surveillance master plan for schools contributed to the *Ley de Educación Primaria* in 1908 which mandated that water and bathrooms be provided for schools (Chaoul, 2012). *La Secretaría de Educación Pública* established a health card for each school child that included height, weight, visual and auditory conditions, and an indication of overall health status. These programs provided the basis for establishing the anthropometric service for schools (*Servicio Antropométrico Escolar*) directed by Nicolas León from 1912 to 1913 (León, 1919).

Continued population growth in Mexico increased demands for health and education facilities. Conditions throughout the country were exacerbated by the revolution (from 1910 to 1920). Hunger, food scarcity, and unstable living conditions were increasingly common. A survey in 1911 revealed a high



prevalence of anemia, while in 1912, about 15 cities were providing food for the school network, serving both breakfast and lunch. At the same time, staff measured the heights and weights of children (28,002 boys, 31,625 girls) between 1910 and 1912 (Gómez, 1913), but unfortunately, the precision of the measurement techniques was questioned.

Anthropometric assessments of schoolchildren continued during the 1920s. Heights and weights of middle class urban public-school children (2,550 males, 2,207 females) were surveyed by the *Departamento de Psicopedagogía e Higiene* from 1922 to 1926 (as reported by Ramos Galván, 1978). Another survey of middle class school youth in Mexico City was done in 1926 and included 100 boys and 100 girls per age group from 5 to 17 years of age. Observations included weight, height, body segments, chest dimensions, grip strength, pulse and breathing frequency, and temperature (Priani, 1929).

Demographic changes and city expansion translated into growing health and economic needs (Table 1). The period between 1934 and 1940 experienced major agricultural reform and industrialization which positively impacted living conditions throughout the country.

A department for infant assistance was created in response to a 1937 mandate of Lázaro Cárdenas. The new program was supervised by Dr. Federico Gómez Santos, and under his leadership, it laid the foundation for one of the major medical and social institutions in Mexico, the *Hospital Infantil de México* (Children's Hospital, Federico Gómez). The hospital was established in 1943, to initiate specific programs for infants and children focused on health and nutrition. The measurement and evaluation of weight, length, and stature (i.e., growth status) were central to clinical practice and to the research program. Research results were published in the *Boletín Médico del Hospital*

*Infantil de México*, beginning in 1944. The department was eventually transformed into the *Oficina de Asistencia Pública*, which emphasized the need for growth studies in low income neighborhoods.

Increased population mobility was a highly visible social phenomenon and was also the driving factor in population growth. Similar migration to other cities also occurred in the 1950s, but to a lesser extent. As a result of this major demographic shift, social, economic, and political problems emerged in rapidly expanding cities (Table 1).

The changes, needless to say, impacted child health, which motivated a group of physicians at the Children's Hospital, Federico Gómez to continue conducting research. Studies focused on nutrition took into consideration marginal and inadequate living conditions, which affected a large number of children. As such, the growth status of children, reflected in height and weight, was a major tool. Results of surveys emphasized that the majority of the child population in the country experienced a nutritional deficit and that the persistence of an inadequate food supply contributed to chronic undernutrition. More importantly, chronically undernourished children were less resistant to stress and disease, resulting in an increase in infant and preschool mortality.

From a study conducted by Federico Gómez Santos and his colleagues, based on height and weight for approximately 10,000 children, a scale for the classification of the severity of nutritional deficiency was developed (Gómez Santos, 1946; Gómez Santos et al., 1947, 1956). The scale would eventually become known as the Gómez classification scale and has been widely used in Mexico, Central America, the Caribbean, and other areas of the world. Three grades of malnutrition were described relative to a theoretical average weight for a child's age. The grades or degrees of malnutrition were related to mortality,

TABLE 1. Demographic changes in Mexico by decade.

Year	Population* size (millions)	Mean age (years)	Life** expectancy (years)	Infant** Mortality /1000	Events
1910	15.2				Revolution
1921	14.5				School assessments
1930	16.5	24	33.9	156.3	Agriculture reform
1940	19.7	23.8	38.8	138.6	Creation of Children's Hospital, Federico Gómez; industrialization
1950	25.8	23.6	46.9	132.0	Urban expansion; graduate studies in pediatrics (1951)
1960	34.9	22.9	57.5	90.3	Beginning of growth studies
1970	46.8	22.3	60.9	76.8	60% urban population; social programs for indigenous communities
1980	66.8		66.2	53.1	Poor nutrition linked to limited diet
1990	81.2	24.5	78.8	36.2	1994 economic crisis; 1999-high food costs
2000	97.5	27.4	75.3	24.9	
2010	112.3		75.4	19.0	

\*Sources: INEGI (1996, 2015). Cien años de Censos and Indicadores sociodemográficos de México (1930–2000)

\*\*Source: INEGI (2001).

i.e., the more severe the malnutrition, the greater the likelihood of mortality (Gómez Santos et al., 1956). By inference, the nutritional status of a child with a body weight greater than 90% of the theoretical average weight for the child's age was classified as normal. Of relevance to the use of growth status in nutritional surveys, the Gómez classification included three essential components: body weight (an anthropometric indicator), a large sample of children studied at the clinic (a reference sample), and specific cut-off values to define grades or degrees of malnutrition (see de Onis, 2000). The Bulletin of the World Health Organization has labeled the 1956 paper by Gómez Santos and his colleagues a "public health classic."

At about the same time, the Instituto Nacional de Pedagogía initiated studies of the physical and functional characteristics of middle-class preschool, elementary, and secondary schoolchildren living in central Mexico City (Rosales, 1950). The data were used to develop a morphological index based on weight-to-height ratios to monitor nutritional status.

The widespread prevalence of undernutrition among a large number of children throughout the country in the 1950s highlighted a need for larger scale clinical and nutrition surveys to better understand the situation in the country. Between 1958 and 1962, the Instituto Nacional de Nutrición (presently Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán) conducted 29 surveys, 21 in rural communities, and 8 in urban or semi-urban communities with marginal living conditions (Pérez Hidalgo and Chávez, 1976). Many of the studies included height and weight measurements of preschool children. Based on the Gómez classification scale (Gómez Santos, 1946), a survey of infant and preschool children conducted between 1958 and 1962 (CONEVAL, 2010) indicated that about 32% of rural and 4% of urban children presented Grade II malnutrition (body weight between 61% and 75% of that expected for age), while 2.5% of that of rural and 1.4% of urban children presented with Grade III malnutrition (body weight is less than 60% of that expected for age).

Social policies also influenced urban growth, including investments in basic services associated with education, sanitation, and transportation. The social security system (Instituto Mexicano del Seguro Social, IMSS), which provided health care for workers, was implemented in 1943. Two of the largest hospitals for the IMSS were established in 1952 and 1963, and in 1970 about one-fourth of the population was covered. Nevertheless, benefits were limited largely to urban areas. Of relevance to the present discussion, a good deal of information on the growth status of Mexican children was obtained as part of the research and health surveillance conducted by physicians and nutritionists from IMSS (Instituto Mexicano del Seguro Social, 2015).

Growth studies during the interval of the 1960s through the 1980s focused to a large extent on the interpretation of the growth status of children under specific living conditions. Most of the information was based on nutritional, health, and anthropological surveys.

A compilation of results from 26 nutrition surveys of 20 rural and six urban communities highlighted nutritional

problems and urban-rural contrasts in Mexico (Zubirán and Chávez, 1963). Severe undernutrition was prevalent among rural communities especially in the southeastern states of the country where 1%–4% of preschool children had weights 40% below normal (Grade III on the Gómez scale) and presented diarrhea, edema, subcutaneous damage, and hair discoloration (characteristics of severe protein-energy malnutrition). In addition, it was estimated that one third of the children surveyed in rural communities showed significant growth failure and delayed maturation (Chávez et al., 1964). Interestingly, schoolchildren were better off than preschoolers, perhaps reflecting differential survival given elevated mortality in preschool children associated with protein-energy malnutrition.

The preceding observations provided, in part, the basis for policy decisions in the 1980s, at a critical period when resources were limited and the Mexican economy was less developed. Poor nutrition and infection were identified as major factors contributing to reduced growth potential among children, which in turn affected adult body size. Establishing health institutions was viewed as a strategic component in addressing environmental, social, economic, and cultural factors affecting the Mexican population, especially in rural areas and marginalized urban neighborhoods. The need for information on growth and maturation among the general population influenced the interest of anthropologists during the course of the following decades. One of the first studies conducted under the auspices of the Instituto Nacional de Antropología e Historia (INAH) was initiated by Blanca Jiménez Lozano in 1955. It was a longitudinal study of preschool children attending day care centers at various government locations and their mothers who had IMSS access to this service. Johanna Faulhaber conducted a mixed-longitudinal study of youth in Mexico City; the aim of the study was to establish a reference for well-nourished middle-class Mexican youth. The study began in 1957 with one-month-old children and continued through 1970 (Faulhaber and Villanueva, 1976). Infants of mothers who were elementary school teachers comprised the initial samples, and children of women working at administration offices were subsequently added. Data on psychological development were collected in 1958 by Guadalupe Carrasco (1961). The middle-class children in the mixed-longitudinal sample of Faulhaber and Villanueva (1976) were, on average, shorter than children of higher socio-economic status in Mexico City (Torregrosa et al., 1966; Ramos Galván and Luna Jaspe, 1964). The sample studied by Torregrosa et al. (1966) was based on the height and weight of 1,500 full-term children under the age of 6 (768 males and 743 females) seen in a private pediatric practices, while Ramos Galván and Luna Jaspe (1964) surveyed two schools in well-off neighborhoods. The urban middle-class sample of Mexican children was closer in height to British children.

The research of Joaquín Cravioto addressed factors affecting growth and nutritional status in a longitudinal sample of rural infants in Tlaltizapan, Morelos (central Mexico), in the mid-1960s (Cravioto and DeLicardie, 1974, 1976; Sanjur et al., 1970). The protocol included indicators of nutritional, pediatric,

and socioeconomic status, as well as physical, mental, and social development in an effort to evaluate the influence of child care and nutrition on progress on mental development, physical growth, behavior, and learning experiences early in life. The underlying assumption was that all stages of intellectual development and school performance were related to nutritional and health conditions to which children are exposed (Cravioto and Arrieta, 1982). Heights and weights of schoolchildren in the community were, on average, shorter and lighter compared to those of children in Mexico City from the same time period (Faulhaber and Villanueva, 1976), and did not differ from those of schoolchildren in the community surveyed about 10 years earlier (Cravioto et al., 1969).

Concurrently with the preceding studies, the anthropometric characteristics of a large mixed-longitudinal sample of well-off Mexico City children were followed from the 1950s through December, 1970 under the direction of Rafael Ramos Galván. Parents of the children were largely engaged in professional occupations and children were followed at a pediatric clinic. The sample spanned birth to 18 years and included 3,433 males and 2,100 females. Anthropometric data included height, weight, segment lengths, breadth, and circumferences, and several derived measures and indices. Some reports were published during the course of the study (e.g., Ramos Galván and Luna Jaspe, 1964), but comprehensive tables and charts based on the entire data set were published as a monograph (Ramos Galván, 1975). Sex-specific tables of means and standard deviations, and selected percentiles between the 3rd to 97th for all measured and derived variables are provided at monthly intervals from 1 to 24 months of age and then at three-month intervals from 2 to 18 years of age. The reference tables and percentiles have been widely used as a reference for Mexico especially among pediatricians with the IMSS.

Economic conditions continued to improve into the 1970s but began to falter late in the decade and the decline continued into the 1980s (Lustig, 1992). Two surveys in the late 1970s and 1980s, Encuesta Nacional de Alimentación en el Medio Rural (ENAL-79 and ENAL-89) indicated practically no improvement in nutritional status in a decade. The overall prevalence of low weight-for-age ratios among children younger than 5 years old declined only slightly from 22% in 1979 to 19% in 1989. Nutritional deficits among indigenous communities were related to feeding practices, such as late introduction and small amounts of solid foods among infants and young children. Small differences were observed in the prevalence of undernutrition between the 1979 and 1989 surveys in the north (8.0% and 7.3%) and south (28.2% and 26.9%) regions, while the central region experienced a reduction in prevalence from 20.7% to 11.5% over this interval.

A major source of information on the growth and nutrition status of children was provided by the national surveys conducted in 1988, 1999, 2006, and 2012 (Table 2). In 1988, wasting was found in 6% and stunting in 22% of children younger than 5 years of age. The last three surveys documented the transition

from acute and chronic undernutrition to the rise in prevalence of excess weight or obesity; this became crucial in the implementation of health and social policies. Improvements in nutrition inferred from the growth status of preschool children highlighted the inequality between regions of the country and especially between communities living under extreme poverty (Table 2).

A second mixed-longitudinal study spanning early through late adolescence was conducted by Faulhaber from 1977 to 1980 (Faulhaber, 1989b). The initial sample included 275 children (132 females, starting at 10 years old, and 143 males, starting at 11 years old) from three public schools, and 235 children (98 females, starting at 12 years old, and 137 males starting at 13 years old) from two secondary schools. The samples were from a largely low-middle socioeconomic status background. Subjects were measured (height and weight, length of the upper and lower extremities, skeletal breadths, muscle circumferences, skinfolds, and craniofacial dimensions) twice per year and were followed to age 15.0 (girls) and age 15.5 (boys). The adolescent youth were, on average, shorter and lighter compared to United States reference data from the 1970s (Hamill et al., 1977), and to the urban reference data analyzed by Ramos Galvan (1975). Estimated annual and semi-annual increments in height during the adolescent growth spurt were reasonably similar to estimates observed in children in the United States (Faulhaber, 1989b).

A comprehensive, multidisciplinary study of two urban settlements of migrants (primarily from the southeast region of Mexico) to the Federal District—one in Iztapalapa (Colonia 1–Lomas de la Estancia) and the second in Coyoacán (Colonia 2–Santo Domingo)—included a major focus on the growth status of children surveyed between 1994 and 1996 (Aréchiga et al., 1999a). All children were born in the Federal District to parents with low socioeconomic status who migrated to the colonias at least 20 years earlier. The cross-sectional sample included children 4–19 years of age from two colonias (Lomas de la Estancia and Santo Domingo), Group 1 (981 males and 1,069 females) and Group 2 (981 males, 837 females); about 90% of children were between 6 and 15 years of age. Despite socioeconomic similarities, children in Group 2 were slightly taller with proportionally longer legs than those in Group 1. The difference likely reflected subtleties in economic and living conditions of the two colonias. Nevertheless, the heights and weights of children were less than corresponding data for middle class children in Mexico City, who had been surveyed in the 1960s (Faulhaber and Villanueva, 1976). Estimated age at menarche (probit analysis) of girls resident in the two colonies differed only slightly, 12.6 and 12.4 years (Aréchiga et al., 1999b), while the estimated median age for the total sample (12.7 years) overlapped those recorded for girls from Mexico City between the 1960s and 1998, which were 12.2 to 12.8 years (Table 3).

Overweight and obesity (based upon body mass index, or BMI) were common in the two urban samples. Prevalence varied to some extent within age groups and between the colonies. Among girls 10–13 years old, the prevalence of overweight and obesity ranged from 32% to 40% in Santo Domingo and

**TABLE 2.** Results of national nutrition and health surveys in Mexico by region; N = national; NR = north region; SR = south region; CR = central region

Dates	Survey and type of data collected	Results by region for children <5 years of age		Overweight/obesity
		Stunting	Wasting	Ps = preschool children Sc = school children
1988	<i>Encuesta Nacional de Nutrición</i> ENN-88. By region. Children and women. Diet, height, and weight	N = 23% NR = 9.8% SR = 34.1% CR = 25.1%	N = 6% NR = 10% SR = 28% CR = 21%	Ps: N = 7.8% NR = 8.9% SR = 5.9% CR = 11.4%
1999	<i>Encuesta Nacional de Nutrición</i> ENN-99. By region. Children and women. Diet, height and weight, blood. Prevalence of undernutrition, anemia, excess weight. WHO/NCHS references (CONEVAL, 2015)	N = 17.8% NR = 7.1% SR = 29.2% CR = 14.5%	N = 2.1% NR = 2.2% SR = 2.3% CR = 1.7%	Ps: N = 9.7% NR = 10% SR = 9.2% CR = 8.0% Sc: N = 24.9% NR = 25.4% SR = 13.6% CR = 17.3%
2006	<i>Encuesta Nacional de Salud y Nutrición</i> . ENSANUT-2006. Results by state and region. All age groups. Diet, height and weight, blood. Prevalence of poor nutrition, anemia, excess weight. WHO/NCHS references (CONEVAL, 2015)	N = 12.7% NR = 7.1% SR = 18.3% CR = 10.8%	N = 1.6% NR = 2% SR = 1.4% CR = 1.5%	Ps: N = 8.3% NR = 12.0% SR = 9.6% CR = 9.9% Sc: N = 35.1% NR = 29.4% SR = 22.3% CR = 26.9%
2012	<i>Encuesta Nacional de Salud y Nutrición</i> . ENSANUT-2012. Results by state and region. All age groups. Diet, height, weight, waist circumference, blood. Prevalence of poor nutrition, anemia, excess weight. (WHO 2006 references)	N = 13.6% NR = 8.9% SR = 19.2% CR = 11.42%	N = 1.6% Data by region not available for 2012 report	Ps: N = 9.7% NR = 12.0% SR = 9.6% CR = 9.9% Sc: N = 34.8% NR = 29.4% SR = 22.3% CR = 26.9%

from 32% to 38% in Lomas de la Estancia. The corresponding prevalence among girls 14–16 years was 20% to 28% in *Santo Domingo* and 24% to 31% in Lomas de la Estancia. The estimated prevalence of overweight and obesity in boys overlapped that for girls between 10 and 13 years old—35% to 39% in *Santo Domingo* and 30% to 42% in Lomas de la Estancia. With the exception of 14-year-old boys in *Santo Domingo* (34%), the prevalence of overweight and obesity in boys 14–16 years old was lower than among girls, 16% and 17% in *Santo Domingo* boys 15 and 16 years old, and 22% to 24% in Lomas de la Estancia boys 14–16 years old (Aréchiga-Viramontes and Betancourt-Léon, 2012). The relationship between the BMI

and both estimated fat mass and lean mass was evaluated using two prediction equations (Hoffman et al., 2012; Ramirez et al., 2012); BMI was somewhat better correlated with estimates of fatness than with estimates of lean mass, as well as limb muscle circumferences. However, correlations between the BMI and estimates of body composition were generally lower with the equation developed for Mexican children (Aréchiga-Viramontes et al., 2013).

Improvements in living conditions varied with region and socioeconomic status. Better-off children and adolescents from Mexico City in the early 1970s (Ramos Galván, 1975) had, on average, statures that approximated medians of the United States

**TABLE 3.** Estimated median ages at menarche and 95% confidence intervals (CI) in samples of adolescents in Mexico; *n* = sample size. All estimates are based on the status quo method (probit analysis)<sup>a</sup> except as indicated. A dash (–) indicates that no data were available.

Region and study, with locality, if available	Year(s) of survey	<i>n</i>	Median age (y)	95% CI
<b>Mexico City, Federal District</b>				
Diaz de Mathman et al. (1968)	1960s	670	12.8	12.6–12.9
Peña Gomez (1970)	1960s	400	12.7	12.5–12.9
Ramos Rodriguez (1986)	1976	871	12.2	11.8–12.4
Faulhaber (1984)	1977–1980	151	12.3 <sup>b</sup>	–
Aréchiga et al. (1999b)	1994–1996	1,454	12.7	11.1–14.1
Siegel (1999) <sup>c</sup>	1998	519	12.5	12.3–12.9
<b>Tamaulipas</b>				
Peña Gomez (1970), Tampico, urban	1960s	416	12.5	12.3–12.7
Peña Gomez (1970), Tampico and Altamira, rural	1960s	212	13.6	13.2–14.2
<b>Oaxaca</b>				
Malina et al. (1977), colonia	1972	151	14.2	13.7–15.1
Malina et al. (1980), non-valley, rural	1977	328	14.4	13.3–17.4
Malina et al. (2004a), valley, rural	1978	101	14.8	14.2–15.4
Malina et al. (2004a), valley, rural	2000–2002	238	13.0	12.7–13.3
<b>Yucatán</b>				
Diaz-Bolio (1964), Merida, urban	1960s	993	12.6	–
Gurri et al. (2001), rural	1992–1996	135	12.8 <sup>c</sup>	–

<sup>a</sup>All analyses were done with probits (SPSS 10.0) using reported data in each report (sample sizes and number of girls who attained menarche in each age group) except as indicated.

<sup>b</sup>Prospective, mixed longitudinal, standard deviation 1.2 years.

<sup>c</sup>Logit analysis, confidence intervals not reported.

growth charts (Hamill et al., 1977), whereas youth from lower socio-economic classes in Mexico City and other urban areas in the country in the 1970s had statures that fell between the 10th and 25th percentiles of the reference, although weight-for-height ratios were appropriate in both groups.

Several studies in the 1990s, however, indicated elevated weight-for-height ratios as expressed in the BMI in several regions of the country. Measurements of schoolchildren from Sonora (north) and Veracruz (Gulf of Mexico) who were studied in the early 1990s (Peña Reyes et al., 2002) suggest that growth among middle-class children from urban areas in México experienced a positive secular increase in body size reflected in heights at the medians (girls) or just below the medians (boys) of the United States reference in contrast to middle-class children from Mexico City who were surveyed in the 1980s (Faulhaber and Villanueva, 1976; Faulhaber, 1989a). Secular changes in weight, on the other hand, indicated weights at the reference medians (boys) and just below the reference medians (girls). The results suggested, perhaps, the emergence of elevated weight-for-height

ratios noted in subsequent national nutrition surveys in Mexico. Nevertheless, results from more recent surveys indicated that the gap in height between well-off children and those of lower socioeconomic status in different regions of Mexico was being reduced, while the prevalence of overweight was increasing at a faster rate. This trend was also apparent among urban samples of schoolchildren from Monterrey (Rangel et al., 1993) and Durango (Tena and Frisancho, 1997), which showed, on average, elevated BMIs compared to the United States reference.

Evidence from health surveys noted that acute undernutrition was no longer a problem, although growth stunting associated with chronic undernutrition varied by region and was still more prevalent in rural communities. In contrast to undernutrition among preschool children, emphasis was placed upon the increasing prevalence of excess weight or obesity in school-aged children and adolescents (Table 2).

An emerging interest in the field of public health is the growth and weight status of children and adolescents in the context of changes in living conditions. This focus, in turn, has

influenced, to some extent, the types of data collected in national and regional surveys, e.g., additional indicators of health status *per se*, habits of physical activity, sedentary behaviors (physical inactivity) and the well-being of youth in general. Of relevance, estimated level of physical activity among adolescents in ENSANUT-2006 was below recommended level. (Shamah Levy et al., 2007). As a result, the development of strategies to promote physical activity among children and youth at schools and in communities was emphasized. Studies on growth and health among schoolchildren and adolescents also began to focus on the identification of other factors, in addition to physical activity, that might promote weight gain or obesity, and in turn, become risk factors for cardio-metabolic diseases. Concern for health complications associated with excessive weight gain and obesity also increased. For example, a study conducted from 1997 to 2000 showed that in a sample of 132 children (62 obese, 70 non-obese)—who were 5–15 years of age with no previous history of disease and were attending the pediatric service at the Hospital Civil de Guadalajara—obesity was associated with abnormal values for total cholesterol, triglycerides, LDL, HDL, and dyslipidemia (Romero-Velarde et al., 2007). The authors concluded that the risk for dyslipidemia increases with childhood obesity.

Based upon data for heights and weights of children and adolescents collected at the last health and nutrition survey (ENSANUT-2012), we observed significant changes over time and with age. Heights of males 10–12 years old showed greater variation among the states in the north and south regions, with less variation in the central region, while heights of females suggested a noticeable plateau at 11 years. If accurate, this trend suggested significantly earlier maturation among girls and perhaps reduced potential for growth, which has implications for future health and reproduction (Peña Reyes and Bali-Chavez, 2014).

The available information at the national level illustrates the nature of themes that will be the focus of research in anthropology and health, emphasizing the need for consistent and up-to-date information on the growth and health status of children and adolescents throughout the country. Of relevance to indicators of growth, there is a need to address measures of physical growth, biological maturation, body composition, and physical activity in the context of risk factors for cardio-metabolic diseases (including DBT), as the precursors of these conditions are often rooted in childhood and adolescence. These issues have not been satisfactorily addressed in the Mexican population in general, or in the indigenous populations of the country.

## GROWTH STUDIES AMONG INDIGENOUS POPULATIONS

The tradition of anthropological studies of the morphology of indigenous adults in Mexico dates to the late 1890s (Faulhaber, 1970). Corresponding studies of indigenous children were relatively limited and spread across time. The subsequent

discussion is organized geographically from north to southeast, and highlights of studies are summarized in Table 4.

Because of concern over the conditions in indigenous communities throughout the country, a program was developed specifically for school-aged children. It was called the *Albergues Escolares* program (shelter at indigenous or rural communities) and provided schooling, housing, and food for indigenous children throughout the country. The programs were conducted and funded by the government under the direction of the *Instituto Nacional Indigenista* and, after 2003, by the National Commission for the Development of Indigenous Peoples (*Comisión Nacional para el Desarrollo de los Pueblos Indígenas* [CDI]). As part of the *Albergues Escolares* program, heights and weights of children were measured following the protocol used in health examination surveys in the United States.

### NORTH

Communities in the *sierra* the mountain regions are often categorized as developmental or traditional. Developmental communities are a mixed population of indigenous and mestizo ancestry, are dependent on commerce and forestry, and have better access to health and educational services, communication, and roads. Traditional communities are largely indigenous with few mestizos, generally live under marginal conditions, and depend upon subsistence agriculture with the nuclear family as the base of production.

Recent studies indicate secular change improvements in the growth status of rural Tarahumara schoolchildren aged 6–11 years between 1990 and 2007, but negligible changes among youth aged 12–14 years (Peña Reyes et al., 2009). Regular and balanced nutritional intake offered at *Albergues* schools (2007 sample) during the school week may differentially benefit younger rather than older children. Also of relevance, children 12–14 years old were born in 1993–1995—a period of major national economic crisis—into households with a marked increase in poverty at levels comparable to the 1960s (Székely, 2005). Although a national program for education, health, and nutrition (*Programa Educación, Salud y Alimentación* [PROGRESA]) aimed at marginalized communities was initiated in 1997, its benefits for rural areas were likely not observed until several years later (Cortés et al., 2002). Moreover, chronically marginal nutritional and living conditions often exert their negative influence on growth before 5 years of age; as such, it was likely that the growth status of 12–14-year-old Tarahumara children born during 1993–1995 was already compromised.

### CENTRAL

Indigenous populations in the central area include the Otomies Nahuas and Totonacos. Given their proximity to the Federal District, the communities are rather easily accessible. The groups also have had, and continue to have, more or less continuous interactions with the major urban center through

TABLE 4. Studies on indigenous populations by geographic region of Mexico.

Dates	Research group description and study	Type of data and general results
		<i>North</i>
1997	Tarahumara children <5 years of age (Monárrez-Espino and Martínez, 2000)	Prevalence of growth stunting 57%; 36% weight-for-age ratios < -2 SD of the United States NCHS reference. Boys were more affected than girls
1999	Preschool children, two Tarahumara and two mestizo (Saucedo et al., 2003)	Rochahi, low weight-for-age ratios (7%), 10%–14% among communities. Stunting was absent in Aboriachi, but prevalence for the other communities was 3%, 7%, and 11%. No OW in Aboriachi, but prevalence was 3%–11% among other communities.
2000	Tarahumara school children 6–14 years (Monárrez-Espino and Martínez, 2004)	Growth stunting in 22% of children 6–12 years; 1% for children 6–9 years, showed wasting; 5% were OW. At 10–14 years, 3% were underweight, 5% OW and <1% Obese.
1990–2007	Tarahumara school children 6–14 years resident in the Sierra in northern Mexico (Peña Reyes et al., 2009)	Significant secular gains in the heights of Tarahumara children 6–11 years, but minor among children 12–14 years suggest relatively recent improvements in health, nutritional and living conditions.
2009	Tarahumara school children 6–12 years (Guachochi; Balcázar et al., 2009)	Growth stunting: traditional, 30%; urban, 10%; semi-traditional, 3%. Overweight was reasonably similar among traditional, 7%, and semi-traditional, 8%, compared to children, 22%, children.
		<i>Center</i>
1978–1987	Otomí and Mazahua youth 6–11 years (Lagunas Rodríguez and Jiménez Ovando, 1995)	Small sex difference in height and weight from 6 to 11 years. Mazahua males and females were taller than Otomí by 2–3 cm, differences persist through late adolescence. Both indigenous groups were consistently shorter and lighter compared to an urban middle-class Mexico City.
1978–1980	Two Nahua- and one Totonaco-speaking communities, 8–18 years of age from Sierra Norte de Puebla (Herrera and López, 1995)	Heights were below middle-class children from Mexico City (-0.5 to -2.5 SD), heights among girls below -3 SD at most ages. Body weights showed a generally similar pattern, but deficits were not <-2 SD units.
1987	Nahua children 6–17 years of age from Cuentepec, Morelos (Ramos, 1987)	Growth of the lower segment was compromised in contrast to growth of the upper segment; attributed to the influence of impoverished living conditions
		<i>South</i>
1968–1978	Zapotec children 6–14 years (Malina et al., 1972)	Smaller heights and weights when compared to rural (Cravioto et al., 1969) and urban (Ramos Galvan and Luna Jaspe, 1964) Mexican children.
1978–1979	Zapotec children 6–13 years (Malina et al., 1980) Zapotec children 6–13 years (Buschang and Malina, 1983)	Height, sitting height, and leg length were less than U.S. children. Estimated annual rates of growth in height and weight of the Zapotec children were also reduced compared to references, more marked for height than for weight.
1971–1978	Zapotec, Mixe, mestizo, from Valles centrales, Sierra norte, Sierra sur, Istmo (Malina and Peña Reyes, 2018)	A 65% prevalence of stunting, and prevalence of overweight and obesity was 1.6% with little variation among children from the different regions
1978–2000	Urban children from Oaxaca de Juárez, Zapotec children 6–13 years (Malina et al., 2008, 2013)	Significant secular improvements in body weight, height, sitting height, estimated leg length, and estimated rates of secular gain overlapped considerably. Secular gains in the BMI were greater in urban rather than rural children
2007	Children from <i>albergues</i> in 158 municipios (Little et al., 2013)	Among marginalized <i>municipios</i> [municipalities], height and weight were more affected. Altitude residence had a negative influence on height but not on weight. 36% reduction in height, 54% increase on BMI with altitude
1976–1978	Tojolabal children 6–15 years. Municipio Las Margaritas, Chiapas (Aréchiga and Serrano, 1981)	Heights and weights of the rural Tojolabal boys and girls were considerably below references for high (Ramos Galvan, 1975) and middle socioeconomic status (Faulhaber and Villanueva, 1976) urban children in the Federal District.
1974–1977 1976–1979	Maya from Quintana-Roo; Nahua from Cuentepec and Morelos; Tojolabal from Chiapas, children 7–15 years (Ramos and Serrano, 1984)	Height differences among groups were relatively small. Mean weights were more variable with considerable overlap among samples. Estimated muscle areas among Nahua and Maya females, and Maya males were similar to reference, but lower in Nahua boys.

(continued)

TABLE 4. (Continued)

Dates	Research group description and study	Type of data and general results
		<i>Southeast</i>
1979–1980	Maya children 9–18 years from rural communities in Yucatán. One with sisal economy and two with corn, one high, the other low (Murguía et al., 1989)	Male-females differences in growth. The corn high SES group taller and heavier from 9 to 14 years, the lower SES heavier than sisal from 16 to 19 years of age, although differences were no-significant. Females from sisal economy taller than the corn groups from 13 to 19 years. Girls smaller at all ages in lower SES-corn. Weights were greater despite of SES for corn economy.
1985–1986	Chemax and Celestún, two rural agricultural and livestock economies, 10–20 years of age (Dickinson et al., 1989)	Celestún (migrants) were taller and heavier than Chemax (Maya traditional). Heights and weights of both communities below two urban reference samples for Mexico (Faulhaber and Villanueva, 1976; Ramos Galván, 1975) from 9 to 15 years.
1993	Adolescents from Merida (northern Yucatán) (Wolański et al., 1993)	Heights and weights overlapped considerably among the three groups of urban girls between 12 and 17 years of age, and did not differ significantly.
1993	Mayan, non-Mayan, and mixed ancestry 12–17 years (Siniarska and Wolański, 1999)	Mean height and weights of Mayan boys below the other two groups at most ages.

intermittent or permanent migrants. The INAH conducted a comprehensive study of the two indigenous groups in 1978. Focus was put on the impact of socioeconomic factors on the biological development of indigenous groups (Lagunas et al., 1982). Initial studies involved the Mazahua-Otomi region in the state of Mexico, while subsequent studies considered the Sierra Norte de Puebla region. The latter area presents a confluence of indigenous groups from the states of Puebla, Veracruz, and Hidalgo, where the economy was dependent on limited agriculture and cash crops (fruit and coffee). Interest in the isolated communities of Nahua- and Totonaco-speaking groups focused on the importance of health status based on growth status in the indigenous groups in marginal conditions (López-Alonso, 1995).

#### SOUTH

Indigenous communities are relatively numerous in southern Mexico and available studies were largely limited to the state of Oaxaca, which has the largest indigenous population in Mexico, including at least 15 different linguistic groups (Serrano et al., 2002). The state has historically lagged behind other regions of Mexico in development. For example, Oaxaca varied between 30th and 32nd among federal entities on the Human Development Index from 1950 to 2000 (*Programa de las Naciones Unidas para el Desarrollo*, 2003). Two other indices developed in Mexico provide more specific information on conditions in the state: an index of nutritional risk for 2000 (Roldan et al., 2004), and an index of marginalization for 2005 (Anzaldo and Prado, 2006). The state ranked 30th for marginalization and 32nd for social malnutrition among the 32 federal entities. The three

global estimates of quality of life and living conditions highlight the marginal status of populations in the state of Oaxaca, compared to other states and the Federal District in Mexico.

Data collected in the 1970s, regarding the growth status of primary-school children 6–14 years old from 18 communities in the *Valles centrales*, *Sierra norte*, *Sierra sur*, and *Istmo* regions of Oaxaca, have been recently summarized (Malina and Peña Reyes, 2018). The sample was largely indigenous. Heights and weights of *albergues* schoolchildren from the same regions of Oaxaca in 2007 were compared to the sample from the 1970s. The growth status of indigenous schoolchildren in Oaxaca improved between the 1970s and 2007, suggesting improved health and nutritional conditions in indigenous communities (Malina et al., 2011). Nevertheless, the mean heights of Oaxacan indigenous children in 2007 approximated the 5th percentiles of the U.S. reference (Peña Reyes et al., 2010).

Another series of studies considered growth status and secular changes among schoolchildren residing in a rural Zapotec-speaking community in 1968, 1978, and 2000, and in a neighborhood of Oaxaca de Juárez in 1972 and 2000 (Table 2). The studies of these indigenous communities also considered secular changes in the height, sitting height, leg length, and muscular strength and craniofacial dimensions, of children, adolescents, and adults. Changes associated with the demographic and epidemiologic transitions in the indigenous communities have also been considered (Malina et al., 2008b, 2008c, 2013). This ongoing study has been referred to as the “Oaxaca Project” by Salzano and Bortolini (2002), who referenced the project as one of the major research contributions to the human biology and genetics of Latin American populations.



## SOUTHEAST

## SKELETAL MATURATION

The Yucatán peninsula in the southeast region of Mexico is the home of contemporary descendants of the Maya. Early studies reported short stature among children and youth whose parents were farmers from Ticul; the data also indicated no evidence of secular change (McCullough, 1982).

Several human biology studies were initiated in the 1980s and led to the development of a program on human ecology at the Center for Research and Advanced Studies of the National Polytechnic Institute (Centro de Investigación y Estudios Avanzados del Instituto Politécnico Nacional [CINVESTAV-IPN]) in Merida in 1984. One focus was nutrition and growth in an ecological context. The program was initiated by Federico Dickinson, Raúl Murguía, and Dolores Cervera, who were later joined by Napoleon Wolański and Anna Siniarska (from Poland), and Gilberto Balam. Francisco Gurri joined them, and his research extended the studies to include the state of Campeche (Valentin and Dickinson, 2005).

Several studies have shown an association between variation in the growth status of rural children and the principal economic activities in the respective communities, for example, traditional agriculture (corn) versus sisal production in one community, and traditional agriculture (corn), cattle raising, sisal production, and fisheries in another (Dickinson et al., 1990). Other studies considered the growth characteristics of adolescents from Merida, who were classified as Mayan, non-Mayan, or as having mixed ancestry based on paternal and maternal surnames (Table 4).

### BIOLOGICAL MATURATION OF MEXICAN YOUTH

The biological maturation of children and adolescents can be viewed in terms of status and timing. ‘Maturity status’ refers to the level of maturation at the chronological age of observation, while ‘maturity timing’ refers to the chronological age at which specific maturational events occur. Though related, the two are not equivalent (Malina et al., 2004a; Malina and Peña Reyes, 2018). Tempo, or rate of maturation, is a related aspect, but is difficult to estimate.

Commonly used indicators of maturity status in growth studies include skeletal age and secondary sex characteristics (breast and pubic development in girls, testicular volume, genital, and pubic hair development in boys). The two more commonly used indicators of maturity timing are age at peak height velocity, and age at menarche. Maturation of the dentition, number of erupted teeth at a given chronological age, dental age, and dental calcification (status), tend to proceed independently of other maturity indicators. Studies of the biological maturation of Mexican children and adolescents have been limited largely to skeletal maturation, dentition, and age at menarche, although data are not extensive.

Three methods for the assessment of skeletal maturation of the hand and wrist are available: the Greulich and Pyle (GP) and Fels methods based on children in the United States, and the Tanner-Whitehouse method, versions TW1 and TW2 based on British children. In version TW3 the reference values are based on samples from several countries (see Tanner et al., 2001; Malina et al., 2004a; Malina, 2011).

A number of studies focused on children residing in the Mexico City region. An earlier study considered ossification of the carpal bones in children living in a poor neighborhood in Mexico City (Jiménez Ovando, 1965). Skeletal maturity status based on the ossified area of the carpals was not associated to growth status. The same X-ray series was employed by Sánchez-Pineda (1968) in a methodological comparison of TW1 and GP skeletal ages. Greulich and Pyle skeletal ages were more delayed than TW1 skeletal ages, which led the authors to conclude that the TW1 method was more appropriate for the Mexican population, under the assumption that the living conditions of British children were closer to those of children living in Mexico City. Consistent with this suggestion, observations in a sample of children 8–10 years old, from a marginal urban community of Mexico City, indicated TW1 skeletal ages that were delayed to the same extent as the deficit in height compared to the British reference (Sáenz, 1980). In the Faulhaber (1981) study, skeletal ages assessed with the TW2 method did not consistently differ from chronological ages among 440 middle-class children from Mexico City, who were 1–13 years old. The mean skeletal ages of the middle-class Mexican children general fell between the 25th and 50th percentiles of the British reference, suggesting a delay in skeletal maturation. Nevertheless, the mean differences between skeletal and chronological ages were generally equal to or less than 0.60 year in both boys and girls, although standard deviations were quite variable.

Studies of skeletal maturation in samples in other regions of Mexico generally had a nutritional focus. Greulich and Pyle skeletal ages among children in the Yucatán were delayed relative to chronological ages, and the delay was attributed to their marginal or poor nutritional status (Chávez et al., 1964). Among children residing in a colony in Oaxaca de Juárez, TW2 skeletal ages were only slightly behind the British reference, while heights and weights were considerably shorter and lighter than the reference, consistent with their somewhat marginal health and nutritional circumstances (Malina et al., 1976). The results suggested, to some extent, dissociation between growth status and skeletal maturity status (TW2 method) in this sample (Malina and Little, 1981).

The radiographs of the children referred above were subsequently assessed with the Fels method (Peña-Reyes and Malina, 2001). The two methods did not provide similar estimates of skeletal age; Fels skeletal ages were more delayed relative to chronological ages than were TW2 skeletal ages, and the

delay (lateness) of the Fels skeletal ages was consistent with the small body size of the children. Differences between TW2 and TW3 RUS (score based on radius, ulna and short bones, i.e., metacarpals and phalanges) and CARPAL (score based only on carpal bones skeletal ages in different samples merit more detailed study.

Another study of middle-class children and adolescents 6–16 years of age—from Guadalajara, Guanajuato, and Yucatán—was based on the assumption that the Fels method may be more sensitive in discriminating either an advance or a delay in maturation than the TW2 method for Mexican children (Peña-Reyes and Cárdenas Barahona, 1995, 1996). Results of maturation determined by the Fels method indicate skeletal ages closer to growth status than TW2-RUS skeletal ages, compared to United States references (Hamill et al., 1977).

#### DENTAL MATURATION

The variable results with the different methods of skeletal age assessment in Mexican children, discussed above, prompted the use of other methods for the further study of biological maturation in the contexts of sport and health (Peña-Reyes et al., 1994; Malina et al., 2000; Magaña-Moheno, 2005; HierroBohigas, 2005; Pereyra-Hernández, 2006; Martínez-Nava, 2007). For example, routine radiographs already available in pediatric and clinical dental practices were utilized in an effort to describe the skeletal maturation of the cervical vertebrae (Pereyra-Hernández, 2006). Subsequently, dental calcification of the permanent teeth was related to maturity indicators described for the cervical vertebrae in a dental series of 391 children 7–16 years old, for whom panoramic dental and lateral cephalic radiographs were available (Peña-Reyes and González, 2010). Calcification of the permanent dentition was completed earlier among Mexican children in comparison to Canadian children, upon whom the protocol for calcification was developed (Demirjian et al., 1973). Calcification was especially more advanced after 8 years of age, leading to a dental age in advance of the chronological age.

Morphological features describing the progress of maturation of the cervical vertebrae between 9 and 16 years of age tended to appear at younger ages compared to observations in Caucasian children in the United States (Lamparski, 1972). The results suggested a more rapid skeletal maturation (by approximately one year) in the cervical vertebrae of Mexican children. The results need to be replicated in other samples from different geographic areas of Mexico.

The eruption of deciduous and permanent dentition was traditionally used to estimate dental maturity status (dental age) in anthropological and clinical studies. More recently, two different strategies have been used: an estimate of dental age based on the number of teeth erupted, or a description of specific teeth at the time of the assessment. Mejía and Rosales (1989) compared the number of teeth and growth status among children from different socioeconomic status. There was no difference in the number of erupted permanent teeth by socioeconomic

status, although variation by sex indicates more teeth among girls compared to boys, within the same socioeconomic status. Using a different approach to estimating dental maturation, the estimated time (age) of eruption of the canines, premolars, and second molars in urban children was earlier in girls than in boys up to 13 years old, after which sex differences were no longer apparent (Faulhaber, 1989). Advanced dental development in girls was generally consistent with other maturity indicators (Malina et al., 2004a).

#### SEXUAL MATURATION

Stages of genital and pubic hair (criteria developed by Tanner in 1962, 1962) were described for a cross-sectional sample of 699 boys from Mexico City, 9–16 years of age (Guízar-Vázquez et al., 1992). The growth status of the boys compared favorably with local reference data for children from Mexico City (Faulhaber and Villanueva, 1976; Ramos Galván, 1975). Median ages for stages of genital development were as follows: G2, 12.1±0.9 years, G3, 13.1±0.8 years, G4, 13.8±0.8 years, and G5, 14.5±0.8 years. The corresponding median ages for pubic hair development were as follows: PH2, 12.7±0.8 years, PH3, 13.5±0.9 years, PH4, 14.3±0.8 years and PH5, 14.5±0.8 years. It is not clear in the report, however, whether these estimates are the median ages of boys in the respective stages, or the estimated age (typically based on probit analysis) when 50% of the boys in the total sample were in the respective stages.

Mixed longitudinal observations of the secondary sex characteristics of urban middle-class youth (143 males and 132 females), between 10 and 15 years old, suggested the following. Estimated median ages at attaining breast stages 2 and 4 were 12.3 and 14.0 years, respectively, while estimated age at menarche was also 12.3 years (Faulhaber, 1995). The development of axillary hair was present in about 50% of girls by 13.0 years and 50% of boys between 13.5 and 14.0 years of age. Facial hair appeared in the nasal (moustache) region in 50% of boys between 12.5 and 13.0 years, and as a beard in 50% of boys between 14.5 and 15.0 years of age, while breaking of the voice was present in 50% of boys between 12.5 and 13.0 years of age (Faulhaber, 1995).

Age at menarche is the most commonly reported maturity indicator in Mexican girls. There are three methods for estimating age at menarche. The prospective method follows individual girls on a regular basis in longitudinal studies, for example, every three or six months, although girls are followed annually in some studies. In contrast to prospective estimates which are based on individual girls followed longitudinally, age at menarche for a cross-section sample of girls can be estimated with the status quo method. The method requires two pieces of information in a sample spanning about 9–17 years of age: chronological age of the girls and whether or not menarche has occurred (yes or no). The data are subsequently analyzed with probits or logits to derive the median age at menarche and 95% confidence intervals for the sample.

The retrospective method requires individuals to recall the chronological age at which menarche occurred. It is influenced by memory and recall bias (the shorter the recall interval, the more accurate the recall, and vice versa). Recalled ages tend to be reported as whole years, typically age at the birthday before menarche. A detailed interview can aid women to recall ages more precisely. The method is most often used with adults. It has limitations with adolescents, since girls who have not yet attained menarche are excluded from the sample.

Estimated ages at menarche for Mexican girls from studies dating to the 1960s are summarized in Table 3. Data are mostly available for cross-sectional samples for the Federal District or Mexico City, and span from the 1960s through the late 1990s. The median ages at menarche range from 12.2 to 12.8 years old, and do not suggest secular differences. In contrast, only one age at menarche based on the prospective method has been reported for middle-class girls in México City, 12.3±1.2 years (Faulhaber, 1984). Estimated ages at menarche of girls from two urban centers, Tampico and Merida, are within the range of those for girls from Mexico City (Aréchiga Viramontes et al., 1999).

Estimated median ages at menarche for rural Tamaulipas in the 1960s, and Oaxaca in the 1970s, are later than those of girls from urban centers. However, the data for recent rural samples suggest a secular decline (Table 3). The estimated median age for rural girls in Yucatan in the mid-1990s (Gurri et al., 2001) is similar to that for urban girls in Merida in the 1960s (Diaz Bolio, 1964). In contrast to the preceding studies, which were based on the status quo method, the retrospective method was used with girls 11–20 years of age, living in Merida (Wolański et al., 1993). The mean age at menarche was slightly earlier in non-Mayan girls (12.0±1.4 years) than in Mayan girls (12.4±1.2 years), and both means are earlier than median ages at menarche for girls from Merida in the 1960s and girls from the rural Yucatan in the mid-1990s (Table 3). The limitations of the retrospective method with adolescent girls should be noted.

Estimated median age at menarche among girls in rural Oaxaca from the same indigenous community has declined from 14.8±1.2 years in 1978 to 13.0±1.0 years in 2000–2002. The estimated rate of secular decline in the rural girls was 0.78 year per decade, which was more rapid than the estimated secular decline in recalled ages at menarche among adult women in the community (Malina et al., 2004b).

## CONCLUSION

Growth studies over the first half of the twentieth century focused to a large extent on the assessment of specific living conditions among preschool children and women. The results provided, in part, the basis for policy decisions during a critical period of limited resources in a less developed (declining is not appropriate for what we want to describe) economy during this period in Mexico. Once poor nutrition was recognized as a major factor contributing to the reduced growth potential of

children, the advent of health institutions to address childhood health created a new scenario. Researchers at these institutions began viewing nutrition and health as strategic components in addressing environmental, social, economic, and cultural factors affecting the Mexican population, especially in rural areas and marginalized urban neighborhoods. Nevertheless, the results from growth and maturation research in the following decades do not reflect a consistent improvement in nutrition and health. Economic conditions continued to improve into the 1970s, but began to falter late in the decade, and the decline continued into the 1980s. A relative improvement was documented from the end of the 1990s to the beginning of the 2000s. Socioeconomic conditions have contributed significantly to modifications in diet, health care, and opportunities for physical activity, in all domains of daily life that, in turn, impact the health status of children and youth. Secular trends in growth and maturation indicate that differences in size among high, middle, and low socioeconomic levels are reducing through time. Height and weight, however, do not increase proportionally, which has resulted in a consistent pattern of elevated weight-for-height ratios, documented by the elevated prevalence of overweight and obesity affecting children and adolescents in the country. Current conditions emphasize the need for consistent and up-to-date information on the growth and health status of children and adolescents throughout the country.

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# History of Human Population Genetics of Central America

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**ABSTRACT.** To frame and evaluate contributions to the development of human population genetics studies in Central America we summarize, classify, and compare the most relevant literature published since the beginning of the twentieth century. The development of human population genetics in Central America is a continuation of studies of morphological variation. From the 1920s to 1960s, emphasis was placed on morphology and the biochemical differences of local indigenous populations. From the 1970s to the 1990s, new serological discoveries made microevolutionary studies possible among indigenous and Afro-Caribbean populations. The molecular genetics investigations that were initiated in the 1990s started a new era of the examination of novel evolutionary questions in the twenty-first century. During this period, use of a wide variety of informative markers enabled the unraveling of demographic histories of national and indigenous populations. Despite steady development of population genetics in Central America over the past century, differences exist in the quantity and quality of investigations in this geographic area. Costa Rica, Nicaragua, and Panama are the most frequently studied countries in comparison with Guatemala, Honduras, Belize, and El Salvador. It is hoped that future research improves this disparity.

**RESUMEN.** Con el propósito de organizar y evaluar las contribuciones de la genética de poblaciones en humanos en América Central, hemos clasificado, resumido, y comparado la literatura más relevante que se ha publicado sobre este tema desde inicios del siglo XX. El desarrollo de la genética de poblaciones en América Central deviene como la continuación de los estudios de variación morfológica y bioquímica que se desarrollaron entre las décadas de 1920 y 1960 sobre poblaciones indígenas locales. Entre las décadas de 1970 y 1990 los nuevos descubrimientos en los estudios serológicos dieron paso a la investigación microevolutiva entre poblaciones indígenas y afrocaribeñas. Las investigaciones en genética molecular que se iniciaron en la década de 1990 en América Central fueron la antesala para plantear en el siglo XXI nuevas preguntas sobre aspectos evolutivos. Durante este último período, se han utilizado una amplia variedad de marcadores informativos que han permitido revelar las historias demográficas de poblaciones nacionales e indígenas. No obstante, a pesar del rápido aumento de publicaciones en los últimos 15 años en América Central es notable la diferencia en la cantidad y la calidad de las investigaciones en esta área geográfica. Costa Rica, Nicaragua y Panamá son los países que cuentan con más investigaciones en comparación con Guatemala, Honduras, Belice y El Salvador. Se espera que futuras investigaciones corrijan esta disparidad.

**RESUMO.** Visando reconhecer e avaliar as contribuições ao desenvolvimento dos estudos de genética de populações humanas na América Central, fazemos um resumo, classificamos e comparamos a literatura mais pertinente publicada desde o início do século XX. O desenvolvimento da genética de populações humanas na América Central é uma continuação de estudos da variação morfológica e bioquímica das populações indígenas locais que foram desenvolvidas entre as décadas de 1920 e 1960. Entre 1970 e 1990, novos descobrimentos sorológicos fizeram possíveis estudos microevolutivos entre populações indígenas e afro-caribenhas. As pesquisas genético-moleculares que se iniciaram na década dos 90 na América Central iniciaram uma nova era de pesquisas com novas perguntas evolutivas no século 21. Durante este período, o uso de uma ampla variedade de marcadores informativos possibilitou deslindar as histórias demográficas de populações indígenas e nacionais.

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

Contudo, apesar do desenvolvimento estável da genética de populações na América Central durante os últimos 15 anos, existem diferenças na quantidade e qualidade de pesquisas dentro desta área geográfica. Costa Rica, Nicarágua e Panamá são os países mais estudados em comparação a Guatemala, Honduras, Belize e El Salvador. Espera-se que futuros estudos corrijam esta disparidade.

## INTRODUCTION

The Central American Isthmus, a swath of land between Mexico and Colombia bordered by the Caribbean Sea to the east and the Pacific Ocean to the west, consists of seven countries: Panama, Costa Rica, Nicaragua, El Salvador, Honduras, Guatemala, and Belize. This region has important implications for biogeography, oceanography, animal migration, and the colonization of North and South American plants, as well as the interaction and settlement of human populations since the late Pleistocene. The latter being an area of research that has fascinated generations of investigators over the last 100 years, since early classification studies of local ethnic groups by physical anthropologists and other specialists (Schultz 1926; Willey and Sabloff 1974; Janzen 1983; Webb 1997; Cooke 2005). Despite this early interest, research centered on evolutionary questions began late in relation to other regions of the Americas. The first investigations to emerge—descriptions and phenotypic comparisons of anthropometrics and biochemistry (ABO blood-system)—began in the first half of the twentieth century in most Central American countries. However, it was not until after the 1970s that a significant number of studies centering on the population genetics of indigenous groups in Costa Rica and Panama were initiated. Technological advances of the second half of the twentieth century, including polymerase chain reaction (PCR), DNA sequencing, and the speed and capacity of microprocessors (Jobling et al. 2014), opened new avenues in the 1980s for anthropological studies. These studies included research on evolutionary relationships between *Homo sapiens* and other hominins, modern human origins, migrations and major demographic expansions out of Africa, and micro evolutionary processes of small-geographic-scale populations. Further technological advances of the twenty-first century have made it possible to study variation across the genome with methods like microarray hybridization and next-generation sequencing (Jobling et al., 2003; Crawford, 2007).

The objective of population genetics is to describe the distribution of allele frequencies in order to explain evolutionary phenomena of populations; that is, reproductive groups that share a geographic space. Changes in gene frequencies are influenced by mutation, natural selection, genetic flow, and genetic drift (Hartl, 2000). In humans, population genetics contextualizes the non-random distribution of alleles caused by social practices and the effect of constructed niches (Fix, 1999; Laland et al., 2010). The effects of geographic isolation on the distribution of certain genes, the consequences of population admixture, and the possible effects on health are among some of the aspects that have

been studied by researchers in Central America. However, until now an all-inclusive genetic history of the human population of the region has not been attempted. The objective of this chapter is to comprehensively review the development of the field of population genetics in Central America from its inception during the mid-twentieth century to the present. However, there are limitations to our ability to present a panoramic view of Central American population genetics due to the fact that a disproportionate number of studies have been carried out in Costa Rica in comparison to other Central American countries. Additionally, we discuss only investigations based on those molecular markers commonly used for population genetics studies. Although other types of research provide alternative information on population dynamics (such as isonomy-based studies), they are not reviewed in this chapter.

We have organized the literature chronologically to identify and synthesize three major trends in research: (a) studies on morphological traits focusing on human classification in Central America, (b) studies on microevolution and phylogenetic relationships based on blood group polymorphisms, and (c) studies on molecular genetics that highlight the population's genetic history and the impact of admixture.

## TYPOLICAL CLASSIFICATIONS

Prior to the development of population genetics, research in Central America followed world historical trends, from the emphasis on classification and description of human types to modern studies based on genomics. These trends reflect shifts in the types of questions being investigated by researchers, developments in science and technology, and variations in the intellectual environment over time (Mielke et al., 2006).

In Central America, biological anthropologists, ethnographers, and archaeologists have long been interested in studying the history of human diversity in the region; however, pre-Columbian and post-Colonial population histories have been largely deduced by diffusionist models (e.g., Coe, 1960; Boudez, 1963; Haberland, 1981; Snarskis, 1984, 1992), or based on contentious ethnohistorical interpretations (e.g., Ibarra, 1990, 2011). The dearth of historical documentation in broad areas of Central America contribute to the difficulty of approximating important demographic events of the past (Baldi, 2013). The field of anthropological genetics in Central America has been central in understanding the causes of human variation, microevolution, and population history considering the insufficiency of other demographic and historical sources.

European exploration of uncharted geographical spaces in the sixteenth century, including Central America, encompassed not only descriptions of flora and fauna, but also of indigenous populations, their social organization, and their physical and behavioral characteristics (Mielke et al., 2006). These observations were based on the subjective, Hippocratic concept of “humors,” the temperament and external appearance associated with a



particular ethnic group. These early colonial demographic estimates and classification of Central American Amerindians were used as a means of military, political, economic, and social control. Human classification determined by visible morphological characteristics of the skin, the hair or the shape of the eyes began in Central America in the sixteenth century. Populations were geographically located and the number of the inhabitants recorded, along with causes of growth or decline—e.g., mortality, migrations, baptisms, marriages. After the sixteenth century, Europeans began documenting the great diversity of indigenous groups in Central America (Frazer, 1939). Their descriptions of “racial types,” despite the strong pejorative charge they convey, provide a general view of the demography, ethnic mosaic, languages, customs, and cultural practices of the region. The mix of different ethnic groups included Spaniards, Africans, and indigenous peoples that were further diversified by the new migratory influx to the region (Hall and Pérez-Brignoli, 2003). The delineation of the human geography (“local races”) continued in the nineteenth and early twentieth centuries, and they are depicted in works by a number of scholars in Costa Rica (e.g., Fernández-Guardia, 1921; Pittier, 1938; Lines, 1952); however, these classifications lacked scientific rigor and diachronic perspective of social and biological evolution.

The organization of this chapter is not meant to imply that trends in research are discrete. The overlapping nature of scientific discovery, a process illustrated by studies carried out during the twentieth and twenty-first centuries, has seen new scientific inquiries as well as the application of new technologies to research questions of the past.

## PHYSICAL AND BIOCHEMICAL CLASSIFICATIONS

Before the discovery of blood-groups systems, protein, enzyme polymorphisms, and DNA analysis, anthropologists described human variation by using quantitative traits such as anthropometrics and dermatoglyphics (Relethford, 2007). In Central America, anthropometric studies were conducted by A. Schultz in 1924 among the Mayangna (Sumo) and Rama Amerindians in eastern Nicaragua (Schultz, 1926). Similar studies were undertaken by Aleš Hrdlička (1926) with the Guna (Kuna) of Panama, and by Laurencich de Minelli among the Boruca, the Guaymí, the Bribri, and the Cabécar groups in Costa Rica (Laurencich, 1966, 1968, 1974). Also, Ada D’Aloja developed demographic and anthropometric research between 1937 and 1939 among indigenous groups from Nicaragua, El Salvador, Honduras, and Guatemala (D’Aloja, 1939, 1940). These investigations relied mostly on typology based on the segregation of human groups according to their external (morphological) characteristics and their geographic location (Figure 1). In 1947 and 1949, T. D. Stewart (1947) recorded basic demographic information, blood samples, and dermatoglyphic data from four indigenous communities in Guatemala. Based on these dermatoglyphic data,

Newman (1960) found a biological division between the Maya of the North Highlands, the South Guatemalan Highlands, and the Yucatan Lowlands, differences which were interpreted to be the result of geographic isolation.

The discovery of blood groups in 1900 led to a shift in the typological paradigm. Rather than anthropometric methods, researchers began to focus on comparisons of Mendelian genetics based on ABO blood-system frequencies, particularly in the Americas (Neel and Salzano, 1964; Neel 1978; Crawford, 2001; Mielke et al., 2006). The assessment of Amerindian genetic variation was possible through the development of electrophoretic methods using primarily blood cell proteins and enzymes referred to as “classic genetic markers” which include ABO, Rhesus, MNS, and Duffy, among others (Crawford, 2007). Based on blood group frequencies, William Boyd (1950) proposed the distinctiveness of the Amerindians, and then blood cells were collected among indigenous groups across the Americas. Classical polymorphism was the first genetic system used for evaluating the origins of these populations, the number of migrations, and the chronology of events (Crawford, 2001). However, these types of studies began to emerge in Central America in the 1960s with Fuentes (1961) among the Guatuso in northern Costa Rica, and with A. Matson and J. Swanson, who compiled and systematized the distribution of blood antigens among indigenous populations from Guatemala, Belize, Honduras, Costa Rica, and Panama using different polymorphic systems (ABO, MNS, P, Diego, Duffy, Kell, haptoglobulins, transferrins, and hemoglobins) (Matson and Swanson, 1961, 1963, 1964, 1965a, 1965b).

Further studies attempted to understand the biological and cultural causes of variability in local indigenous populations, for example, those carried out by Gian Franco De Stefano and Jorge Jenkins among the Rama, Miskito, Mayangna, Subtiaba, and Ladino populations between 1969 and 1971 in Nicaragua (De Stefano and Jenkins, 1970–1971, 1972). Apart from the anthropometric, PTC testing, and serologic information collected in Nicaragua, De Stefano and his colleagues included in their analyses linguistic affiliation, history, geographical location, and demographic relationships among native and mestizo populations. Other studies based on fieldwork carried out between 1969 and 1972 highlight the importance of genetic and environmental components that have contributed to the phenotypic asymmetry of populations from Mexico and Belize (Baume and Crawford, 1980).

Morphological studies were developed within the context of the research conducted by Barrantes and his colleagues on populations including the Bribri, Cabécar, and Guaymí from Costa Rica and Panama after the 1970s (Barrantes, 1993a). A number of these studies demonstrate the applicability of dermatoglyphics and dental morphology for inferring population structure at the tribal level (Brenes and Barrantes, 1983, 1986; Quesada and Barrantes, 1983, 1986, 1991; Segura-Wang and Barrantes, 2009).

These investigations, led by De Stefano, Crawford, and Barrantes, mark the transition between anthropometric studies and

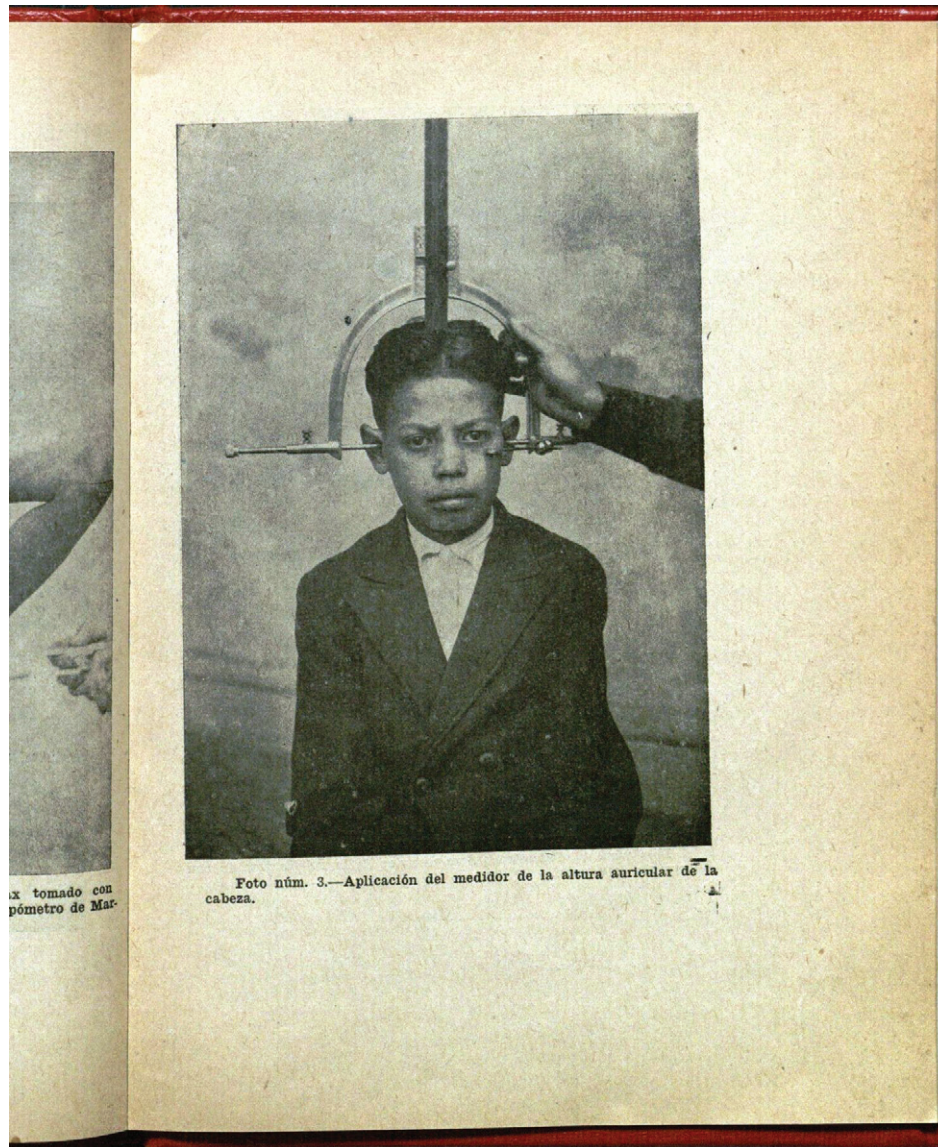


FIGURE 1. Page from a book typical of anthropometric studies among indigenous populations of the east coast of Nicaragua. Photograph taken by Ada D'Aloja (1939).

those that attempted to explain the microevolutionary consequences in Central American populations.

### MICROEVOLUTIONARY STUDIES BASED ON CLASSICAL GENETIC POLYMORPHISMS

Innovations in biochemistry, genetics, and serology produced additional genetic markers, for example, those encoded in the human leukocyte antigens (HLA) or in immunoglobins (GM and KMs), which can yield insights on migration patterns and

evolution (Crawford, 2001). HLA markers have been used to compare populations, to better understand the history and structure of Chibchan populations in southern Central America (SCA: i.e., Nicaragua, Costa Rica, and Panama), to determine the origin of Maya, and to establish the ethnic profile of the Garifuna on the Caribbean coast of Central America (Dykes et al., 1981).

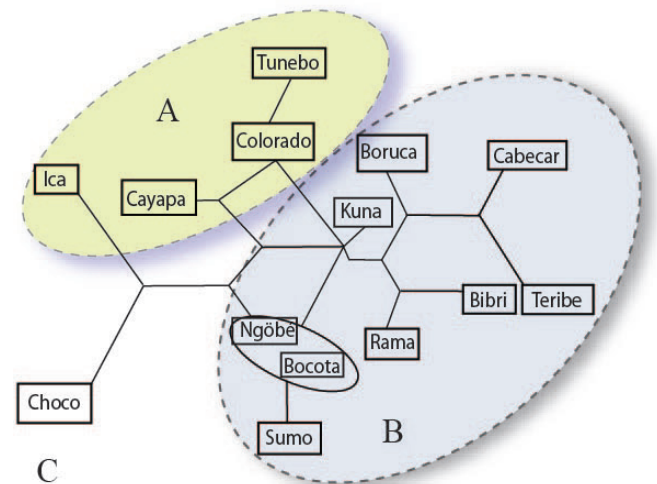
Based on HLA, Gómez-Casado et al. (2003) highlight the genetic particularity of the Maya of Guatemala in comparison with the Mesoamerican Zapotec, Mixe, and Mixtec Amerindians, and with the Arawaks, the first recorded inhabitants of the Caribbean Islands, as well as with Chibchan populations in Colombia (Kogi and Arsario). A second study based on HLA class

II alleles indicated that the Maya of Mexico and Guatemala are distinct populations (Vargas-Alarcón et al., 2011).

In Costa Rica and Panama, serological studies continued the research that James V. Neel had begun in the 1950s among the Xavante in Brazil and the Yanomamo in Venezuela (Neel and Salzano, 1964, 1967; Neel, 1978). Neel sought to understand which evolutionary forces shape the genetic structure of populations and how conditions that regulate survival and reproduction had changed from “pre-civilized” indigenous groups to modern populations (Neel, 1994). Fieldwork and the collection of demographic and ethnographic data were instrumental in testing such models in vivo (Ventura, 2003). The proposal by Fitch and Neel (1969) of the genetic relationship between the Guaymí from western Panama and the Yanomamo from southern Venezuela was a crucial advance in the understanding of the population structure and history of the indigenous groups in SCA. This hypothesis was later tested by Spielman et al. (1979) who did not find evidence of any such relationship, but instead discovered two new private polymorphisms (DH\*BGUA and ACP\*BGUA) among the Guaymí and the absence of albumins among the Yanomamo (Tanis et al., 1977). A subsequent study among the Guaymí including blood markers, anthropometrics, and linguistics, found substantial differences from the Yanomamo as well as indications of the early divergence of the two groups around 4000 years ago. This study was one of the first that combined genetics, linguistics, and anthropological methods in the study of human variation and evolution in Latin America (Crawford, 1979).

These works heeded new comparative studies on indigenous groups of similar linguistic phyla. The work of Barrantes et al. (1982) is the first attempt to establish the intra-population variation between two Guaymí communities from Costa Rica (Limoncito and Abrojo) and their relationship with other Chibchan-speaking populations from SCA and northern South America. This study proposed the relationship of three geographically separated groups: Central American, northern South American, and Chocoan-speaking populations. Most of the indigenous Chibchan-speaking populations cluster together (Figure 2). Subsequent analyses of three systems—blood group, plasma proteins, and erythrocyte proteins—were conducted by Barrantes using a combination of newly gathered data and previously published sources, Barrantes (1993b) proposed that kin structure migration and the fission and fusion of villages were responsible for the population structure of the Guaymí from Panama and Costa Rica.

Nevertheless, using a bigger sample size of 22 Chibchan-Paezan populations from Colombia and Central America and 25 polymorphisms, Layrisse et al. (1995) did not find clear phylogenetic relationships among these populations. Baldi (2013), using data from literature, tested the hypothesis of the genetic relationship among Chibchan-speaking populations from Central America and Colombia by analyzing 22 alleles of seven blood group systems of 24 populations (MNSs, P, Kidd, Diego, Rhesus, ABO, and Duffy). The results indicated spatial association among Chibchan populations from Central and South America



**FIGURE 2.** Minimum string network showing genetic relationships among South American Chibchan Populations (A), Central American Chibchan populations (except Sumo) (B), and a Chocoan-speaking population (C). Diagram modified from Barrantes et al., (1982).

and demonstrated that heterozygosity values and distance from the centroid (*r<sub>ii</sub>*) indicate that most Chibchans presented lower genetic heterozygosity than other non-Chibchan populations from Central America.

Subsequent publications (Barrantes et al., 1990; Thompson et al., 1992; Bieber et al., 1996; Barrantes 1998; Azoifeifa et al., 1998, 2001) proposed that the genetic structure of Chibchan speakers of SCA was likely the result of kinship, environmental conditions, and geographic isolation. The combination of these factors generated higher frequencies of transferrins D-Chi, the 6PGD allele, and the absence of the Diego A\* allele (DiA\*), as well as other rare, regionally restricted polymorphic variants. In accordance with these observations, the authors of the studies mentioned above concluded that the genetic differentiation of Chibchan populations in SCA underpins an in situ development of Chibchan-speaking populations and their divergence around 7000 B.P. (years before present).

Despite their importance in studies of population genetics, classical genetic markers provide only a gross approximation of the complexity and the genetic history of Central American indigenous populations. However, they paved the way for later studies of greater evolutionary resolution such as investigations of molecular markers. In addition, microevolutionary studies based on blood polymorphisms provided the foundation for the hypothesis of the coevolution of culture and genetics in the Isthmo-Colombian Cultural Area (ICCA) which is occupied predominantly by Chibchan speakers and includes northern Colombia, Panama, Costa Rica, Caribbean Nicaragua, and portions of

eastern Honduras (Constenla, 1991; Barrantes, 1993b; Cooke and Ranere, 1992; Fonseca, 1998; Hoopes and Fonseca, 2003).

## MOLECULAR POLYMORPHISMS

Unlike the indirect investigation of biochemical markers such as protein and enzyme polymorphisms that are influenced by natural selection (Destro-Bisol et al., 2010), four principal discoveries have permitted the direct study of the DNA molecule in the last forty years. Restriction enzymes make it possible to cleave strands of DNA in specific positions; DNA hybridization techniques facilitate the comparison of different species through the similarity or difference of their nucleotide constitution; PCR creates “copies” of DNA sequences in geometric progression; and automated DNA sequencing permits the rapid characterization of the human genome (Rubicz et al., 2007). These inventions established the genetic variability and worldwide phylogenetic relationships among and within human populations by facilitating the study of several DNA polymorphisms, the non-recombining portion of the Y-chromosome (NRY), and autosomal DNA (Bhasin and Walter, 2007). In addition to mitochondrial DNA (mtDNA) and the NRY, autosomal DNA data provide the combined history of males and females due to the chromosomal reshuffling through generations. These three systems are commonly used today for the study of the genetic history of isolated populations and of national gene pools in Central America.

Studies of Central American mtDNA polymorphisms consist of the sequence of hypervariable sections 1 and 2 (HVS-I and HVS-II) of the mtDNA control region, whole genome sequences, and the analysis of restriction fragment length polymorphisms (RFLPs), which facilitates the study of haplogroups—groups of related haplotypes that share a common ancestor and are correlated by cultural affiliation, language family, and geographic location (O’Rourke et al., 2000). The RFLPs are used to characterize single nucleotide polymorphisms (SNPs) that define the major haplogroups present in America (A, B, C, D, and X) inherited through the maternal side (Rubicz et al., 2007). Additional resolution of the mtDNA haplogroups, assisted by full genome sequences, has led to the classification of 15 founder subclades (<http://www.phylotree.org/>). From the paternal side, two deep clades are present in Amerindian populations: C and Q (O’Rourke and Raff, 2010).

An increasing number of mtDNA, Y-chromosome, and autosomal genetic studies in SCA have attempted to achieve two main goals: first, to understand the evolutionary implications of the peopling of Central America in a local and a broader continental context; and second, to look at history of the genetic admixture within national gene pools.

### CHIBCHAN STUDIES IN SOUTHERN CENTRAL AMERICA

To test whether the *in situ* microevolutionary hypothesis, previously proposed by Barrantes and others, or the continued

gene flow across cultural areas explains most of the genetic history and population structure of Chibchan-speaking populations in SCA, recent research has been based on different levels of genetic resolution.

The first attempt to test the hypothesis of the early tribalization and microevolution of Chibchan populations from Panama and Costa Rica estimated their separation from other linguistic families early in the Holocene based on mtDNA (Torroni et al., 1994). A subsequent examination of the haplotype diversity of the Ngöbé from Panama (Kolman et al., 1995) detected lower diversity values at the HVS-I and II regions and a population expansion around 6800 B.P. Low levels of genetic diversity were also reported among the Guna from western Panama, and the Huetar from Costa Rica indicating that Chibchan-speaking populations experienced a population bottleneck around 10,000 B.P. (Batista et al., 1995, 1998; Kolman et al., 1995).

While examining the genetic variability of the Huetar from the Central Valley of Costa Rica, Santos et al. (1994) discovered a distinctive 6-bp deletion in the mtDNA HVS-II region between nucleotide pairs (np) 106 and 111. This mutation, named the “Huetar deletion,” corresponds with the *MspI* site loss at nucleotide position 104 within the haplogroup A2 that appears in some Chibchan-speaking populations of Central America, including the Teribe, Bribri, Cabécar, Boruca, Guaymí (Ngöbé and Buglé), Guna (Torroni et al., 1993, 1994; Santos and Barrantes, 1994a, 1994b; Santos et al., 1994), and Chorotega, an Oto-Manguean-speaking population (analysis in progress by this chapter’s authors). The Huetar deletion was defined as the mitochondrial A2af lineage and is also present in high frequency among contemporary Panamanians and across SCA (Perego et al., 2012).

Kolman and Bermingham (1997) carried out the first study that contrasted the mtDNA (HVS-I and HVS-II), nuclear, and Y-chromosome genetic markers of two Chocó-speaking populations from eastern Panama—the Emberá and Wounan—and two Chibchan-speaking populations—the Guna and Ngöbé. Contrary to previous studies, the authors concluded that patterns among the Chocoans differ from the reduced diversity found in other Chibchan populations.

A number of recent studies have attempted to understand the genetic structure and diaspora of Chibchan speakers from Central and South America. Melton et al. (2007) examined the hypothesis of biological relationships between Chibchan populations of SCA and northern Colombia. This study found a low haplotype diversity and reduced heterozygosity among Chibchans likely caused by population drift. Furthermore, the absence of shared mtDNA haplotypes indicates an early split from an ancient stock during the Pleistocene/Holocene transition. The human diaspora from Central America to northern South America (based on mtDNA) might have occurred between 14,000 and 8,000 B.P. coupled with a shift in subsistence from hunting and gathering to horticulture. After this episode, Chibchan populations remained geographically isolated between SCA and northern South America. The transition to the Holocene facilitated the exploitation of and adaptation to a variety of microenvironments,

allowing for sedentarism and relative genetic homogeneity due to reduced genetic flow from other regions. According to this model, population growth in the Central American isthmus inhibited subsequent migrations from the north and might have induced northern South American populations to move further south. This study also found a genetic relationship in the distant past with Mayan populations from Central America. This possible relationship provides a more complex scenario than the in situ microevolutionary hypothesis proposed by the Barrantes group (Barrantes et al., 1990) due to its higher molecular resolution in comparison with blood polymorphisms.

Subsequent studies examined Y-chromosome and mtDNA variation in five populations (Rama from Nicaragua and Huetar, Maleku, and Guaymí from Costa Rica) to look at the evolutionary history and genetic relationships of the Chibchan speakers and their neighboring populations (Melton, 2008; Baldi, 2013; Melton et al., 2013). Deep phylogenetic relationships found at the mtDNA level indicate that central and northern South American Chibchans share a number of haplotypes or are separated by only one mutational step. Similar relationships were found with other Mesoamerican populations, while divergence from South American and Andean groups was indicated. In addition, coalescent dates based on haplogroup A2 suggest that the separation of Chibchans from founding Paleoindian populations occurred early in the Holocene followed by their geographical isolation (Melton, 2008; Baldi, 2013).

Chibchan populations characterized by their low mtDNA diversity due to genetic drift contrast with the recent flow of males of African and Euro-Asiatic origin. Also, the NRY shows little ancestral differentiation between Mesoamerican, Chibchan, and Chocoan populations (Melton et al. 2013) and unclear population structure from the paternal side (Ruiz-Narvaez et al., 2005; Ascunce et al., 2008).

These studies demonstrate that compared to the Y-chromosome, mitochondria was less impacted by demographic processes after European colonization in the sixteenth century. The population structure inferred by the mitochondria is consistent with recent studies of autosomal microsatellites that show a relative lack of differentiation between Mesoamerican and Andean populations and a close relationship between Chibchans from eastern South America and SCA. Further studies are needed to clarify whether these relationships were caused by ancient or more recent population events (Wang et al., 2007).

Contrary to the previous scenario, Reich and associates proposed that Chibchan speakers from SCA experienced a reverse gene flow to Central America after the initial peopling of South America (Reich et al., 2012). The continued gene flow hypothesis states that most of the genetic history in this region is explained by a back migration and subsequent gene flow across the Caribbean coast of Central America (Moreno-Estrada et al., 2013). Therefore, this hypothesis entails the absence of cultural and biological continuity and a relative isolation of Chibchan populations. This proposal is backed by the implementation of large scale genotyping microarray using autosomal markers, and it implies that

Chibchan speakers of SCA are not the direct descendants of the late Pleistocene hunter-gatherers that inhabited the region, contradicting the region's cultural history (Cooke et al., 2013).

Future genetic and genomic studies of extant and extinct populations will elucidate the population history of Central American indigenous groups on a local and continental level. Ancient DNA (aDNA) is an important tool for understanding regional migration history, including the interactions and dispersal of populations in the remote past (Raff et al., 2011).

Central America is the region where the fewest number of published studies have been carried out when compared with the rest of the continent, and thus additional aDNA investigations are necessary to understand the initial colonization of the isthmus and the level of genetic continuity of the local populations. Additionally, aDNA studies provide reference points necessary to critically evaluate demographic models and to propose alternative hypotheses for the dispersal of populations in the Americas (Raff et al., 2011). Caribbean Central America was initially colonized by ~13,000 B.P. (Chatters et al., 2014), and Mayan populations in Copan, Honduras (750–1300 B.P.), present high frequencies of haplogroup C, which is relatively low in contemporary Mayan populations from Central America (Merriwether et al., 1997).

This is not to say that there have not been repeated attempts to study aDNA in pre-Colombian populations in Costa Rica, Nicaragua, and Panama. The first of these investigations was attempted by N. Baldi in 2004 with a sample provided by Richard Cook (Smithsonian Tropical Research Institute in Panama) from the Juan Diaz archaeological site (1600–1900 B.P.) under the tutelage of Dr. Dennis O'Rourke at the aDNA laboratory of the University of Utah. Unfortunately, the DNA was so degraded that it could not be amplified. Researchers await advances in extraction methods based on next generation sequencing that may make it possible in the near future to recuperate highly degraded DNA from the tropical regions of Central America (Templeton et al., 2013; Wade, 2015).

#### SOUTHERN MESOAMERICA AND THE CARIBBEAN COAST OF CENTRAL AMERICA

This section is organized in three major trends of genetic studies that have been carried out on the Caribbean coast of Central America and southern Mesoamerica: (a) descriptive studies on admixture of the national populations of Central American countries, (b) studies of the origin of the Mayan populations of Guatemala, and (c) studies of migration and microevolution of Afro Caribbean populations in Honduras, Belize, Nicaragua, and Costa Rica.

##### *Admixture Studies in Central America*

Knowledge of the Amerindian genetic component gleaned from mtDNA, autosomic markers, and NRY has also served to estimate the level of admixture in Central American populations and for forensic applications in El Salvador (Martínez-Jarreta et

al., 2004, 2005; Lovo-Gómez et al., 2007a), Belize (Flores et al., 2014), Costa Rica (Rodríguez et al., 2007), Nicaragua (Núñez et al., 2010, 2012; Vargas-Díaz et al., 2011), Honduras with a national pool population, and the Garifuna (Matamoros et al., 2004, 2008, 2009; Herrera-Paz et al., 2008). In the elaboration of these reports, between 6 and 18 autosomal and Y-STRs (Y-chromosome short tandem repeats) of Central American populations were screened with the idea of creating a database for forensic and parental testing applications.

Other investigations have centered on understanding the grade of admixture within each country or indigenous subpopulation, for example, in El Salvador the indigenous populations of Conchagua, San Alejo, Izalco, and Panchimalco show significant statistical differences compared to metropolitan samples (Lovo-Gómez et al., 2007b).

A study by Núñez et al. (2010) in Nicaragua utilized the mitochondrial control region (HVS-I and HVS-II) and STRs of the Y-chromosome of 165 mestizos and found that the Native American contribution to present-day Nicaraguans accounts for most of the maternal lineages (~90%), whereas the majority of Nicaraguan Y-haplogroups show a Spanish contribution of 69%, followed by 20.3% African, and 10.6% Amerindian. The biparental contribution was studied with a base in 6 autosomal loci by Morera (2006), who was able to estimate that the Nicaraguan population was made up of 47% European, 37% indigenous, and 16% African descent. However, studies carried out in Panama with better resolution and sample size utilized complete mitochondrial sequences and determined that 83% of the mitochondria in the Panamanian genetic pool was of American origin, 14% of African origin, and 2% European (Perego et al., 2012).

The majority of studies reporting the genetic structure and admixture in Central America have been carried out in Costa Rica using a variety of markers. The first analysis of the entire country was accomplished using classical markers (Morera et al. 2001). Subsequent investigations used STRs and mtDNA sequences (Campos-Sánchez et al., 2006), SNPs and Ancestral Informative Markers (AIMs) (Wang et al., 2008, Segura-Wang et al., 2010, Campos-Sánchez et al., 2013). The results obtained regarding ancestry were similar, showing 50% European ancestry, 30% Amerindian, and 10% African in central provinces, with a larger presence of Amerindian and African origins in coastal regions. Additionally, Campos-Sánchez et al. (2013) reported an Asian component of 5–10% in the population, originating with migrations from China to Costa Rica during the last 150 years.

The aforementioned studies provide evidence that Central American gene pools are composed of widely varied groups including Native American, European, African, and other populations, and indicate that admixture can be contributed primarily to European males reproducing with indigenous women.

#### *Mayas from Southern Mesoamerica*

Other studies have focused on understanding the history of the Maya of Mesoamerica and their relationship with other

indigenous populations in the area. The Maya are a group of populations extending from southern Mexico, Guatemala, Belize, northern and western Honduras, and El Salvador that share a common linguistic family of approximately 30 languages (Carmack, 1994).

At this time, few investigations based on molecular markers have focused on understanding the relationship between the Maya and other Mesoamerican populations. In a study based on polymorphic Alu insertions (PAI), Herrera et al. (2007) found that the Yucateco from Mexico and the Kakchikel and K'iche from Guatemala are not genetically homogenous. Another study using autosomal STRs found that the Huastec are significantly divergent and that substructures exist among the Poqomchi,' Yucatec, Ch'orti,' and K'iche (Ibarra-Rivera et al., 2008). This incongruity was also manifested in two separate HLA studies as was pointed out earlier in this chapter (Gómez-Casado et al., 2003, Vargas-Alarcón et al., 2011). To test this hypothesis, Justice (2011) examined the mtDNA and NRY of the Mayan Poqomchi' and Ch'orti' from Guatemala and compared them to other Latin American Indigenous populations, arriving at the conclusion that the Maya as a whole share a common history and a close genetic relationship, although some populations are more divergent than others, such as the K'iche. In addition, the Maya are considered biologically distinct from Chibchan and other Mesoamerican and South American populations.

#### *Central American Caribbean*

Two populations inhabiting the Caribbean coast of Central America are of interest in population genetics: the Garifuna, a community with strong African admixture, and the Indo-Limonense population ("Culíes"). Both populations are historically tied to the slave trade and labor migrations that shaped the human genetic diversity of the region.

Black Caribs, known as Garifuna (or Garinagu), currently inhabit the Caribbean coast of Central America from Belize to Nicaragua (Gullick, 1976). The Garifuna are the result of admixture of three distinct groups: enslaved Africans brought to the new world by Europeans, Native American Caribs who are the descendants of Arawaks, and Europeans (Crawford et al., 1981). Records indicate that in 1665, English slave ships sailing from the West Indies wrecked off the coast of the island of St. Vincent. A great number of the shipwrecked sailors and slaves swan ashore where a number intermarried with indigenous Caribs living on the island. The new population admixed, incorporating indigenous traditions, such as the preparation and consumption of bitter manioc, with African traditions, particularly the musical traditions of drumming and dancing. By the end of the eighteenth century, some 2,500 Garifuna were transplanted by the Spanish army to the island of Roatan (Crawford, 2001). As the population expanded, the Garifuna spread to the coast of Honduras in 1832, and later to more than 54 villages along the coast of Central America. Some estimates suggest that there are over 200,000 Garifuna living in present-day Central

America (Paz-Bailey et al., 2009; Herrera-Paz et al., 2010). The expansion of the Garifuna on the Caribbean coast is considered one of the most salient examples of biocultural adaptation in the New World, due to the fact that this hybrid population has the highest birthrate of any population in the Americas, with an average of 10.9 children per woman, despite an endemic malaria epidemic. The population structure of the Garifuna is a product of a series of fusions and fissions of their gene pool (Brennan, 1983; Crawford, 2001). It is probable that one of the factors contributing to the success of bio-cultural adaptation has been the sickle-cell gene which occurs at a rate higher than expected for natural selection (Firschein, 1961; Crawford, 1983).

Although Crawford (1984) led a successful program of biocultural investigation among the Garifuna in Central America between 1975 and 1976, little is known of the impact of the African and indigenous components in the genetic composition of the Garifuna of Honduras and of other populations of the American Caribbean beyond blood-group polymorphisms. In the last decade, several studies with high genetic resolution have been carried out to better understand the population dynamics, structure, and phylogenetic relationships of the populations across the Caribbean. For example, Monsalve and Hagelberg (1997), using mtDNA samples from Garifunas in Belize, determined that nearly 100% of individuals presented African lineage. Later, Salas et al. (2005) estimated that the mitochondria of Afro-descendent Colombian Choco and Garifuna of Honduras was 16% Native American and 86% African. Similarly, Herrera-Paz et al. (2010) studied the allele frequencies of autosomal STRs in Honduran Garifuna and, like Salas et al. (2005), concluded that this population presented signatures of the founder effect in its low levels of genetic variability when compared to other world populations.

A comprehensive study of the Indo-Limonense, a population that originated in Central India but relocated to the province of Limon, Costa Rica as indentured servants, was carried out by Lorena Madrigal and associates (Madrigal et al., 2012). Through an analysis of mtDNA and the Y chromosome, the team confirmed the Indian origins of the population and quantified the effect of genetic flow and admixture over time (Castrì et al., 2007). In addition to other components of the population structure, they evaluated inbreeding and marriage patterns (Madrigal et al., 2007, 2011). After a century in the Atlantic region, the Indo-Limonense show a distinct level of genetic mixture and integration with the mestizo population and the Caribbean Afro-Costa Rican population.

## CONCLUSION

The study of genetics of Central American populations has passed through three historical periods. The first, from the 1920s to the 1960s, based descriptions of human variation on quantitative physical traits; anthropometric measurements were made and genetic variation was measured using classical markers of

local indigenous groups. This phase is characterized by description and by the absence of scientific queries about indigenous populations in accordance with the paradigm of fixed racial traits, which was common among physical anthropologists during the first half of the twentieth century (Armélagos and Van Gerven, 2003).

During the second historical period, which stretched from the 1970s to the 1990s, studies led by Barrantes in Costa Rica and Panama, Crawford on the Caribbean coast of Honduras, Guatemala, and Belize, and De Stefano in Nicaragua increased attention to the cultural, demographic, and environmental variables responsible for indigenous and Afro-Caribbean population structure. Their research programs, carried out among the indigenous populations of southern Central America and the Garifuna, substituted statistical methods for typological methods as tools for testing hypotheses and included fieldwork to collect biological specimens, as well as biomedical, demographic, and ethnographic information. By deepening the knowledge of genetic structures and genetic flow that result from inter-ethnic contact, these pioneering contributions allowed for better interpretation of biological variation and highlighted the distribution of gene frequencies and private polymorphisms of Chibchan-speaking populations in Central America. This makes it possible for researchers to assess the genetic structures of these groups and to propose the model of in situ microevolution. Meanwhile, investigations with the Garifuna of the central and northern Caribbean coast of the isthmus provided information regarding the evolutionary consequences of migration, such as genetic flow between populations with different geographic origins. The selective pressures of the malarial environment, high fertility rate, and sociocultural adaptations enabled the Garifuna to successfully colonize the coast of Central America and expand in record numbers.

The third historical phase, which began in earnest during the 1990s and continues today, is marked by the incorporation of techniques and methods from the field of molecular biology, which allow a higher grade of genetic resolution and direct scrutiny of polymorphisms. This permits researchers to test new and old hypotheses, to approximate the genetic structure and history of indigenous populations inhabiting various cultural areas, and to establish the level of gene flow among populations. Current research emphasizes the complexity of demographic processes in the region, which are seen as a product of historical and social development. Despite technological advances, unresolved questions remain about central aspects in the field, for example, whether (a) dispersion and aggregation in situ or (b) genetic flow from outside Central America is responsible for the majority of the genetic history and structure of Chibchan-speaking populations. Doubtless, further investigation in the region will resolve this incongruity of theories, as has occurred in the more commonly studied areas of North and South America.

The study of microsatellites and SNPs markers across the genome has made it possible to determine the geographic identity of the admixture in Central America and to quantify the genetic contribution of indigenous groups to a country's population as

**TABLE 1.** Contributions to human population studies (genetics and morphological variation) during the twentieth and the beginning of the twenty-first century in Central America based on 117 scientific publications.<sup>a</sup>

Decade	Belize	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama	Total references
1920–1930	0	1	1	1	2	0	1	6
1931–1940	0	1	1	1	1	0	0	4
1941–1950	0	0	0	0	0	0	0	0
1951–1960	0	3	0	0	0	0	0	3
1961–1970	0	1	0	2	3	4	1	11
1971–1980	1	0	0	0	6	2	2	11
1981–1990	2	2	0	2	1	7	3	17
1991–2000	1	0	0	1	1	9	7	19
2001–2010	0	6	7	6	3	23	8	53
2011–2015	2	4	0	0	7	6	2	21
Total references	6	18	9	13	24	51	24	145
(%)	(4%)	(12.5%)	(6%)	(9%)	(17%)	(35%)	(16.5%)	

<sup>a</sup>This table shows 145 scientific references contained within 117 peer reviewed articles, book and book chapters, Ph.D. dissertations on investigations into human morphological variation, classical and molecular markers, genetic epidemiology, isonomy, and DNA forensics. Some investigations include more than one country. **BELIZE:** Baume and Crawford, 1980; Dykes et al. 1981; Crawford, 1984; Monsalve and Hagelberg, 1997; Phillips-Krawcsak, 2012; Flores et al., 2014. **GUATEMALA:** D'Aloja, 1939, 1940; Matson and Swanson, 1959; Newman, 1960; Sutton et al., 1960; Matson, 1963; Crawford et al., 1981; Crawford, 1984; Gómez-Casado et al., 2003; Zegura, 2003; Herrera et al., 2007; Wang et al., 2007, 2008; Ibarra-Rivera et al., 2008; Justice, 2011; Vargas-Alarcón et al., 2011; Martínez-González et al., 2012; Reich et al., 2012. **EL SALVADOR:** D'Aloja, 1939, 1940; Martínez-Jarreta et al., 2004, 2005; Saul et al., 2004, Lovo-Gómez et al., 2007a, 2007b; Salas et al., 2009; Monterrosa et al., 2010. **HONDURAS:** D'Aloja, 1939, 1940; Firschein, 1961; Matson and Swanson, 1964; Brennan, 1983; Crawford, 1984; Merriwether et al., 1997; Matamoros et al., 2004, 2008, 2009; Salas et al., 2005; Herrera-Paz et al., 2008, 2010. **NICARAGUA:** Shultz, 1926; D'Aloja, 1939, 1940; Matson and Swanson, 1963; De Stefano, 1970–1971, 1973; De Stefano and Jenkins, 1970–1971, 1972, 1972–1973, 1974, 1976; De Stefano et al., 1979; Roberts and De Stefano, 1986; Azofeifa et al., 1998; Morera, 2006; Melton, 2008; Núñez et al., 2010, 2012, 2013; Núñez, 2011; Vargas-Díaz et al., 2011; Baldi, 2013; Melton et al., 2013; Baldi et al., 2014. **COSTA RICA:** Fuentes, 1961; Matson and Swanson, 1965a; Laurencich, 1966, 1968, 1974; Spielman et al., 1979; Barrantes and Azofeifa, 1981; Barrantes et al., 1982, 1990; Brenes and Barrantes, 1983; Quesada and Barrantes, 1983, 1986, 1991; Barrantes, 1988, 1993a, 1993b; Torroni et al., 1993, 1994; Santos and Barrantes, 1994a, 1994b; Santos et al., 1994; Bieber et al., 1996; Barrantes and Morera, 1999; Azofeifa et al., 2001; Madrigal et al., 2001, 2007, 2012; Morera et al., 2003; Zegura, 2003; Mathews et al., 2004; Morera and Barrantes, 2004; Ruiz-Narvaez et al., 2005, 2010; Campos-Sánchez et al., 2006, 2013; Herzberg et al., 2006; Castri et al., 2007; McInnes et al., 2007; Melton et al., 2007; Rodríguez et al., 2007; Wang et al., 2007, 2008; Lewis and Long, 2008; Melton, 2008; Jasinska et al., 2009; Segura-Wang and Barrantes, 2009; Segura-Wang et al., 2010; Wang et al., 2010; Amorim et al., 2011; Reich et al., 2012; Melton et al., 2013; Céspedes-Garro et al., 2014. **PANAMA:** Hrdlička, 1926; Matson and Swanson, 1965b; Tanis et al., 1977; Spielman et al., 1979; Barrantes et al., 1982, 1990; Barrantes, 1988, 1993a, 1993b; Torroni et al., 1993, 1994; Batista et al., 1995; Kolman et al., 1995; Bieber et al., 1996; Kolman and Bermingham, 1997; Zegura, 2003; Ruiz-Narvaez et al., 2005; Castro et al., 2007; Melton et al., 2007; Wang et al., 2007, 2008; Asuncion et al., 2008; Lewis and Long, 2008; Perego et al., 2012; Reich et al., 2012.

a whole—a contribution that varies due to the historical processes unique to each nation. These new research possibilities have revitalized interest in subpopulations that had previously been subsumed in national populations: the migratory history of groups like the Indo-Limonense, the tripartite ethnicity of the Garifuna, and the oriental component of the Costa Rican population are all recent areas of anthropological, sociological, and demographic interest. In the near future, these studies of genetic diversity of Central American populations have a great potential to enhance, through admixture mapping, our understanding of the genetic bases of complex traits, which in turn could contribute to the identification of genes that influence diseases and genetic disorders (Zhu et al., 2004).

Despite these areas of strength in Central American investigations, additional research is needed. Table 1 shows that the majority of studies combining morphological variation and

human population genetics from the 1920s through 2015 have been carried out in Costa Rica (35%), followed by Nicaragua and Panama (34%), leading to a disparity of population studies from the other four countries of Central America (31%). According to 145 country references in 117 peer-reviewed journals, chapters in books, and Ph.D. dissertations between 1920 and 1970, 17% of the publications were based on morphological and biochemical variation of indigenous populations. Between 1971 and 2000, most of the research (47%) focused on microevolutionary studies in indigenous and Afro-Caribbean populations using classical genetic markers and genetic polymorphisms. Interestingly in the last 14 years (2001–2015) the amount of research has increased by 51% compared to previous decades. This surge in research includes a wide variety of areas of interest, for example admixture studies, demographic approximations based on isonomy and genealogical studies, migration, and disease.



In contrast to investigation programs carried out before the 1990s, when contextual information was routinely collected along with biological samples for each population of interest (e.g., medical, demographic, ethnographic, and geographic data), to echo the criticism of Thompson et al. (1992), the fundamental problem in current Central American sample collection is its paucity of anthropological background and its implicit assumption that with enough genetic data, evolutionary reconstructions are possible. In fact, genetic data make more sense when analyzed alongside demographic, geographic, and sociocultural information collected in the field. Fortunately, in recent years there has been recognition of the importance of cultural niches and social practices as factors that drive evolution, phenomena that have been approximated by our multidisciplinary and multinational research program in Central America where the ethnographic context of the populations is central to our investigations.

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# Biodemography Research and the History of Central American and Northwestern South American Populations

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**ABSTRACT.** This chapter provides a brief revision of the most relevant work on biological markers and diseases that have contributed to the field of biodemography in Central America and northwestern South America. The history of the populations that inhabit both regions was reconstructed through historical records and through abundant information provided by studies on biological markers which reveal demographic aspects of the populations before and after European conquest. These studies consider an original north-to-south peopling of the continent from Asia, high genetic similarity between Central American and northwestern South American indigenous populations due to retrograde migrations imposed by the dense Amazonian tropical forests, and variable degrees of tricontinental admixture in modern populations with strong sex bias. Traces of European colonialism still persist and influence inequality, violence, and massive local and international migrations, which in turn models epidemiological landscapes. Finally, economic, demographic, and nutritional transitions are enhancing quality of life for the people from both regions. However, transitions pose new challenges in public health due to the influence of problems from the developed world, such as the increased prevalence of cardiovascular and degenerative diseases.

**RESUMEN.** Este capítulo provee un breve resumen del trabajo más relevante sobre marcadores biológicos y enfermedades que han contribuido al campo de la biodemografía en Centro América y el noroeste de Sudamérica. Se reconstruyó la historia de las poblaciones que habitan ambas regiones a través de registros históricos y de la abundante información proporcionada por los estudios con marcadores biológicos que revelan aspectos demográficos de las poblaciones antes y después de la conquista y colonia europea. Estos estudios consideran un poblamiento original de norte a sur del continente desde Asia, alta similitud genética entre las poblaciones aborígenes de Centro América y el suroeste de Sudamérica debido a las migraciones retrógradas impuestas por las densas selvas de la Amazonia, y grados variables de mezcla tricontinental en las poblaciones modernas con un gran sesgo de género. Rastros del colonialismo europeo persisten hoy en día e influyen la desigualdad, la violencia, y las migraciones locales e internacionales masivas, que a su vez moldean los paisajes epidemiológicos. Finalmente, las transiciones económica, demográfica y nutricional están mejorando la calidad de vida de la gente de ambas regiones. Sin embargo, las transiciones imponen nuevos retos en salud pública debido a la influencia de los problemas típicos del mundo desarrollado, tales como el aumento de prevalencia en las enfermedades cardiovasculares y degenerativas.

**RESUMO.** Este capítulo fornece um breve revisão do trabalho mais relevante sobre marcadores biológicos e doenças que têm contribuído no campo da biodemografia na América Central e do noroeste da América do Sul, acompanhado de abundante bibliografia. A história das populações

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

que habitam ambas as regiões são reconstruídas por meio de registros históricos e através da abundante informação fornecida pelos estudos com marcadores biológicos. Estes estudos revelam aspectos demográficos das populações antes e depois da conquista e colonização europeia, tais como um povoamento original de norte a sul do continente proveniente da Ásia, alta similaridade genética entre as populações indígenas da América Central e do sudoeste da América do Sul devido às migrações retrógradas impostas pelas densas florestas da Amazônia e por fim, vários graus de mistura tricontinental nas populações modernas com uma grande polarização de gênero. Vestígios do colonialismo europeu persistem hoje e influenciam a desigualdade, a violência e as migrações massivas locais e internacionais que por sua vez moldam as paisagens epidemiológicas. Finalmente, as transições econômicas, demográficas e nutricionais estão melhorando a qualidade de vida dos povos de ambas as regiões. Porém, as transições colocam novos desafios para a saúde pública devido ao incremento dos problemas do mundo desenvolvido, como o aumento na prevalência das doenças cardiovasculares e degenerativas.

*To the memory of my beloved father, Francisco Herrera Doninelli, and to all fine Latin American physicians.*

*“Poverty is the worst form of violence.”*

—Mahatma Gandhi

## THE REGIONS UNDER STUDY

The Central American isthmus is formed by a relatively narrow strip of land that connects the sub-continent of North and South America. Bound to the north by Mexico and to the south by Colombia, it consists of seven independent countries, and is bordered by the Caribbean Sea and the Pacific Ocean to the northeast and southwest, respectively. From north to south, the seven countries are: Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama. Meanwhile, northwestern South America comprises four countries—Colombia, Ecuador, Venezuela, and Peru—which, together with Bolivia, are referred to as ‘the Andean states.’ All five states share similar geography, with the Andes cordillera to the north and west, and the Amazonian tropical rain forest to the south and east. The predominant indigenous language in the Andean region is Quechua, although the Chibchean Amerindian language group extends widely into Colombia, Venezuela, and Central America (Torero, 1984; Constenla-Umaña, 1991).

From a geopolitical point of view, the Central American countries share similar histories from the time of conquest, colonization, and independence from Spain in 1821, with the exceptions of Panama—which adhered to Gran Colombia soon after independence, acquiring its own independence in 1903—and Belize (formerly, British Honduras), which was ruled by England and renamed Belize in 1973 (Beluche, 2003; Johnson, 2003).

Gran Colombia comprised the territories of Venezuela, Colombia, Panama, and Ecuador, which were united as a single nation between 1819 and 1822. This country split into individual republics in the early 1830s. Peru also became an individual

country after independence, except for a short period of three years (1836–1839), during which it formed a confederation with Bolivia (Toro Jiménez, 2004).

## BIODEMOGRAPHY RESEARCH IN CENTRAL AND NORTHWESTERN SOUTHAMERICA

Humans are highly complex, multifaceted beings. As organisms, the human body can be studied from the standpoint of biology and biomedical sciences. As intelligent, social creatures, aggregations of individuals—such as families, tribes, cities, and countries—have structures and dynamics which are best described by demography. The presence and distribution of biological traits may influence demographic variables such as fertility, mortality, longevity, and migrations. However, the opposite also holds true, that is, historical and actual demographic structure can influence the evolution of traits, or the distribution or dispersal of specific diseases. Biodemography takes into account these two-way relations between demography and biology or biomedical studies.

The demographic history of a population leaves an evolutionary track in hereditary molecular markers, both neutral and those related to diseases. Hence, polymorphic molecules can be examined to elucidate that history. Though many lines of evidence may be considered, the following categories show the most important population studies, using markers and diseases of biomedical interest in both regions, and reflecting historical tendencies in mainstream science.

### MARKERS

#### *Blood Groups*

The first blood groups to be discovered, ABO in 1901 and Rh in 1937 (Landsteiner and Wiener, 1940), were found to be important in blood transfusions and in the pathogenesis of hemolytic disease of the fetus and the newborn due to alloimmunization (Chavez et al., 1991). The number of the known genetically determined molecules present in erythrocytes increased gradually to more than 30 currently recognized, including MNS and Duffy (Bristol Institute for Transfusion Sciences and the International Blood Group Reference laboratory, 2015). Duffy is involved in resistance to malarial infection due to *Plasmodium vivax* (Miller et al., 1976).

The knowledge that blood group variants exhibit different frequencies depending on the analyzed population boosted the research worldwide, contributing to anthropological and demographic studies. Blood groups and other biochemical markers, often referred to as classical genetic markers, have been amply tested in general mestizo populations (Santillán, 1996; Beltran et al., 1999; Rodríguez Larralde et al., 2001; Echandi, 2013), as well as in ethnic groups from Central and northwestern South



America (Santiana, 1953; Reynafarje, 1957; Tejada et al., 1961; Matson and Swanson, 1963a; 1963b; Matson et al., 1966a; 1966b; Roisenberg and Morton, 1970; Schapiro, 1972, Kirk et al., 1974), shedding some light in demographic and evolutionary issues such as admixture estimates (Sans, 2000) and peopling processes (Layrisse, 1963; Barrantes, 1990; Labarga, 1997; Azofeifa et al., 1998), as well as in malaria susceptibility (Spencer et al., 1978; Montoya et al., 1994; Gonzales et al., 2012; Vasquez and Tobon, 2012).

#### Microsatellites

The advent of new tools used in molecular biology and the automation of genetic typing in the 1980s and 1990s opened a door in biodemography. First, the discovery of highly polymorphic loci such as neutral mini- and microsatellites, and the genetic fingerprint developed by Alec Jeffreys (Jeffreys et al., 1985); and second, the polymerase chain reaction (PCR) developed by Kary Mullis (Saiki et al., 1988) gave way to a new era of human identification and paternity testing, enhancing forensic sciences. Particularly, variations in loci called microsatellites displayed adequate results in forensic testing (microsatellites usually indicate population differences by the number of repetitions of a core sequence of four or five nucleotides). The possibility of assessing the number of repeats of multiple microsatellite loci (also referred to as short tandem repeats, or STR) from a subject in a single multiplex reaction facilitated individual testing and research.

In a paternity or forensic test, the probability that the assumed father is the actual father—and the probability that a biological sample such as a blood stain truly corresponds to an assumed subject—largely depends on the proportions of the genetic variants (alleles) in a reference population, that is, the one to which the assumed father or subject most probably belongs. Therefore, to assess such frequencies, studies for every human population are needed. As a collateral gain of such studies, features of anthropological interest such as population structure, differentiation (Slatkin, 1995; Michalakis and Excoffier, 1996; Balloux and Lugon-Moulin, 2002), and racial admixture (Choisy et al., 2004) can be explored through microsatellite allele frequencies.

Studies on forensic autosomal and Y-chromosome microsatellite loci in the regions are extensive, and databases of genotyped populations provide a framework for forensic laboratories, which can perform more reliable probability calculations using gene frequencies from the true reference populations rather than from related ones (which are commonly used as proxies when there is no genotype data available). Research includes, but is not limited to, the following studies (by country):

Belize	Flores et al. (2014)
Guatemala	Martínez-González et al. (2012, 2015)
El Salvador	Lovo-Gómez et al. (2007a, 2007b); Monterrosa et al. (2010)

Honduras	Herrera-Paz et al. (2008, 2010); Matamoros et al. (2008, 2009)
Nicaragua	Núñez et al. (2010, 2012); Vargas Díaz and Huete Pérez (2010)
Costa Rica	Carvajal-Carmona et al. (2003); Campos Sánchez et al. (2006); Melton et al., (2013)
Colombia	Carvajal-Carmona et al. (2000); Yunis et al. (2000); Paredes et al. (2003); Rondón et al. (2006); Gómez et al. (2008); Rey et al. (2009); Ossa Reyes (2010); Rojas et al. (2011)
Venezuela	Chiurillo et al. (2003); Bernal et al. (2006); Borjas et al. (2011)
Ecuador	Gonzalez-Andrade et al. (2003, 2006, 2009); Sánchez-Q. et al. (2003); Gonzalez-Andrade and Sánchez (2004)
Peru	Pérez et al. (2003); Builes et al. (2006); Crossetti et al. (2008); Talledo et al. (2010)

Although the aim of most of this research was to assess allelic and genotype frequencies for forensic purposes *per se*, some of them are expressly conceived to uncover structure and micro-differentiation among recently split or admixed populations. For instance, Melton et al. (2013), intended to reconstruct the pre-Colombian structure of Lower Central American peoples, and Carvajal-Carmona et al. (2000), explored the contribution of Sephardic gene flow to the people of a Colombian region. Both groups utilized sets of Y-chromosome microsatellites together with Y haplogroups (used to reveal more profound lineages) in their work.

High mutation rates, stepwise mutations with gain or loss of one repeat, and neutral or near neutral alleles and genotypes (low selective pressure) make forensic microsatellites suitable markers for the study of relatively recent demographic history (De Knijff et al., 1997; Dogan et al 2014; Purps et al., 2014).

#### Human Leukocyte Antigens (HLAs)

Human leukocyte antigen (HLA) classes I and II are highly polymorphic proteins implicated in the presentation of antigens to T-lymphocytes. It is known that particular HLA haplotypes are linked to specific diseases (Bertrams and Spitznas, 1976; Arnaiz-Villena et. al, 2013), and that mismatches in haplotypes between donor and recipient in allotransplants are related to transplant rejection (Lee et al., 2002). Additionally, the HLA DQ  $\alpha$  locus was once used in forensic genetics together with other genetic markers (Budowle et al., 1995).

Although local pathogen diversity could explain geographic differences in the diversity of HLA variants due to balancing selection to some extent, demographic history may be largely responsible for their world distribution (Prugnolle et al., 2005). Both gene- or phylogeny-based analyses (as in mitochondrial and Y-chromosome haplogroups studies) and frequency-based analyses (as in microsatellite studies) can be performed with HLA data.

The HLA class I (loci A and B) and class II (loci DRB1 and DQB1) gene frequencies and extended haplotype frequencies were used by Arnaiz-Villena (2010) to reconstruct the peopling of the Americas, suggesting a genetic contribution from Pacific islanders in addition to the known migrations from Asia through Beringia. Population studies on HLA alleles and haplotypes, through both serological and genetic analysis, have contributed to anthropogenetics, and additionally, allows the search for matches between potential donors and recipients in organ transplantation (Arrieta-Bolaños et al., 2012).

Some population HLA studies in the regions include: Guatemala: Amerindian (Gómez-Casado et al., 2003; Arnaiz-Villena et al., 2013); Nicaragua: General population (Morera et al., 2001; Morera, 2015). Colombia: from Cartagena (Caraballo et al., 1992); Amerindians (Yunis et al., 1994; Briceño et al., 1996a; 1996b); African Americans (Trachtenberg et al., 1996); from Medellín (Rodríguez et al., 2007), and Southwest Colombia (Arrunategui et al., 2013). Venezuela: From Zulia (Rivera et al., 1998), and Amerindians (Ramos et al., 1995; Echeverría et al., 2008); and Ecuador: Amerindians (Trachtenberg, 1995). This list does not include the abundant literature on HLA specific genotypes or haplotypes and their relation to diseases.

#### *Whole Genome Analyses*

During the present century, the rapid technological advances in DNA analysis have resulted in a new revolution in biomedicine, allowing the possibility of sequencing whole genomes with relatively low error rates in just a few days and at low prices. Plummeting prices will permit, perhaps in a few years, newborn screening (NBS) for genetic diseases and for determining genetic susceptibility to multifactorial conditions in the physician's office, (Beckmann, 2015) and may pave the road to other instances of personalized medicine as well (Ingelman-Sundberg, 2015).

Whole genome sequencing (WGS, the complete reading of the three billion base pairs that comprise the human genome) studies in diverse populations are greatly increasing the lexicon of human genetic diversity. As an example, a single WGS study carried out on 642 individuals of African ancestry by the Consortium on Asthma among African-ancestry Populations in the Americas (CAAPA), lead to the discovery of 20.7 million new single nucleotide variants (SNVs). These variants can be used later for the design of DNA chips with which sets of individuals that suffer a specific condition (patients) and healthy controls can be genotyped for many thousands of single nucleotide polymorphisms (SNPs), the so-called genome wide association studies (GWAS).

The rationale of GWAS is simple. If a particular SNP is involved in susceptibility to a given polygenic, complex disease, then its allele frequencies will significantly differ between patients and healthy controls, with the susceptibility allele raised in frequency in patients. But also, allele frequencies of SNPs spanning the neighborhood of the susceptibility locus will be different between patients and controls due to linkage disequilibrium. Then, assessing allele frequencies of thousands of SNPs evenly

distributed in all chromosomes by genotyping a high number of patients and healthy controls, should allow the identification of susceptibility loci of relatively common illnesses such as bronchial asthma, allergies, hypertension, and some psychiatric and neurologic disorders, among others.

Whole genome sequencing, GWAS, whole exome sequencing (WES), or even typing of a single locus generate data that can be uploaded to public databases and then used to reconstruct the demographic history of populations. Additionally, the so called "ancestry informative markers (AIMs)," —SNPs in which one of the alleles shows a substantially higher frequency than the other in a continental or local population, but not in others—allow the estimation of admixture proportions from putative parental populations (Galanter et al., 2012). Admixture may have a great influence in health and disease processes in Latin America.

#### *Surnames*

Patterns of genetic variation across human populations reflecting demographic history can be ascertained through a variety of informative evolutionary elements, in addition to biomolecules. For instance, Cavalli Sforza (1997) showed that qualitative phonemic phylogeny across multiple languages strongly correlates with genetic phylogeny. Although unlike genes, phonemes do not experience genetic drift (Creanza et al., 2015), and consequently, are not suitable in revealing internal genetic structures (within populations). On the other hand, surnames are transmitted in a similar way as paternally inherited Y-chromosome genetic markers, specifically the nearly neutral ones (King and Jobling, 2009).

Since Crow and Mange (1965) published their seminal paper on isonymy the use of surnames to elucidate the structure of human populations has gone through many refinements (Colantonio et al., 2003). Essentially, isonymy calculation is useful to epidemiology and clinical medicine because it is suitable for the estimation of inbreeding, a risk factor for recessively inherited genetic disorders (Dipierri et al., 2014). From the point of view of demography historical migrations can be inferred from the frequency of surnames which are used for estimating kinship among populated places. In addition, the peopling history of a place can be recreated to some extent because immigration events leave their signature in the distribution of frequencies (Herrera-Paz, 2014). Recently isonymy studies have gained popularity due to the availability of surname databases for entire countries.

For both Central America and northwestern South America, isonymy calculations at the level of whole countries are available only for Venezuela (Rodríguez-Larralde et al., 2000) and Honduras (Herrera-Paz et al., 2014). In some countries, studies are available for certain local populations including: Venezuela (Castro de Guerra et al, 1990; Rodríguez-Larralde and Castro de Guerra, 2012; Pinto-Cisternas et al, 2014), Colombia (Bedoya et al., 2006; Rojas et al., 2012), Peru (Pettener et al., 2013), Costa Rica (Madrigal et al., 2001; Sáenz and Barrantes, 2009), Nicaragua (Baldi et al., 2014), and Honduras (Herrera-Paz 2013a; 2013b). These studies have been useful in assessing

the approximate magnitude of migrations among resident populations versus genetic drift (isolation), as well as inbreeding and, finally, isolation by distance (the correlation of geographic distance and genetic differentiation between two populations).

## DISEASES

### Bronchial Asthma

Bronchial asthma is a multifactorial heterogeneous condition in which race is an important etiological factor and people of African descent suffer from increased prevalence and severity compared to other populations. Asthma burden exhibits high variability in the Americas due to the geographic variability of tricontinental (African, European, and Amerindian) genetic proportions (Forno et al., 2015), but also due to the diversity of environments, socioeconomic inequality, and the presence of parasites and allergens. For instance, the school-age (six to 16 years old) population from the Garifuna people, who live in villages dispersed throughout the Caribbean coast of Honduras, has shown extremely high prevalence for asthma (Santos-Fernández et al., 2016). We believe that the interactions of helminth infestation (particularly *Ascaris lumbricoides* and *Trichuris trichiura*) with some African genetic variants, elevated by a founder effect (genetic bottleneck) that took place upon the arrival of the ethnic group to Honduras in 1797, may be partially responsible for such high prevalence.

Findings from deep WGS conducted in populations with African ancestry in the Americas composed of asthma patients and non-asthmatic controls were recently published in two papers: Mathias et al. (2016), and Kessler et al. (2016). The asthma patients and controls in the study included 41 subjects from the Honduran Garifuna group and 31 Colombians. Using different clustering analyses applied to the generated data, we found that Garifuna genetic makeup substantially differs from that of other African-ancestry populations of the Americas included in the study, which may be attributed to the founder effect. This fact represents an outstanding opportunity for the discovery of susceptibility alleles, not only for asthma, but for other diseases as well, as the bottleneck may have randomly raised the frequency of many deleterious genetic variants which otherwise may be in low frequencies due to natural selection.

At this moment, important GWAS investigations of asthma in populations of African descent from Peru and Colombia are being conducted by CAAPA, using a high-density SNP chip that was developed for GWAS studies in African ancestry populations through a partnership between CAAPA and the genetic engineering industry (Consortium on Asthma among African-ancestry Populations in the Americas, 2014). The chip was constructed in part with the inclusion of newly discovered SNVs from the WGS.

### Soil Transmitted Helminths

Almost any biochemical, genetic, or biological marker, in addition to diseases, can contribute to biodemography. Latin

America is afflicted by both, diseases from the developed world (cardiovascular and degenerative), and from the underdeveloped world (infections and parasites). Important epidemiological research has been conducted in Latin America on malaria, Chagas, Leishmaniasis, schistosomiasis, intestinal helminths, trachoma, leprosy, and lymphatic filariasis, most of them falling within the category of neglected tropical diseases that affect primarily the poorest peoples of the Americas (Hotez et al., 2008). Particularly, intestinal parasites such as hookworm and other soil transmitted helminths have gained attention due to their high prevalence in the regions under consideration, but also for their possible interactions with other diseases.

From the evolutionary point of view, it is convenient for the host to develop the necessary weaponry to fight the parasite, and on the other side, it is convenient for the parasite to dampen the host's antiparasitic weaponry, but also to keep the host healthy to ensure its own survival. Atopic response helps the host guard against the parasite, so, the parasite has to reduce that response. In this way, parasitic infections may induce opposite responses in the host, either protecting against or exacerbating atopic diseases depending on some conditions, for example the genetic background of the host, the time and age of exposure, and socioeconomic conditions.

Today it is recognized that parasitic infections in childhood or adulthood protect individuals from many inflammatory and autoimmune diseases by means of parasitic immunosuppression (Maizels et al., 2014). Many studies show the negative relationship between different intestinal helminths and atopic disease, to the point that therapeutic trials using parasites to treat them are being conducted worldwide (Tilp et al., 2013). However, parasitic infections by *Ascaris lumbricoides*, *Trichuris trichiura*, and hookworms (*Necator americanus* and *Ancylostoma duodenale*), all of them highly prevalent in Central America and northwestern South America, are also associated with chronic deleterious effects on nutrition and growth, levels of iron and vitamin A, and cognitive development in children. Moreover, despite abundant evidence of the modulation of allergies by parasites, some research points to a positive correlation between wheezing and helminths infections in preschool children (Alcântara-Neves et al., 2010), which may also be the case in Garifuna youngsters previously mentioned.

The magnitude of the intestinal parasite problem in Latin America can be found in Saboyá et al. (2013) and references therein. Studies addressing the relationship between nematodes such as *Ascaris lumbricoides* and allergies have been conducted in Colombia by L. Caraballo (Caraballo and Zakzuk, 2012; Caraballo, 2013; Bornacelly et al., 2014; Buendía et al., 2015), and in Venezuela by Hagel et al. (2013) as well as other teams.

### Gastric Cancer

Central and South American countries show some of the highest incidences of gastric cancer in the world with *Helicobacter pylori* infections playing a central role. Many genetic studies have been conducted in both regions, most of them to

test candidate genes, or to replicate associations found in GWAS studies performed in other populations. Several of these studies focus on cytokines—signaling molecules from the immune system—for example, interleukin 1B and its receptor (Alpizar-Alpizar et al., 2005a; Morgan et al., 2006; Con et al., 2007; Gehmert et al., 2009; Con et al., 2009; Chiurillo et al., 2010; Martinez et al., 2011a; 2011b). Other regional genetic tests have targeted P53 (Alpizar-Alpizar et al., 2005b), detoxification enzymes (González et al., 2004), Prostate Stem Cell Antigen (PSCA) (Rizzato et al., 2013), and polymorphisms in 8q24 (Labrador et al., 2015), among others.

There is recent evidence that points to a disruption of co-evolution between human continental populations and their corresponding continental *H. pylori* strains as possibly contributing to genesis and severity of gastric cancer. Kodaman et al. (2014) demonstrated that African *H. pylori* is relatively benign in populations of African ancestry, but deleterious in predominantly Amerindian individuals. This is reflected in differences in gastric cancer severity in the two Colombian regions analyzed in the study underscoring the profound effects of tricontinental admixture in the new world during the colonial period, which even today, continues to affect processes of health and disease.

## DEMOGRAPHIC HISTORY OF CENTRAL AND NORTHWESTERN SOUTH AMERICA

### PEOPLING OF THE REGIONS

The original population of both regions consisted of Amerindian tribes who were descendants of sojourners from Asia who entered the Americas through the dry passage of Beringia or by following the coastline in the late Pleistocene, during the last glaciation more than 15,000 BP (Goebe et al., 2008; Kitchen et al., 2008). The evidence from molecular markers pointing to a single migratory wave that gave rise to paleo-American indigenous groups—separated from those that gave rise to the Nadene and Eskimo Aleut speaking peoples—is abundant, ranging from Immunoglobulin G allotypes (Williams et al., 1985), to mitochondrial and Y-chromosome haplotypes (Fagundes et al., 2008; Bortolini et al., 2003), and genomic SNPs (Reich et al., 2012).

The process of microdifferentiation of human groups throughout pre-Columbian America was rather complex, mainly led by isolation and interpopulation flow, but also by local adaptation to diverse environments and agriculture. The decrease in genetic variability in a continental north-south cline from Beringia suggests that the peopling of the continent followed this direction, mainly along the Pacific coastline (Wang et al., 2007; Yang et al., 2010). Evidence from early South American sites and mitochondrial DNA studies points to a rapid occupation of the continent (Dillehay et al., 2008; Bodner et al., 2012). In South America, the high genetic diversity within populations, together with a low diversity among populations in the West is consistent with a high migration flow between the groups that inhabited the highlands of the Andean cordillera. Comparatively, populations

seem to have experienced greater isolation to the east of the sub-continent, most probably due to the appearance of the large and dense forested zones of the Amazonian region at the end of the last Ice Age, in the early Holocene, which served as natural barriers. Thus, throughout the Andean region we find populations widely differentiated from the Eastern (Amazonian) and Southern ones (Tarazona-Santos et al., 2001; Fuselli et al., 2003; Lewis Jr et al., 2007; Wang et al., 2007).

On the other hand, scarce genetic differentiation is found between Mesoamerican (from Mexico and northern Central America) and South American Andean populations (Wang et al., 2007). The first Spaniards to reach the Central American land bridge (the narrow strip formed by Costa Rica and Panama) found a variety of villages in various environments—from homes scattered in forests and highlands, to large, densely populated settlements situated in the savannahs or along rivers—whose inhabitants also spoke a variety of languages (Cooke, 2005). At least a portion of the variability in the types of villages and peoples observed by the Spanish could be attributable to the fact that the Central American land bridge was a confluence area between an indigenous population residing in the territory for several millennia, and Mesoamerican and South American populations that arrived more recently (Cooke, 2005).

Gravel et al. (2013), analyzing WES and WGS, concluded that the split of the common ancestor of Mexican (Mesoamerican) and Colombian (South American) Amerindians dates back some 12,200 BP. Y-chromosome studies support rapid southward migrations from Mexico—the gateway for the first wave of paleo-Americans—through Central America to the Andean region along the Pacific Coast (Battaglia et al., 2013). Glotto-chronological evidence indicates that the Chibchean language in South America split from other related languages about 7,000 BP in the Central American land bridge, separating into subfamilies about 5,000 BP due to adaptations to agriculture and sedentary lifestyle (Umaña, 1991; Cooke and Ranere, 1992). Thus, Central America and the Andean region show strong genetic links, mainly due to their common Chibchean ancestry, but also because of retrograde migrations from South to Central America. Currently, populations belonging to the Chibchean language family are numerous in Central America and northern South America, extending from Honduras to Colombia, traditionally called the “Intermediate Area,” or the “Isthmus-Colombian Area” according to Hoopes and Fonseca (2003).

It can be inferred that the genetic similarity found between indigenous inhabitants of both regions has its genesis in the continuum of the pre-Columbian southward expansion, retrograde migrations from South America to Central America due to the dense Amazonian forests limiting expansion further south, and the subsequent strong trading ties between southern Mesoamerica and populations inhabiting the central valleys of the Andean heights (Cook, 2014). However, later migrations also could be contributing to genetic similarity. Important migratory flows among indigenous groups were recorded during the colonial period, such as the export of slaves from Central America to South America and the Caribbean islands. For instance, it is

documented that significant numbers of indigenous slaves were exported from Nicaragua to Peru and from Honduras and Nicaragua to Panama during the first century of Spanish occupation (Ramírez, 2007; Newson, 1992).

#### DISEASES, DEPOPULATION AND ADMIXTURE

Little is known about the nature of the diseases that afflicted the inhabitants of the New World prior to the arrival of Columbus in 1492. However, epidemiological patterns must have differed from those of the Old World in various ways. Pre-Columbian populations suffered mainly from chronic, endemic diseases, in contrast with the acute, epidemic conditions that prevailed in Europe. In the Americas, most diseases were zoonotic, and the low density of the herds probably restricted epidemic spreads (Newson, 1992). Merbs (1992), citing several authors, claims as the most likely prevailing pre-Columbian infectious diseases those caused by *Treponema* (pinta and syphilis), tuberculosis, leishmaniasis, fungal diseases such as coccidioidomycosis, and para-coccidioidomycosis, various streptococcal and staphylococcal infections, Rocky Mountains fever, Lyme disease, legionellosis, Verruga Peruana, hydatidic disease and various intestinal parasites. Meanwhile, rubella, measles, smallpox, bubonic plague, malaria, typhoid, cholera, yellow fever, encephalitis, scarlet fever, amoebic dysentery, and some helminths were unknown to Amerindians and brought by the Spanish.

Estimates of the pre-Columbian indigenous population in Central America show a wide range of variation depending on the author; however, in both Central and northwestern South America this population was most probably very large. The number of inhabitants in Central America should have been somewhere between 800,000 and 13.5 million people throughout the whole isthmus (Newson, 1992). In northwestern South America, in Quito, Ecuador alone, it is estimated that by 1534 the number of indigenous people was between 750,000 and 1,000,000 (Austin Alchon, 2001).

Wightman quotes Francisco de Toledo, the representative of the King of Spain in the Viceroyalty of Peru, who in 1570 stated that he had passed through “innumerable Indians” when approaching the city of Cusco, the ancient capital of the Inca Empire in the Central Andes (Wightman, 1990). Notwithstanding, prior to that date the local population had already experienced a sharp decline due to the Spanish conquest and infighting between groups of conquistadors. In Colombia, numbers must have ranged between 450,000 and 1.4 million, most of them Chibchas (Uribe, 1964).

After the conquest, the demographic landscape of the Americas changed dramatically. The initial contact between conquistadors and Amerindians resulted in violent demographic changes and in a humanitarian disaster. A great number of European settlers quickly spread with a simultaneous decline of indigenous peoples, who were subjected to a process of forced miscegenation. Studies with matrilineal and patrilineal molecular markers in Guatemala (Söchtig et al., 2015), Colombia (Carvajal-Carmona et al., 2000; Seielstad, 2000), and Venezuela (Castro de Guerra

et al., 2011) show a sex bias in the genetic contribution of the founders of modern admixed populations, with a predominance of a Spanish male component and an Amerindian female component, which also can be extended to other Latin American countries according to historical and molecular data (Quijano, 2000; Salzano, 2004; Bonilla et al., 2004; Bryc et al., 2010a). In this sense, Spanish colonization of Latin America differed substantially from the English colonization of North America. The estimated proportion of Spanish men to women who entered the Americas during the colonial period was about 10:1, mainly due to the number of conquistadors. The first English settlers were groups of families fleeing religious prosecution, and they had left England with no military protection. When the English arrived in North America, they sought depopulated areas, where they could build homes and farms, and attempted to learn about the land from the indigenous groups they encountered. The Spanish, on the other hand, set out with the express desire to forge new trade routes and leverage Spain’s control of the high seas. When they came to the Americas, they used military force to exploit the resources and indigenous peoples in highly developed centers at the behest of the Spanish court. (Barahona, 2002).

Directional mating has resulted in a much higher variability of the indigenous genetic component compared to the Spanish, as noted by Gravel et al. (2013), and sex bias with an excess of indigenous females in the founders of mestizo populations is true even in the case of Costa Rica, a country that has been traditionally considered to descend from a highly pure and homogeneous Spanish ancestry, especially in the Central Valley (Morera et al., 2012). In large part, conquistadors who raped and abused indigenous female slaves during the conquest and colonial period spawned the first generations of mestizos, who were marginalized and later became rebellious spirits of Spanish colonial America (Barahona, 2002).

Forced genetic admixture was only one of the causes of the indigenous population decline. Other factors include the slave trade, warfare, abuse, and perhaps the most important, the introduction of Old World diseases (mainly measles and smallpox) against which the indigenous peoples did not have any resistance. The contribution of both pandemic and local epidemic outbreaks to the depopulation of indigenous groups was prominent (Newson, 1992). On the other hand, migration was a ubiquitous phenomenon in Spanish colonial America. While the Spanish occupied most fertile lands in the valleys and plateaus, many indigenous peoples were forced to retreat to the highlands, in an effort to escape not only Spanish exploitation, but also diseases such as malaria. Since then, they have lived in the relative isolation of rural communities, which have become highly endogamous in many cases (Madrigal et al., 2012; Herrera-Paz, 2013a, Herrera-Paz, 2016). Table 1 shows the estimated indigenous population totals in five countries (four in Central America and one in South America) at present, according to Del Popolo and Oyarce (2006), who cited various studies in compiling these data.

Genetic variability in Spanish colonial America was increased by the African component introduced by the African slave trade. African slaves came from several diverse areas, including Ghana,

**TABLE 1.** Estimated size of indigenous population and percent of total country population in five Central American and South American countries (Del Popolo and Oyarce, 2006).

Country (Year)	Indigenous population	% of Total population
Guatemala (2002)	4,433,218	39.5
Panama (2000)	285,231	10.0
Honduras (2001)	440,313	7.2
Ecuador (2001)	830,418	6.8
Costa Rica (2000)	65,548	1.7

Guinea, Nigeria, Congo, Angola, Senegal, Gambia, and the gulfs of Benin and Biafra (Ramírez, 2007; Salzano and Sans, 2014).

Currently, populations of African descent tend to be located in towns or cities near the coast, as in the case of the Garifunas along the Honduran Caribbean coast, and the Colombians of African descent on the Pacific coast (Herrera Paz et al., 2010; De Castro and Restrepo, 2015). Indigenous peoples with more or less pure ancestry prefer to live towards the hinterlands, with intermediate zones of variable admixture. However, tricontinental admixture has been complex with wide variations among countries and cities. The designations of “Latin American” and “African American” apply to a wide range of populations, heterogeneous in terms of the proportions and dynamics of admixture (Curtin, 1969; Wang et al., 2008; Bryc et al., 2010b; Via et al., 2011). Furthermore, genetic variability has been gradually increasing in cities due to urbanization.

One important consequence of genetic admixture is an increment in confounding effects in studies of molecular markers that are used in the search for genetic variants that contribute to complex diseases. Nevertheless, admixture also offers a unique opportunity for discovering those genetic variants through admixture mapping, a tool that is increasingly being used to localize disease genes in populations of recently mixed ancestry in which the ancestral populations have differing genetic risks (Seldin et al., 2011; Campbell et al., 2012; Pereira et al., 2012; Torgerson et al., 2012). Additionally, admixture has been used in examining the impact of genetic variability in physical appearance (Ruiz-Linares et al., 2014).

## CENTRAL AMERICA AND NORTHWESTERN SOUTH AMERICA TODAY

### INDIGENOUS GENETIC COMPONENT AND SOCIOECONOMIC INEQUALITY

The epidemiology and demography of Latin American populations have been strongly influenced by the intensity of population dynamics such as habitat changes, admixture, isolation, and

the intense socioeconomic and political domination of Europeans. From the colonial period to the present day, European influence has resulted in segregation, rural poverty, and the relegation of Amerindian and African minorities to the lowest social strata. One consequence has been the limitation of their access to health services, with the resulting increment of diseases (Torres, 2001; Engle et al., 2007; Hotez et al., 2008; Schady et al., 2015)

Even within urban localities, socioeconomic status correlates with proportions of admixture. For example, a higher proportion of African or indigenous genetic component in people from lower socioeconomic strata—in contrast to a greater proportion of European genetic component in higher socioeconomic strata—has been found in the urban population from Caracas, Venezuela (Martínez et al., 2007). Amerindian ancestry has been proved to be closely linked to several diseases, such as type 2 diabetes mellitus (T2DM) and cancer (Campbell et al., 2012; Pereira et al., 2012). Poor socioeconomic status correlating strongly with the proportion of Amerindian component is a confounding factor for elucidating the genetic contribution in such diseases, making it difficult to determine if higher prevalence is mainly due to Amerindian ancestry or to poverty. Furthermore, indigenous ancestry highly correlates with malnutrition in children, as can be seen in Guatemala, the country with the highest proportion of Amerindian population within both studied regions. By the end of the twentieth century, Guatemala showed the highest prevalence of chronic malnutrition in Latin America measured by height-for-age (Pebly and Goldman, 1995).

Today, certain populations of Latin America still cannot escape the burden of colonization and continue to struggle with high economic and social inequality. Latin America has been considered the most unequal region in the world, resulting in several demographic and social patterns, such as a large rural-urban migration flow (World Bank, 2006). It is likely that rural poverty and hunger are the main expulsive forces that have guided the process of urbanization; hence, availability of employment and the comfort offered by urban locations are powerfully attractive factors. In Honduras, there is a population flow across the whole country towards two suburban areas surrounding the main cities of San Pedro Sula and Tegucigalpa (Herrera-Paz, 2013c). Similarly, the highest positive migration balance in El Salvador corresponds to the capital town San Salvador (Rincon, 2011). Guatemala, albeit with a preferential net migration to the capital, shows a low rate of internal migration presumably for being the Central American country with the largest indigenous population, and as evidence shows, there is a trend among Latin American indigenous people to take hold of their land and migrate less frequently than mestizos (Valdés, 2008; Vignoli and Busso, 2009). The trend of rural-urban migration is also observed in Nicaragua (Vivas-Viachica, 2007), as well as in Costa Rica, a country with a strong tendency toward concentrated deconcentration, that is, net migration from large cities to smaller ones nearby (Varela, 2009).

In northwestern South America, Colombia is a special case in which a historical multipolar war has been the major cause of migrations, originating a very high proportion of forcible

displacement which hold different socio-demographic characteristics when compared to economic migrants (Gómez Builes et al., 2008). Colombia has a high rate of internal migration, where about 40% of the total population of the 10 metropolitan areas can be considered migrant. Additionally, 7% of that same population is considered recent migrant (Silva and Guataquí, 2007).

A negative average net migration is observed within cities in Peru, with expulsive cities doubling in number the attractive ones. Furthermore, a negative correlation is observed between the magnitude of negative migration balance within cities and the population size. The capital city Lima is, by far, the most attractive in the country (Instituto Nacional de Estadística e Informática de Perú, 2009). Among the 25 major Peruvian regions, 15 hold negative migration rates, while negative migration is seen in 12 of the 21 Ecuadorian provinces (Royuela and Ordoñez, 2018).

Interestingly, in opposition to the general tendency within major administrative regions in other countries, federal entities that experienced a recent positive net migration in the Bolivarian Republic of Venezuela outnumber those with a negative one. Also, the federal area with the greatest negative net migration in the country is the Federal District, reflecting a recent dispersal pattern from this location which may have its genesis in the political conflicts that afflict the nation since the beginning of the current century, although reduction of rural poverty could be an additional contributing factor (Gerencia General de Estadísticas Demográficas, 2011).

Both poverty and inequality are known catalysts for crime. Violence impacts demography and economy in a direct manner—as targeted victims tend to be from the economically active segment of the population—but indirectly as well, by aggravating or by increasing the prevalence of several morbid processes. For instance, evidence shows that the prevalence of chronic degenerative pathologies, such as bronchial asthma and cardiovascular diseases, increases in violent environments especially when exposure to violence begins in childhood (Exley et al., 2015; Sugglia et al., 2015).

Human calamity produced by violence and poverty is an important factor in unidirectional international migrations, boosting mobilizations between countries, as for example massive migrations from Nicaragua to Costa Rica (Morales-Gamboa, 2008). By far, the highest emigration rates in Latin America are verified from Central American countries to the U.S. which in many cases could be compared to a human stampede. In the 2010 U.S. census, a total of 6,186,400 individuals were found to be Hispanics from 10 of the countries in Central America and northwestern South America, an increment of 3,546,508 with respect to 2001 (Ennis et al., 2011). Money sent back by these people to their families (remittances), represents an important fraction of the GDPs of their home countries, especially in Central America. However, obtaining exact estimations of the amounts remitted is difficult, mostly due to underregistration of monetary transactions (Serrano Calvo, 2000).

Although few will doubt that development is beneficial, it creates a whole new set of problems, such as those related to

changes in nutrition and lifestyle due to transition from scarcity to abundance.

#### LOCAL ADAPTATIONS AND THE THRIFTY GENOTYPE

Not all differentiation among Amerindian groups has been guided by random changes related to demographic history. Evolution of many Y-chromosome haplotypes, mitochondrial haplotypes, and several other markers—such as microsatellites—depends mainly on stochastic processes such as migration and genetic drift following the neutral theory of molecular evolution (Kimura, 1979). On the other hand, whole genomes, exomes, or autosomal SNPs used for GWAS studies may involve a large number of loci experiencing purifying selection, that is, new mutations are deleterious and therefore negatively selected and removed from the gene pool. Consequently, these loci are highly conserved, being monomorphic or showing very low minor allele frequencies (MAF).

In contrast with the pervasiveness of purifying selection, directional selection (positive selection of new, adaptive alleles) may involve fewer genes, but reflects greater phenotypic adaptations. Additionally, directional selection may increase genetic differences between groups more than within groups, while the opposite holds true for purifying selection (Nielsen, 2005; Harris and Meyer, 2006; Barrett and Hoekstra, 2011). Insights arise from comparisons between the human and chimpanzee genomes, which reveal that only a handful of genes undergoing positive selection—ascertained by the presence of non-synonymous mutations—are responsible for neurological phenotypic differences between both species (Hill and Walsh, 2005). Although the number of genetic loci under selection might be smaller than approximate neutral ones, the proportion of inter-group differences attributable to them is directly relevant to diseases susceptibility (Bamshad, 2005). In the evolution of the American indigenous phenotypes, ecological adaptations to diverse environments, sedentarism, contaminants, pathogenic agents, agriculture, and periods of famine during and after colonization must have guided divergence, at least in part.

One important factor shaping human evolution has been food, both from the qualitative and quantitative perspectives, as well as a part of resource transfers between and within generations, impacting the evolution of life history traits. Particularly, the ‘thrifty’ genotype hypothesis, put forth by Neel (1962), basically states that the genotype that predisposes an individual to obesity is advantageous for survival when food is scarce since it leads to the efficient storage of nutrients.

The thrifty genotype may not only involve loci responsible for metabolism but also those responsible for the conservation of water and sodium, as well as other traits such as adipogenic, physiological, behavioral, and morphological mechanisms of conservation. The salt consumption of ancient hunter-gatherers is estimated to have been less than three grams per day, whereas industrialization has increased dietary salt intake up to tenfold, with a mean of six grams/day (Brown et al., 2009; Anderson et al., 2010). Salt added to food during processing is the most

substantive source in developed countries, while in developing countries salt added at home in cooking and at the table is the main source. Economies experiencing the nutritional transition—such as most of those in Latin America—have both dietary sources of salt. According to the Committee on Public Health Priorities to Reduce and Control Hypertension in the U.S. Population, as much as 30% of the prevalence of hypertension can be attributable to an excess of dietary salt consumption; therefore, high hypertension prevalence in Latin American countries is not surprising (Institute of Medicine et al., 2011). Percentages of prevalence reported for each of the four northwestern South American countries are: Colombia, 23%; Ecuador, 28.7%; Peru, 24%; and Venezuela, 33% (Sánchez et al., 2009).

The pathway of epistatic genes in the renine-angiotensin-aldosterone system (RAAS) could be subjected to evolution, and alleles that protect from hypertension could be under selection in some extreme environments in the Americas. For that matter, Rupert et al. (2003) found significant genetic differences in RAAS between lowlander Amerindians and Quechua highlanders of Peru. They suggest that adaptations in RAAS pathway may be partially responsible for high altitude tolerance in Quechuas with the additional gain of low incidence of hypertension and cardiovascular diseases. Quechua is the largest Amerindian group in the south, inhabiting the Andean cordillera with more than 12 million speakers in Colombia, Ecuador, Peru, Bolivia, Chile, and Argentina, showing also a high genetic diversity (Scliar et al., 2012).

Hypoxia due to high altitude has driven Quechua populations to several adaptations beyond the RAAS pathway. In a study performed in Peruvian women, Kiyamu et al. (2012) found that developmental adaptations—that is, those that arise from long-term exposure to high altitude since childhood—were important in enhancing pulmonary function through a rise in vital capacity. The Amerindian genetic component was strongly linked to an increased pulmonary residual volume, confirming that genetic and developmental adaptations could be equally important. Meanwhile, Bigham et al., using GWAS data obtained from highlanders living in the Andean *altiplano*, found evidence of natural selection in specific genes from the so-called hypoxia inducible transcription factors (HIF) pathway (Bigham et al., 2009).

The thrifty genotype may be responsible for body proportions of populations that thrive in high altitude environments. For instance, Pomeroy et al. (2012) found significant differences in limb length between lowlander and highlander Peruvian children. Shorter limbs in highlanders are most probably due to the expression of the thrifty genotype under stressful conditions, not only imposed by low oxygen concentration, but also by other factors such as cold temperatures, poor nutrition, high ultraviolet radiation, socioeconomic problems, and geographic isolation.

Economic and demographic shifts in the twentieth century still might be modeling the cultural and genetic makeup of autochthonous populations. For example, men from the Miskitu people—an admixture of Amerindians and African descendants from the Atlantic coasts of Honduras and Nicaragua—are regionally famous for their deep diving abilities. Many have

worked as lobster harvesters since 1960 and diving illnesses are typical among them (Dunford et al., 2002; Barratt and Van Meter, 2004). It is easy to imagine that positive selection in genes related to deep underwater diving abilities is taking place. On the other hand, nutritional transition, which exposes Miskitu to dietary regimes different from their traditional ones, has increased the prevalence of obesity, with its negative health consequences, especially among people from higher socioeconomic status (Arps, 2011).

#### SOCIOECONOMIC SHIFTS: THE GUATEMALAN CASE

Nutritional transition is leading to an increasing fraction of Latin American populations from hunger to abundance with the adverse consequences derived from the thrifty genotype, which may program the malnourished child to save energy and raise the caloric intake in adulthood, when there is a better availability of food.

In Latin America the prevalence of metabolic syndrome, that is, the set of clinical manifestations related to a high risk of cardiovascular diseases, is equal to or even greater than that in highly developed countries. This difference may be linked to alimentary improvements, particularly in calory intake (alimentary transition). However, there are large differences in prevalence between countries as well as in the proportions of men and women who suffer from the syndrome. In countries of the Andean region, Cuevas et al. (2011) citing various studies report a higher prevalence in Venezuela and Ecuador compared to Peruvian Andean highlanders, and while in Venezuela and Peru the proportion is higher in women, men predominate in Ecuador. Differences in historical ecological conditions such as dietary customs among Amerindian populations, and different proportions of European admixture, are factors that must have shaped the genetic component underlying such variation. Environmental etiological factors, such as rural-urban migrations with the consequent increment of caloric intake and decreased physical activity may be playing an important role. Additionally, unhealthy dietary habits may be affecting rural autochthonous communities as well. In a recent trip to an isolated rural community of Amerindian Lenca people from Honduras, I could observe what might be a shift from healthy to trashy food. Sadly, people prefer food with empty calories such as carbonated beverages instead of milk or fruit juice, and snacks instead of eggs.

The programming of phenotypes and health risk related to nutrition and the thrifty genotype begins in early childhood, and even before birth. Schroeder et al. (1999) found a significant increment in abdominal obesity—measured by the waist-to-hip ratio—in men and women from Guatemala who suffered from severe stunting—assessed by height-for-age scores—during early childhood. This correlation was higher in the cases of rural-urban migrants. In that same study, short and thin newborns had significantly greater adult abdominal fatness compared with long and thin or short and fat newborns, or children who became stunted after birth.



The existence of households with a stunted child and an overweight mother—opposite sides of the malnutrition spectrum, namely the double burden of malnutrition (DBM)—is a growing problem in Guatemala (Lee et al., 2012), a country that also holds a very high proportion of women with abdominal obesity (Aschner et al., 2009), most probably because they, in turn, were stunted children during the nutritional transition. Prevalence of DBM and abdominal obesity is higher in indigenous than in non-indigenous Guatemalan populations (Ramírez-Zea et al., 2014). Under these conditions, it would not be surprising if the prevalence of cardiovascular diseases progressively increases in the near future, as it is well known that abdominal adipose tissue is a better predictor of cardiovascular diseases and death than body weight, total adiposity, or body mass index (Larsson et al., 1984; Lee et al., 2008).

In the past, fertility rates in indigenous populations could have been affected by social inequality and ethnic poverty since malnutrition leads to short stature, and as shown by Pollet and Nettle (2008) in a study performed in Guatemalan women, short height is linked to a reduction in reproductive success. Additionally, chronic malnutrition leads to high infant morbidity and mortality.

In the period from 1950 to 1981 Adams (1988) reported that the total Guatemalan indigenous population increased, in absolute numbers, from 1,491,725 to 2,536,523; however, expressed as a percentage of the country it rather decreased from 53.5% to 41.9%. This decline could be attributable to several factors such as rural-urban migration, high mortality rates in the economically active fraction of the population, high infant mortality due to malnutrition and a lack of health services, and relatively low reproductive success. Particularly, the prevalence of malnutrition in Guatemala has been the highest in Latin America and among the highest in the world (Marini and Gagnolati, 2003). Nevertheless, nutritional transition and reduction in child mortality rates—among other variables—in the last two decades could be causing a population “rebound,” as it is also the case for other indigenous populations of the Americas (McSweeney and Arps, 2005; K. McSweeney, 2005).

Not all Latin American countries are at the same stage of the demographic transition, that is, the change from high to low fertility and mortality rates due to industrialization and socioeconomic development. For instance, Costa Rica is in an advanced stage, while Honduras, Guatemala, El Salvador and Nicaragua are currently undergoing moderate transition. On the other hand, in most countries, including Guatemala, the indigenous fraction is still in an incipient stage with a relatively high fertility rate, added to a high mortality rate in the economically active fraction derived from high risk labors (Del Popolo and Oyarce, 2006). Figure 1 shows age pyramids for both regions constructed with information provided in national censuses (Flores Fonseca, 2003; Instituto Nacional de Estadísticas y Censos de Nicaragua, 2006; Dirección Nacional de Estadísticas y Censos, 2009; Instituto Nacional de Estadísticas e Informática de Perú, 2009; Centro Andino de Altos estudios, 2010; Statistical Institute of Belize,

2010; Instituto Nacional de Estadísticas de Guatemala, 2011; Instituto Nacional de Estadísticas y Censos de Costa Rica, 2011; Sistema Nacional de Información de Ecuador, 2012; Instituto Nacional de Estadísticas y Censos de Panamá, 2015; Instituto Nacional de Estadísticas de Venezuela (2015a, 2015b)).

It is possible that the fertility rate in indigenous people behaves differently from the general mixed population due to changes related to modernity. A successful adaptive strategy available to the nondominant Amerindian ethnicities could be biological reproduction and expansion. Since most ethnic groups in Central America are rural cultivators, the most effective move is the expansion of the population through raising fertility rates, and its migration to new unpopulated areas. Consequently, while in the past the contraction followed by slow expansion of the indigenous peoples in Guatemala (and other countries) has placed them in a precarious situation, it is expected that in the long run they will occupy a much more important political and economic role. As a result of expansion, new ecological problems such as environmental damage and loss of biodiversity in rural localities could be rising, as it is the case for other American indigenous settlements (McSweeney, 2005). As of 2002, the Guatemalan indigenous population was totaled 4,433,218 individuals which accounts for 39.5% of the country (although the percentage has been steadily contracting, this contraction is decelerating) (Del Popolo and Oyarce, 2006).

One consequence of poor nutrition in pregnant women is low birthweight (LBW), defined as a weight of less than 2,500 g at birth, a condition that increases neonatal and post-neonatal mortality, and infant morbidity as well (Ramakrishnan, 2004). But malnutrition is not the only factor that causes LBW and its genesis is multifactorial including genetic, psychosocial, demographic, obstetric, and toxic factors (Kramer, 1987). One factor that has proven to be correlated to LBW, stillbirth, and other adverse pregnancy outcomes (in addition to chronic pulmonary obstructive disease and cancer in adults and acute infectious disease in the young) is the presence of air pollutants, especially in rural areas of developing countries where wood stoves are used (Korc and Quiñones, 2003; Šrám et al., 2005; Pope et al., 2010). Boy et al. (2002), in a study carried out in Quetzaltenango, Guatemala, after correcting for confounding effects, found that children born to mothers habitually cooking on open fires had the lowest mean birth weight, followed by those using chimney stoves; whilst Thompson et al. (2011), also in rural Guatemala, found a high prevalence of LBW in children of both mothers who used open fire and those that used chimney stoves, albeit with the latter weighing on average 89 grams more (see also Boy et al., 2002).

Pollutants expelled by poorly ventilated stoves with incomplete combustion are mainly of three types: Particulate matter (PM), Carbon monoxide (CO), and polycyclic aromatic hydrocarbons (PAHs), all the same contained in cigarette smoke, but without the nicotine (Kim Oanh et al., 1999). All three contaminants have been related to LBW (Astrup et al., 1972; D. Tang et al., 2006; J.C. Bonner, 2007). In Guatemala, where 83% of rural

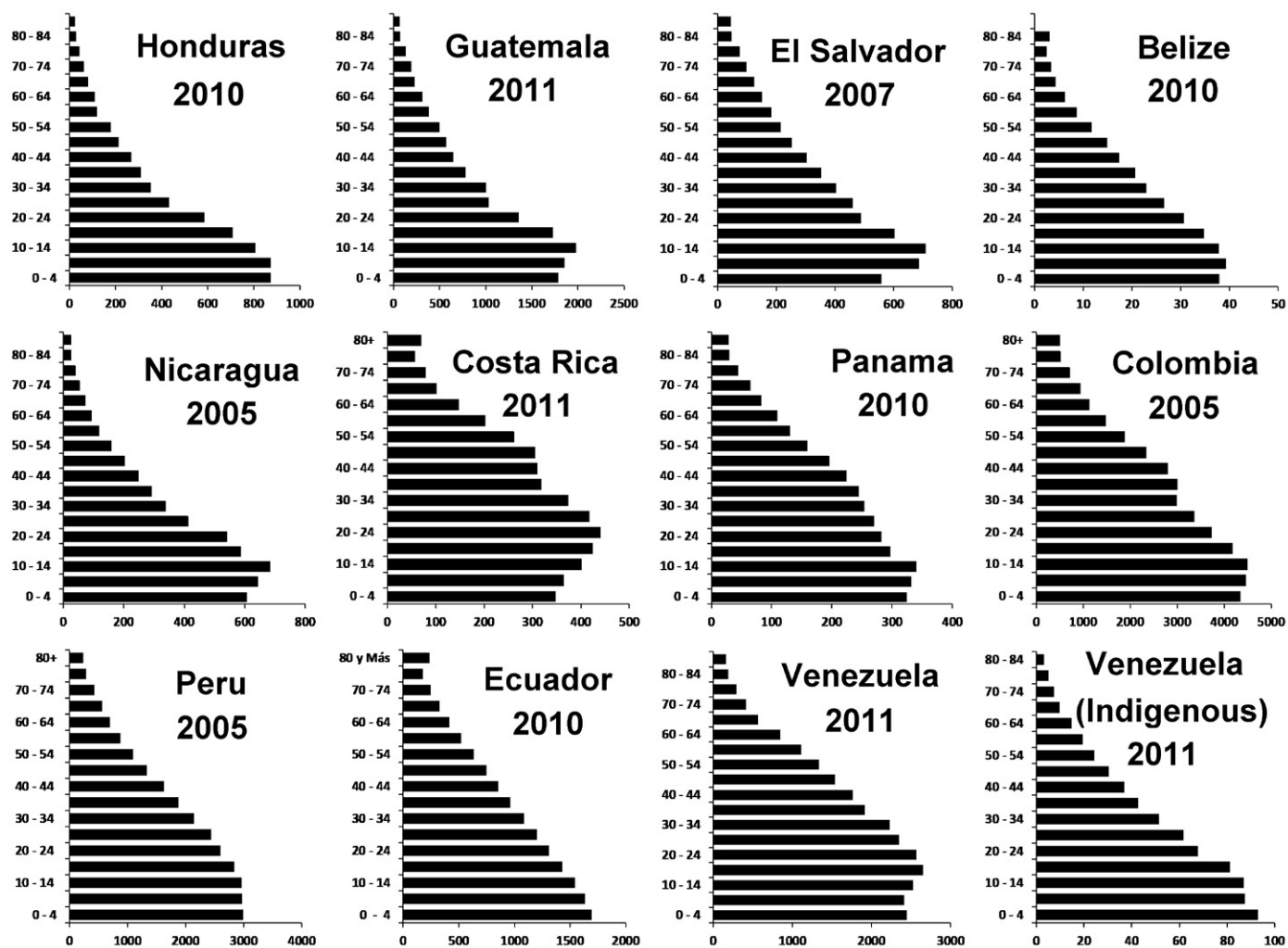


FIGURE 1. Age pyramids of Central and northwestern South American countries, with men and women pooled together: *x* axis = thousands of individuals; *y* axis = age group.

Households use wood for cooking, given the negative impact of this practice on health, the evolution of genes related to resistance to environmental contaminants must be taking place, especially those that modulate oxidative stress (Prüss-Üstün et al., 2008). There is strong evidence that Glutathione S-transferases (GST), a group of detoxification enzymes that protect cells from xenobiotics that include environmental carcinogens, chemotherapeutic agents, and oxidative stress produced by the conjugation of glutathione with a variety of electrophilic compounds, might be evolving under conditions of open fire cooking in Amerindian populations including those in Guatemala (Gattás et al., 2004; Klautau-Guimarães et al., 2005; Suarez-Kurtz et al., 2007; Thompson et al., 1984).

In summary, socioeconomic transition in Guatemala (as in the rest of Latin America) has brought obvious benefits, and good examples are the reduction in malnutrition and related

morbidity and mortality, advances in public health with a decline of infectious and parasitic diseases, and improvements in air quality in households due to the introduction of gas and electric stoves. Latin American rural populations, and largely urban ones, are presently found in the intermediate stage of the nutritional transition showing an increment of life expectancy, but also of the prevalence of the so-called nutrition-related noncommunicable diseases (also known as NR-NCDs, the term includes physical activity and body composition rather than diet solely) with the thrifty genotype playing an important role (Popkin, 2003; 2006). The combination of increased life expectancy and prevalence in nutrition-related diseases may result in an increment in the number of years of disability with the consequent higher long-term medical costs; that is, if sanitary systems and socioeconomic improvements are capable of prolonging life but not independence and health.

The confluence of epidemiological aspects from developed and underdeveloped countries due to economic transitions, socioeconomic inequality, hunger, isolation, violence, and massive migrations, are factors still modeling the genetic makeup of the populations of Central America and northwestern South America. This fact poses an enormous challenge for healthcare systems due to the changing epidemiological landscapes, but also represents a natural laboratory for biodemography and related disciplines.

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# An Overview of Data Integration in Population Genetics in the Antilles Islands

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**ABSTRACT.** Latin America in general, and in particular the Caribbean islands, presents ideal material for population genetics studies due to the complex factors that influenced the contributions of Amerindians, Europeans, and Africans to the gene pools of different populations. The admixture studies have greatly facilitated the understanding of the historical processes involved in the configuration of the present Antillean populations. Each one of the Caribbean islands displays distinct microevolutionary, demographic, historical, and social processes. The divergent genetic variations in the Antillean islands reflect the different migratory processes of Europeans, Africans, and Native Americans into the Caribbean basin. In general, native populations were decimated all over the region, but other components are related to either the Europeans in former Spanish colonies, or Africans in all other islands.

**RESUMEN.** América Latina en general, y en particular las Islas del Caribe son un material ideal para estudios de genética de poblaciones, debido a los complejos factores que influyeron en las contribuciones de los amerindios, europeos y africanos a los genofondos de diferentes poblaciones. Los estudios de mezcla han contribuido en gran medida a comprender el proceso histórico en la conformación de las actuales poblaciones Antillanas. En cada una de las Islas del Caribe se han producido procesos microevolutivos, demográficos, históricos y sociales que particularizan a las mismas entre sí. Las diferencias genéticas divergentes presentes en las Islas Antillanas indican diferentes procesos migratorios de los europeos, africanos y nativos americanos en la cuenca del Caribe. En términos generales, las poblaciones nativas fueron diezmadas en toda la región, en tanto que las otras contribuciones están relacionadas al origen de los colonizadores europeos: en las colonias españolas predomina la contribución europea, pero en todas las otras islas la principal contribución es africana.

**RESUMO.** Em geral, a América Latina e em particular as Ilhas do Caribe são um material ideal para os estudos genéticos de populações, devido aos complexos fatores que interferirão nas contribuições dos ameríndios, europeus e africanos dos genofondos das diversas populações. Os estudos referentes as misturas contribuem em grande medida a compreensão dos processos históricos na conformação das atuais populações antilhanas. As diferentes genéticas presentes nas ilhas antilhanas mostram diversos processos migratórios dos europeus, africanos e americanos nativos na bacia do Caribe.

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

## INTRODUCTION

The significant geographic and historic characteristics of the microevolution and genetic heterogeneity of the Antillean Island populations can be summarized as follows: 1) the Antillean population stemmed from successive migratory waves which came from Sub-Saharan Africa, Europe, and the Caribbean basin; 2) the environmental conditions

are not generally homogeneous, the geography and climate in the region vary among Caribbean islands; 3) admixture among Europeans, Africans, and Native Americans has taken place since colonial times.

The Caribbean islands are well known for the heterogeneous distribution of three main ancestral genetic components, from Native Americans, Europeans, and Africans, and the geographic structuring of their population (Salzano and Bortolini, 2002; Moreno-Estrada et al., 2013). These populations commingled in distinct ways, giving rise to a highly contemporary, multiethnic, admixed population. The European colonization of the island territories, previously occupied only by American Indians, started on the coast and gradually reached the interior. The progression of colonization, including the importation of African slaves, was highly diverse in different Caribbean regions as far as European, African, and Amerindian lineages were concerned. This complex process is consequently reflected in the variability in the genetic composition of the Caribbean populations.

### COMPONENTS OF THE CARIBBEAN POPULATIONS

The Antillean islands have been inhabited for more than 7,000 years, having been populated in several waves mostly from South and Central America (Torres-Cuevas, 2001; Sued-Badillo, 2011). The earliest peoples who settled in the Caribbean islands were hunter-gatherer Paleoindians (Dacal Moure and Rivero de la Calle, 1986; Tabio, 1988; Torres-Cuevas, 2001; Moreno-Estrada et al., 2013). They possibly came from the Florida Peninsula (Torres-Cuevas, 2001). Some archaeological evidence suggests that a second wave to Cuba, Hispaniola (present Dominican Republic and Haiti) and Puerto Rico possibly came from Central America and the Yucatan Peninsula (Rodriguez Ramos, 2011). A third wave of fisher-gatherers arrived in Cuba from South America more than 4,000 years ago (Dacal Moure and Rivero de la Calle, 1986; Tabio, 1988). Later, according to the most recognized Antillean dispersal hypothesis, agriculturalists reached the region by a direct jump from South America, followed by dispersal into the Lesser Antilles and westward (Keegan, 1995; Moreira de Lima, 1999).

The prominent Amerindian ethnic groups in the pre-Hispanic period were the Guanahatabeyes, Siboneyes, and Tainos (Dacal Moure and Rivero de la Calle, 1986; Tabio, 1988; Rouse, 1992; Granberry, 2012). The Siboneyes of Cuba and Hispaniola were culturally different from each other. In just a century after the arrival of the Europeans, all the Siboneyes were decimated. The Late Ceramic population, commonly called Tainos, represented the predominant indigenous culture in the Antillean islands (Tabio and Rey, 1985; Dacal Moure and Rivero de la Calle, 1986; Tabio, 1988; Rouse, 1992). They mostly disappeared as an ethnic group during the Spanish colonial period (Azcarate Rossel, 1934). According to Pérez de la Riva (1972), the few Native Americans that survived through the early period

of colonization gradually fused into the Spanish populations during the first decades of the seventeenth century. In reality, the indigenous groups did not completely disappear after the conquest, but gradually blended with other cultures in the first half of the nineteenth century (Reyes Cardero, 2009).

Beginning in the colonial period, the immigration of Yucatecan Mayas from the Yucatan peninsula in Mexico to the Antillean Islands lasted for several centuries, with Cuba as their primary destination (Novelo, 2012). The Yucatecan Maya were, in most cases, taken by force to work as domestic servants and in construction. In the nineteenth century they were sent as prisoners arrested during the conflict known as the “Caste War” in Yucatán and sold as slaves (Novelo, 2012). The continuity of Yucatecan and other Mexican migrations over several centuries left a biological impact in the genetic background of the current Cuban population (Alegre et al., 2007). By the Royal Decree of 21 July 1511, the Spanish king granted a license to bring native Lucayans to Cuba and Puerto Rico, under the pretext of the decline of this population on the island (Saco, 2006). It is clear that the process of continuous admixing and gene flow of Native Americans from different Caribbean islands contributed to the refinement of the current genetic structure of the different populations. However, this same process indicates that there is not a direct continuity between the original inhabitants of the Antilles, and the present-day populations of Cuba, Santo Domingo, and Puerto Rico.

In the Lesser Antilles, an indigenous people known as the Caribs were present. They may have descended from the mainland Caribs (Kalina) of South America, but they spoke an unrelated language known as Island Carib. Historically, it was thought that their ancestors were mainland Caribs who conquered the islands from their previous inhabitants, known as the Igneri. However, linguistic and archaeological evidence disputes the notion of a mass emigration and conquest. Irving Rouse and others suggest that a smaller group of mainland Caribs conquered the islands without displacing their inhabitants, eventually adopting the local language but retaining the traditions of their South American origin (Rouse, 1992). Today, the Caribs and their descendants continue to live in the Lesser Antilles; the Garifuna, or Black Caribs, a group of mixed Carib and African ancestry, also lives principally in Central America (Sweeney, 2007).

The transatlantic African slave trade represented an important international movement of people from one continent to another (Uya, 1989; Manning, 2009). Regional African slave trading is grouped into eight broad regions along the Atlantic coast of Africa, following the terminology adopted by historians. From north to south they are: Senegambia, the Sierra Leone region, the Windward Coast, the Gold Coast, the Bight of Benin, the Bight of Biafra, West Central Africa, and Southeast Africa. These areas are approximations, as historians do not have complete information on all slave-supply lines from the interior of Africa to coastal places of trade, and because these slaving hinterlands varied greatly over time (Curtin, 1969; Thornton, 1992). At present, little is known about the movement of slaves within

Africa, or the internal African economic, social, and political factors that contributed to the slave trading process (Fage, 1969, 1980; Saco, 2006). Moreover, little is known about the speed of changes in African historical conditions, or how they might have influenced the growth of the slave trade to the Americas.

The African component in the Caribbean populations starts with forced migration over several centuries (Franco, 1961, 1975; Thomas, 1997); according to some authors, it was in 1513 that the first African slaves arrived in Cuba (Saco, 2006). King Ferdinand II of Aragon gave the first permit for the importation of large numbers of African slaves to work in the gold mines in Hispaniola. It is believed that it was not until the last third of the sixteenth century that the slave trade between Spanish colonies in the Americas and Africa was structured and established on a regular basis (Aguirre Beltran, 1946; Klein, 1986; Thomas, 1997; Smallwood and Elliot, 1998).

The trans-Atlantic slave trade spanned from around 1520 until 1888 (Uya, 1989). During the period of 1521–1620, most of the African slaves were transported to Spanish colonies in the Caribbean (Curtin, 1969; Smallwood and Elliot, 1998). They were followed by the Portuguese and eventually the Dutch, French, and English (Smallwood and Elliot, 1998). An estimated 9 to 12 million Africans were taken from their homeland to become slaves in the Americas (Curtin, 1969; Lovejoy, 1982). The coastal African regions of Senegambia, Benin, and Wolof profited and grew from the slave-gathering system in the interior regions of Africa and the establishment of major slave ports. Two other slaving nations that grew and prospered in West Africa were Dahomey and Lagos (Ortiz, 1916; Castellanos and Castellanos, 1988). In fact, many of the slaves captured in other regions were sold at the mouths of the Niger and Congo rivers. The ‘coast of slaves,’ which was east of the Volta River from the Bight of Benin, was the area where traffic became more intense, and where the native kings did not allow the Europeans to build permanent settlements (Williams, 1987; Thomas, 1997). The cruelty of slavery that starts in the heat of the catch, and casts its sinister shadow during the march to the port of embarkation, was one of the darkest aspects of the slave trade. Another aspect was the regional distribution of the different ethnic groups once they arrived in the Americas. In the case of Cuba, the distribution of African slaves showed differences between ethnic groups in different regions of the country, which was a feature of the slave trade (Lachatañere, 1961). A study of the ancient DNA of African slaves from the Caribbean island of Saint Martin demonstrates that the individual African ancestry is closely related to the specific ancestries of the Yoruba and Bantu groups (Schroeder et al., 2015).

From 1680 to 1715, thousands of North American Indians were sold into slavery by the English; some were sent to British Caribbean colonies including Jamaica, Barbados, St. Kitts, and Nevis (Handler, 1969; Smallwood and Elliot, 1998). Many Native American groups began to assist and harbor runaway African slaves and intermingle with them (Katz, 1986). The Garifuna (Black Caribs) originated on Saint Vincent Island, in

the West Indies, as a cultural and biological amalgam between Amerindians (the Arawak and Island Caribs) and West Africans. A total of 2,026 Black Caribs was deported by the British in 1797 to the Bay Islands. From there, they later migrated to Honduras, Central America, where they became known as “Garifuna” (Crawford, 1983).

The Caribbean islands were colonies of four major European empires until the end of the nineteenth century. The French established control over Martinique and Guadalupe (Lesser Antilles) and after 1697, seized the western half of Hispaniola (Haiti) from Spain. The British and French gradually moved to dominate nearly all of the Lesser Antilles. Jamaica was conquered by the English in 1655. In general, these empires created the association of slavery with sugar cane production. The Europeans maintained a segregated society in the Caribbean islands, and the African slaves were the great majority of the population. In the French and English Antilles, the European-to-African ratio was 1:10 (Friedländer, 1944). Since 1636, the islands of Bonaire, Curaçao, and Aruba have been under Dutch administration. Collectively, Aruba and the other Dutch islands in the Caribbean are often called the Netherlands Antilles or the Dutch Caribbean (Sullivan, 2006).

The European populations of Cuba and Puerto Rico were mainly Spanish (Diaz Soler, 1953; Guerra, 1971; Le Riverend, 1986), and most of the original Spanish immigrants seem to have come from the Canary Islands (Le Riverend, 1986). The non-Spanish whites were systematically excluded. However, at the end of the eighteenth century, large groups of French from Haiti settled in the eastern part of Cuba (Guerra, 1971). During the nineteenth and twentieth centuries, there was heavy Spanish immigration, which in the case of Cuba accounted for 56% of the total number of the first waves of immigrants (Naranjo Orovio, 1993). In Cuba and Puerto Rico, the composition of the Spanish population was modified by immigrants from different regions of Spain who intermingled and formed a population group called “Criollos.”

Most of the European countries that controlled American colonies were located on the west coast of Europe, which had a strong seafaring heritage. The Caribbean basin became an active region for European ships to enter and vie for possession of each island. Many of the Caribbean islands changed hands several times before finally being secured as established colonies by a particular empire.

The cultural traits of each of the European empires were injected into the fabric of the islands they colonized; thus, the languages, religions, and economic activities of the colonized islands reflected those of the Europeans rather than those of the native people. The four main European powers in the Caribbean were the Spanish, English, Dutch, and French. Other countries that held possession of various islands at different times were Portugal, Sweden, and Denmark. The United States gained Cuba and Puerto Rico as territories as a result of the Spanish-American War, and later purchased the Virgin Islands from Denmark in 1918. Sweden controlled the island of Saint Barthélemy from

TABLE 1. Historic Caribbean colonies.

Colonizing nation	Colonies
Spain	Cuba, Hispaniola (Haiti and Dominican Republic), Puerto Rico <sup>a</sup>
Great Britain	Bahamas, Jamaica, Cayman Islands, Turks and Caicos Islands, Antigua, Dominica, Saint Lucia, Saint Vincent, Grenada, Barbados, Virgin Islands [now British V.I.], Trinidad and Tobago, Montserrat, Anguilla, Saint Kitts and Nevis
The Netherlands	Curaçao, Bonaire, Aruba, St. Eustatius, Saba and Sint Maarten (south half)
France	Haiti (the part of Hispaniola won from Spain), Guadeloupe, Martinique, Saint Martin (north half), Saint Barthelemy
Denmark	Virgin Islands <sup>b</sup>
United States	Puerto Rico, <sup>a</sup> U.S. Virgin Islands <sup>b</sup>

<sup>a</sup> Puerto Rico became a legal territory of the USA after the Spanish–American War ended on 13 August 1898.

<sup>b</sup> The Virgin Islands of Saint Croix, Saint John, and Saint Thomas became a legal U.S. territory in 1916 when they were sold to the USA by Denmark.

1784 to 1878 before trading it back to the French, who had originally colonized the island. Portugal had originally colonized Barbados before abandoning it to the British (Table 1).

Colonialism drastically altered the ethnic makeup of the Caribbean. Amerindian groups were virtually decimated after the arrival of Europeans and later, Africans. The current social hierarchy of the Caribbean can be illustrated by social hierarchy in Mexico (Nutini and Isaac, 2009). Those of European descent are at the top of the pyramid and control a higher percentage of wealth and power even though they are a minority of the population. In the Caribbean, the middle class includes mulattos, or people with both African and European heritage, many of whom include managers, business people, and professionals. In some countries, such as Haiti, the minority mulatto segment of the population makes up the power base and holds political and economic advantage over the rest of the country. The working poor at the bottom of the pyramid make up most of the population. In the Caribbean, the lower economic class contains the highest percentage of people of African heritage (Chaves and Zambrano, 2006). Another feature of colonization was that the Spanish and Portuguese emigrated with far fewer women than the English, who generally came with their families. The Spanish and Portuguese conquistadors mixed with indigenous and African women, with interracial sex a common occurrence (Esteva Fabregat, 1988; Nash, 1989; Manning, 2009). Also, in Spain and Portugal the importation of slaves from Africa was a common practice in the seventeenth century (Phillips, 1990).

Many slaves managed to escape from European oppression once on American soil, a phenomenon known as *marooning* (*cimarrones*). In Dutch Guiana, these maroons took refuge in the equatorial Amazonian forest, and reconstructed entire communities known as the *Noir Marron* (or *Bushinengué*) (Price and Price, 2002).

Not only was colonialism the vehicle that brought many Africans to the Caribbean through the slave trade, but it brought many people from Asia to the Caribbean as well. Once slavery became illegal, the colonial powers brought indentured laborers to the Caribbean from their Asian colonies. Cuba was the destination for over 100,000 Chinese workers, so Havana can claim the first Chinatown in the Western Hemisphere (Meagher, 2008). In Jamaica approximately 1,000 Chinese indentured servants were contracted to work in plantations between 1838 and 1918 (Lai, 1998).

Laborers from the British colonies of India and other parts of South Asia came by ship to various British colonies in the Caribbean. At the present time, about 40 percent of the population of Trinidad can claim South Asian heritage and a large number follow the Hindu faith.

The Spanish conquest of the islands of the Caribbean region constituted the first stage in a process of conquest and colonization in the Americas that lasted more than 300 years, and whose effects remain readily apparent to the present day. The slave society on the Antillean islands also operated in a very rigid social hierarchy; Creole slaves had much greater life expectancy, fecundity, and upward social mobility than those born in Africa (Klein, 1986). The entire society was also highly endogamous, the one glaring omission being the high frequency with which white men fathered children with their slaves, providing an opportunity for intergenerational social mobility. Slaves born of mixed parentage were more often the recipients of more favorable positions, including domestic laborers and tradesmen. Slaves of color were also much more likely to be manumitted by their owners (Klein, 1986; Castellano and Castellanos, 1988).

Some islands, such as Jamaica and Haiti, are almost entirely populated by persons of African descent, while Cuba and Puerto Rico have a creolized white majority, and the majority of the Dominican Republic population is mulatto. Maroon communities, which, as noted earlier, evolved from runaway slaves maintaining distinct identities while they proliferated throughout the Caribbean, now persist in only Suriname and Jamaica. In the southern Caribbean, in Trinidad and Suriname, there are substantial numbers of persons of Asian descent from India. In Trinidad and Tobago, descendants of Asian Indians constitute about 44 percent, and about 38 percent in Suriname. Descendants of Javanese laborers brought from Indonesia, who live in distinct ethno-cultural communities, constitute about 15 percent of Suriname's population. There are Hindus and Muslims as well as Christians and Jews. The colors are spread out on a spectrum as varied as the hierarchy of social classes. Income and color variations coexist within the same ethnic and racial groups, spawning manifold identities.



## THE STUDY OF ADMIXTURE PATTERNS IN THE ANTILLEAN ISLANDS

Admixture studies have greatly contributed to the understanding of historical processes in the genetic configuration of the present Antillean populations, as they show and allow quantification of the unique components originating from different populations. While various markers (for example, classical markers or AIMS) can have notable differences, it is clear that the indigenous component is smaller in the islands than in Central America or northern South America, showing that the indigenous population was decimated during the conquest and colonization of the Caribbean region. On the contrary, the African component is usually high, between 20 and almost 90%, which is consistent with the history of the region (Andrews, 2004).

Table 2 presents the admixture average of European, African, and Native American contributions for some island populations. An important aspect of these studies is the evidence of the presence of the Native American component in these populations. The differences between the values of admixture may be the result of the particular demographic, social, and economic processes that occurred on each of these islands. In some studies, the Native American component, when considering the three-parental population model, indicates that the population

should be considered as a hybrid between Spanish and Africans (Cintado et al., 2009). In some island populations, the European component is greater than the African, especially in the former Spanish colonies. Blood samples provided for genetic analyses reveal that the gene pool of the Black Caribs on Saint Vincent contains the highest proportion of Amerindian genes (“approximately 50%”), while the coastal communities exhibit a greater African component—“up to 80%” (Crawford, 1983). In addition, admixture estimates for the Puerto Rican population reveal signs of gene flow from mainland Africa: 26% when JC virus strains were examined (Fernandez-Cobo et al., 2001) and 27.2% based on mitochondrial DNA (mtDNA) haplogroup data (Martinez-Cruzado et al., 2005), which assesses the DNA inherited from the female line. However, in contrast to Cuba, Native Americans serve as the major contributor to Puerto Rico’s maternal gene pool (Martinez-Cruzado et al., 2005). In general in the Lesser Antillean islands, the West African admixture is greater than in the other islands, with minimal European and Native American components.

The frequencies of mtDNA in some Caribbean populations are displayed in Table 3. In a study in Cuba concerning the geographical origin of the mtDNA haplogroups, 45% are of African origin, 33% of Native American origin and 22% are of West Eurasian origin (namely, Europe and the Middle East). Another

**TABLE 2.** Admixture estimate (%) in some Antillean populations. A dash indicates that the component is not present; AIM = Ancestry Informative Marker.

Country	Marker	Estimated admixture (%)			Reference
		European	African	Native Americans	
Puerto Rico	Classical marker	45	18	37	Hanis et al. (1991)
	AIM	53.3	29.1	17.6	Bonilla et al. (2004)
	AIM	57.2	27.4	15.4	Lai et al. (2009)
Caribbean born	AIM	65.9	20.2	13.9	Ziv et al. (2006)
Cuba	Classical marker	62.0	18.0	20.0	Hanis et al. (1991)
	Classical marker	59.3	40.7	—	Hidalgo (1998)
	AIM	72.0	20.0	8.0	Marcheco-Teruel et al. (2014)
	HLA sequencing	56.2	43.8	—	Cintado et al. (2009)
	AIM	73.0	26.2	0.8	Diaz-Horta et al. (2010)
Jamaica	AIM	12.4	84.4	3.2	Benn-Torres et al. (2007)
	AIM	10.3	81.4	8.3	Benn-Torres et al. (2013)
Barbados	AIM	10.2	89.6	0.2	Benn-Torres et al. (2007)
Saint Thomas	AIM	10.6	86.8	2.6	Benn-Torres et al. (2007)
Dominican	AIM	28.1	55.6	16.2	Benn-Torres et al. (2013)
Grenada	AIM	12.1	81.1	6.8	11
Saint Kitts	AIM	8.2	85.9	5.8	Benn-Torres et al. (2013)
Saint Lucia	AIM	17.9	74.5	7.5	Benn-Torres et al. (2013)
Saint Thomas	AIM	16.9	77.4	5.6	Benn-Torres et al. (2013)
Trinidad	AIM	15.8	75.0	9.2	Benn-Torres et al. (2013)
Saint Vincent	AIM	12.8	80.6	6.5	Benn-Torres et al. (2013)

study about the analysis of mtDNA in Cuban population indicates that 34.5% have Native American ancestry, 38.8% African ancestry, and 26.7% Eurasian ancestry (Marcheco-Teruel et al., 2014). These studies highlight the importance of the contribution of Native American and African females to the formation of the Cuban population. In a sample of the population of Puerto Rico, the mtDNA maternal haplotypes in a sample of the population was of 61.3% of Native American ancestry, 27.2% African ancestry, and 11.5% West Eurasian ancestry. Most Dominicans fall within three major continental ethnic groups. Genetic studies of the mtDNA of Dominicans found that racial admixture in the population of the Dominican Republic is primarily European and African, but there is also a noticeable Native American element in the population. Based on mtDNA, approximately 15% of Dominicans have a strict female line of descent from Native American women. Another 15% have a Eurasian component, whereas most of the population of the Dominican Republic, 70%, has mtDNA of African origin, meaning that the majority of the population of the Dominican Republic is descended from unions of European men with African women. The great majority of the genetic profiles observed in Jamaica could be allocated to L sub-Saharan haplogroups (97.5%), a result consistent with previous studies showing very few non-African maternal lineages in Jamaica. The mtDNA components represented in the American slave trade originate in a very widely distribution throughout the sub-Saharan African continent, largely as a result of the Bantu dispersals (Salas et al., 2005).

In the Cuban samples studied, there is an excess of European Y-chromosome haplotypes (Marcheco-Teruel et al., 2014). Most of the haplotypes are of Eurasian ancestry (81.8%), while 17.7% have African ancestry and only two haplotypes are of Native American ancestry. Additional results suggest that several non-European Y-chromosome haplotypes have origins most

likely from North Africa and the Middle East. In Haiti the predominant Y-chromosome (SNPs) is the African (80.2%) and the Native American is absent (Simms et al., 2012). In the Jamaican population, the Y chromosomes (SNPs) from Africans have a high frequency (78.6%), while those from Europeans have a relatively low frequency (19.3%), results which are similar to those found in the Haitian population (Simms et al., 2012).

Comparisons of the variation of maternally-inherited mtDNA and paternally-inherited, non-recombining Y chromosome (NRY) have provided important insights into the impact of sex-biased processes (such as migration, residence pattern, and others) in the genetic variation of populations in the Antillean islands. Particularly, the Spanish and Portuguese men accepted mixing with indigenous and African women (Nash, 1989; Manning, 2009). In the English-speaking Caribbean, nearly 30% of the individuals display a European Y-chromosome component, and the rest, an African component (Benn-Torres et al., 2007).

## ABNORMAL HEMOGLOBINS AND G-6-PD DEFICIENCY

Some alleles that are common in certain specific populations are present in the Antillean islands. The hemoglobin S (Hgb S), the hemoglobin C (Hgb C), and the glucose-6-phosphate dehydrogenase (G-6-PD) deficiencies are related to the existence of pathological conditions in Africa and Mediterranean Europe (Weatherall and Clegg, 2001; Beutler, 2008; Howes et al., 2013). These conditions are present in the admixed Caribbean populations as a consequence of gene flow from waves of African and European immigration to the Caribbean. The distribution of Hgb S and Hgb C in the Antillean islands shows a close relationship with the areas that were most directly impacted by the

TABLE 3. Frequency distributions (%) of mitochondrial DNA haplogroups in Caribbean countries. A dash indicates the haplogroup is not represented.

Country	Percent of mtDNA haplogroup			Reference
	European	African	Native American	
Cuba	22.0	45.0	33.0	Mendizabal et al. (2008)
Cuba	26.7	28.8	34.5	Marcheco-Teruel et al. (2014)
Puerto Rico	11.5	27.2	61.3	Martinez-Cruzado et al. (2005)
Jamaica	2.5	96.5	1.0	Deason et al. (2012)
Dominica	—	72.0	28.0	Benn-Torres et al. (2007)
Grenada	14.0	86.0	—	Benn-Torre et al. (2007)
Saint Kitts	2.0	98.0	—	Benn-Torres et al. (2007)
Saint Lucia	2.8	96.2	—	Benn-Torres et al. (2007)
Saint Vincent	5.4	92.7	1.8	Benn-Torres et al. (2007)
Trinidad	8.2	87.7	4.1	Benn-Torres et al. (2007)

**TABLE 4.** Prevalence of hemoglobins (Hgb) S and C in the Antillean populations.

Country	Hgb S (%)	Hgb C (%)
Antigua & Barbuda	10.0	2.0
Barbados	7.0	5.0
Cuba	6.1	3.0
Cuba (Central Region)	3.1	0.3
Curaçao	10.7	6.4
Dominica	13.1	1.2
Dominican Republic	7.0	1.1
Granada	10.0	2.0
Guadalupe	9.2	2.6
Haití	10.0	3.0
Jamaica	10.0	3.6
Martinique	9.4	4.2
Netherlands Antilles	10.0	2.0
Puerto Rico	7.1	1.2
Saint Lucia	14.0	3.8
Saint Vincent	8.7	2.7
Saint Thomas	9.1	4.0
Suriname	17.1	2.6
Trinidad	11.1	2.9

Source: Hidalgo (1981); Martínez and Cañizares (1982); Colombo and Martínez (1985); Colombo et al. (1994); Saenz Renauld et al. (1993); Modell and Darlison (2007).

African slave trade (Arends, 1971; Sáenz Renauld et al., 1993). Differences in ethnic composition and degree of admixture, as well as variations in the selective pressure of malaria from region to region, are responsible for the different frequencies of Hgb S and Hgb C in the Caribbean regions (Table 4). Several studies analyzed the effects of Hgb S and Hgb C on the risk of severe malaria and, in vitro, on potential mechanisms of protection (Colombo et al., 1994; Fairhurst et al., 2003; Kreuels et

al., 2010). Table 5 shows the  $\beta^S$  common haplotype frequency distribution among some Caribbean islands. The data indicate that the Benin and Bantu haplotypes were the most prevalent; the Senegal haplotypes were present in low frequencies in all the samples. The presence of the three common African haplotypes is in accordance with the historical records about the Caribbean pattern of slave trade (Smallwood and Elliot, 1998).

Glucose-6-phosphate dehydrogenase is a potentially pathogenic inherited enzyme abnormality and, similar to other human red blood cell polymorphisms, is particularly prevalent in countries where malaria is historically endemic. The spatial extent of *Plasmodium vivax* malaria overlaps widely with that of G-6-PD deficiency; unfortunately, primaquine, the only drug licensed for the radical cure and relapse prevention of *P. vivax* and for blocking the transmission of *P. falciparum*, can trigger severe hemolytic anemia in G-6-PD deficient individuals. Glucose-6-phosphate dehydrogenase deficiency is found worldwide with varying frequencies, depending on the region and ethnic group (Motulsky, 1965). Mutations in the G-6-PD gene located on the X chromosome usually result in reduced enzyme stability (and thus, reduced activity in older erythrocytes) in all red cells in hemizygous males and homozygous females. There is variable phenotypic expression in heterozygous females depending on X-inactivation patterns (Cappellini and Fiorelli, 2008). As with other sex-linked disorders, phenotypic screening of male subjects is the preferred approach for the assessment of G-6-PD deficiency prevalence and allelic frequency in the population.

The present distribution of the African variant of G-6-PD deficiency has been shown to have a relatively high frequency in the same Antillean islands as the HBB\*S and HBB\*C genes (Arends, 1971; Hidalgo, 1981). These results confirm the African admixture present in those islands. In Nigeria and Ghana, the African countries which supplied most of the slaves for Jamaica and other Caribbean regions (Patterson, 1967), the G-6-PD deficiency has a high prevalence.

The distribution of G-6-PD deficiency in the Antillean islands is shown in Table 6. From the point of view of population genetics, the prevalence of genes associated with G-6-PD

**TABLE 5.** Frequency distributions (%) of the typical  $\beta^S$  haplotypes in some Caribbean countries. A dash indicates that the haplotype is not represented.

Country	$\beta^S$ Haplotypes						Reference
	Arab-Indian	Bantu	Benin	Senegal	CAR	Atypical	
Cuba	—	41	51	8.0	—	—	Muñiz et al. (1995)
Cuba	—	48.2	40.7	11.1	—	—	Muñiz et al. (2000)
Guadalupe	—	11.5	77.0	8.7	2.8	—	Kéclard et al. (1996)
Jamaica	—	8.3	76.0	5.2	—	10.5	Bitoungi et al. (2015)
Trinidad	3.2	17.3	61.8	8.5	3.5	—	Bitoungi et al. (2015)
Suriname	—	29.9	50.8	2.3	14.1	0.6	Bitoungi et al. (2015)

TABLE 6. Prevalence of G-6-PD deficiency in several Caribbean countries. A dash indicates that the deficiency is not prevalent.

Country	Male ( <i>n</i> )	Prevalence (%)	Female ( <i>n</i> )	Prevalence (%)	Reference
Cuba (Total)	7,957	0.6–16.1	1,813	0.7–10.2	Monteiro et al. (2014)
Cuba (Central Region)	2,489	5.6	385	6.0	Hidalgo et al. (1987)
Cuba (Newborn)	209	6.2	—	—	Hidalgo et al. (1987)
Curaçao	573	14	213	10.3	Monteiro et al. (2014)
Jamaica	976	13.5	524	4.1–28.3	Monteiro et al. (2014)
Puerto Rico	56	5.4	143	2.8	Monteiro et al. (2014)
Saint Lucia	427	14.8	143	2.8	Monteiro et al. (2014)
Suriname	1,507	3.2–20.2	422	1.4	Monteiro et al. (2014)
Trinidad	328	13.4	—	—	Monteiro et al. (2014)

deficiency is maintained in mixed populations due to the predominant African component. To date, sixteen G-6-PD mutations have been reported in the Antillean islands (Monteiro et al., 2014).

#### THE CYSTIC FIBROSIS (CF) $\Delta$ F508 MUTATION IN THE ANTILLEAN ISLANDS

There are significant differences between the frequency rates of cystic fibrosis (CF) mutations in the Antillean islands and Latin America (Arzimanoglou et al., 1995; Perez et al., 2007), but in all populations the most common mutation is the  $\Delta$ F508 mutation (Bobadilla et al., 2002). The frequency of the  $\Delta$ F508 mutation is shown in Table 7. The different frequencies of this mutation in various Antillean populations are a consequence of varying ethnicities on each island, and possibly reflect the processes of natural selection and genetic drift. The elevated  $\Delta$ F508 frequency rate of 80.0% in the Dominican Republic is interesting, though this high value may be a sample bias. In particular, newly revealed genetic heterogeneity data could help explain the long observed—but poorly understood—concepts of variable expressivity and reduced penetrance. Traditionally, their effects on phenotypic differences have been considered to be relatively insignificant, particularly in the case of the variable expressivity of CF.

TABLE 7. Cystic fibrosis  $\Delta$ F508 mutation frequency distributions (%) in the Greater Antillean Islands.

Country	$\Delta$ F508 %	Reference
Dominican Republic	92.0	Arzimanoglou et al. (1995)
Puerto Rico	77.0	Arzimanoglou et al. (1995)
Cuba	34.0	Collazo et al. (1995)
Cuba	37.9	Collazo et al. (2009)

## CONCLUSION

A broadly defined Caribbean includes the Antilles (the Greater Antilles and the Lesser Antilles), the Grenadines, the Windward Islands, the West Indies, and Bermuda (though the latter is situated well to the east in the Atlantic Ocean). Excluded here are the coasts of the Gulf of Mexico and Florida. Even in Caribbean regions with larger European settlements, such as Cuba and Puerto Rico, with the adoption of sugar as a monoculture, the number of African slaves increased dramatically and the number of European indentured servants decreased equally, so that the Caribbean truly felt the influence of Africa.

European-American mestizos in the Antillean islands are descendants of a complex admixture between Amerindian groups, Europeans (the Spanish and other ethnic groups), and Africans. Although a substructure among these populations has been observed for several genetic markers, the distributions of polymorphisms in genes according to the different regions of this country have not been explored. In general, we must distinguish between two dynamic processes in hybridization: an external one, consisting of gene flow, and an internal one, consisting of genotypical readjustment until equilibrium is reached. In the Caribbean islands, both processes are strongly influenced by economic and social factors. Gene flow between different ethnic native groups possibly began as the islands received waves of immigrants from South America, Central America, and also from North America (Florida peninsula). During the historic period, European immigrants and African slaves also mix, creating disequilibrium between the sexes in Cuba and Puerto Rico, with the predominance of native women and European men, as in Latin America in general. But the situation of other islands is different because the African component predominates: in Jamaica and several smaller islands the main contribution is clearly African, with a slight imbalance between sexes involving African women and European men. When considering the Americas as a whole, the Native American component is low in the Caribbean, North American, and the Rio de la Plata regions, but the historic processes

cannot be compared: while the two latter regions have native populations relatively smaller than the rest of the continent and were colonized more recently, this is not true in the Caribbean region. Moreover, the Caribbean region received a high quantity of African slaves, on a scale comparable only with Brazil, but at present, the African contribution in Caribbean countries is only comparable with some communities with strong African components in Brazil or Venezuela, but no country in the rest of the Americas has similar values. More studies with different genetic markers will facilitate the recovery of information and the understanding of processes that are still not resolved, such as the origin and permanence of the populations involved in the different waves of indigenous groups that occupied the islands, as well as the different origins of the African slaves who reached the region.

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# Assessing the Biological and Cultural Diversity of Archaic Age Populations from Western Cuba

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**ABSTRACT.** Recent evidence about the subsistence strategies and food consumption patterns of Cuban Archaic groups suggests a greater diversity existed among these groups than previously thought. The paleodietary reconstructions in the sites of Canímar Abajo, Cueva del Perico I, Cueva Calero, and Guayabo Blanco have changed some long-rooted assumptions regarding the use of plants and the differential consumption of other natural resources. Based on this new evidence, the notion of culturally and biologically homogeneous Archaic Age populations is no longer supported. Although the biological differences between late ceramic groups and Archaic Age populations have been largely assessed and demonstrated, the biological and cultural variations between the Archaic groups have received less attention. In this chapter we first summarize the evidence for variations in subsistence strategies and food consumption patterns among these populations. Then, we contrast these results with other lines of bioarchaeological evidence to explore whether such differences in subsistence correlate with biological differences among these populations. This chapter explores new perspectives on the cultural and biological diversity of Caribbean groups and poses new questions for future research in Caribbean archaeology to better understand the biological and cultural identity of Antillean Archaic Age populations.

**RESUMEN.** La evidencia reciente sobre las estrategias de subsistencia y los patrones de consumo de alimentos de los grupos antiguos cubanos sugiere la existencia de una mayor diversidad de la que previamente se pensaba. Las reconstrucciones paleodietarias en los sitios de Canímar Abajo, Cueva del Perico I, Cueva Calero y Guayabo Blanco, han cambiado las teorías aceptadas durante largo tiempo en relación al uso de plantas y el consumo diferencial de otros recursos naturales. Basados en esta nueva evidencia, la noción de poblaciones arcaicas biológicamente homogéneas es insostenible. Aunque las diferencias biológicas entre los grupos ceramistas tardíos y las poblaciones arcaicas hayan sido ampliamente evaluadas y demostradas, las variaciones biológicas y culturales dentro de las poblaciones arcaicas han sido menos estudiadas. En este capítulo, resumimos primeramente la evidencia con respecto a las variaciones en estrategias de subsistencia y los patrones de consumo de alimentos entre estas poblaciones. Seguidamente, contrastamos estos resultados con otras líneas de evidencia bioarqueológicas para examinar si las diferencias en las actividades de subsistencia de estas poblaciones se correlacionan con variaciones biológicas. Este capítulo explora nuevas perspectivas sobre la diversidad cultural y biológica de los grupos aborígenes del Caribe y plantea nuevos interrogantes para investigaciones futuras sobre la arqueología caribeña, lo cual propiciarían un mejor entendimiento de la identidad biológica y cultural de las poblaciones Arcaicas de Las Antillas.

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

**RESUMO.** Evidências recentes sobre as estratégias de meios de vida e padrões de consumo alimentar dos antigos grupos cubanos sugere que houve uma maior diversidade entre esses grupos que se

pensava. As reconstruções paleodietárias do material de Canímar Abajo, Cueva del Perico I, Cueva Calero e Guayabo Blanco mudaram algumas teorias estabelecidas há muito tempo sobre o uso de plantas e o consumo diferencial de outros recursos. Com base nessas evidências, a noção de populações cubanas biologicamente e culturalmente homogêneas não se sustenta. Embora as diferenças biológicas entre os grupos ceramistas arcaicos e populações antigas têm sido extensivamente testadas e comprovadas, variações biológicas e culturais dentro das populações antigas foram menos estudadas. Neste capítulo, primeiro resumimos as evidências que recentemente publicamos para as mudanças nas estratégias de subsistência e padrões de consumo alimentar entre essas populações. Em seguida, comparamos estes resultados com outras linhas de evidência bioarqueológicas para examinar se essas diferenças na sobrevivência estão correlacionadas com diferenças biológicas entre estas populações. Este capítulo explora novas perspectivas sobre a diversidade cultural e biológica dos grupos no Caribe e levanta novas questões para futuras pesquisas em arqueologia do Caribe para uma melhor compreensão da identidade biológica e cultural das populações Arcaicas das Antilhas.

## INTRODUCTION

The current Cuban classification systems recognize three main groups among pre-colonial indigenous populations: *Preagroalfareros* (Preagroceramists), *Protoagricolas* (Protoagriculturalists), and *Agroalfareros* (Agroceramists; commonly known as Taino) (Tabío, 1984). This distinction relies mainly on the presence or absence of ceramics (and its characteristics) as indicators of subsistence strategies. The term *Preagroalfareros* is used for groups that lacked pottery; while *Agroalfareros* are recognized as those who had elaborately decorated pottery. The *Protoagricola* are described as those with very simple ceramics and a microlithic industry, as well as shell artifacts similar to those used by the *Preagroalfareros*. Based on the presence or absence of elaborate ceramics (including *burén*) and other technological or typological characteristics, pre-colonial Cuban archaeological groups were understood within an evolutionary paradigm as transitioning from simple hunter-fisher-gatherers to more economically and socially complex agriculturalists (Tabío and Rey, 1966; Tabío, 1984; Jiménez and Jiménez, 2009).

The Preagroceramists have also been referred to as *Ciboney-Guanahatabey* (Harrington, 1935), *Ciboney* “Guayabo Blanco” and *Ciboney* “Cayo Redondo” (Rouse, 1942; Tabío and Rey, 1966), *Guayabo Blanco* or *Aunabey* (Ortiz, 1943), *Apropiadores* (Guarch Delmonte, 1990), populations with Mesolithic traditions (Dominguez et al., 1994), *Complejo I and II* (Herrera Fritot, 1951), and *Pretribales* (Alonso et al., 2008). Despite differences in nomenclature, these populations were understood, in general terms, as being closely related biological groups of fisher-gatherers who arrived in Cuba around 4000 BCE without agriculture or ceramic traditions, but with tool kits consisting of stone and shell artifacts (Tabío and Rey, 1966; Tabío, 1984). According to that, they are largely similar to Archaic Age groups described from analogous sites in the Caribbean (Keegan and Hofman, 2017), and although not ideal, we use the term “Archaic” in this chapter to denote populations that predate the late ceramic groups’ (Ceramic Age) arrival into the Antilles.

Recent findings indicate greater cultural differentiation among Archaic populations than previously acknowledged, as evidenced by dietary traditions (Chinique de Armas et al., 2016), and dental modifications and morphology (Alarie and Roksandic, 2016; Roksandic et al., 2016). Given the central position of Cuba in the ethnographic Caribbean, allowing access from the neighboring regions of North, Central, and South America, we can expect to find a greater diversity among source populations leading to a mosaic of cultural and biological groups.

The origins and migrations of Archaic Age populations in Cuba have been the subject of numerous discussions in Cuban archaeology. They are centered around two main hypotheses. The first, proposes that the early migrants came from South America (Harrington, 1935; Rouse, 1942), while the second proposes that they migrated from Florida (Febles, 1991). Migrations from Cubagua Island (off the northeast coast of Venezuela) to Cuba, as proposed by Cruxent and Rouse (1961), have been widely accepted by Cuban archaeologists. The similarities between the Manicuaroid tool tradition of Cubagua and the shell artifacts found in Cuban Archaic archaeological contexts (such as the gouge) support this hypothesis. Although there is currently no evidence of such a migration on the islands between the Venezuelan and Cuban coasts, according to a mathematical model of ocean currents and winds (Callaghan, 1993) a direct migration from the mainland was certainly possible. On the other hand, there are similarities between some artifacts found in Cuba and Florida (Rouse, 1960). Both groups used very similar shell gouges and stone balls, which indicates Florida as another potential point of origin. In addition, the DNA study of Archaic Age populations by Lalueza-Fox et al. (2003) supports both pathways and favors a South American origin. In a more recent study, the presence of haplogroup A in some indigenous individuals, suggests that migrations from Central America cannot be excluded (Roksandic et al., in press). In light of this evidence, a multi-vector pattern of migration proceeding from different regions, mainlands, and islands in the Caribbean seems more probable, supporting the vision of the Caribbean as a dynamic and diverse region (Rodríguez Ramos et al., 2013).

Although some studies have discussed the biological differences between late ceramic Arawak and Archaic Age groups (Coppa et al., 2008; Valdés Pi, 2009), less attention has been given to the analysis of biocultural variations within Archaic Age populations. We suggest that a better understanding of the biological and cultural identity of these groups will contribute substantially to the untangling of many current issues in Caribbean archaeology, and notably the origin and routes of migration of early populations. In this chapter, we first summarize the evidence we have recently gathered concerning variations in subsistence strategies and food consumption patterns within Cuban Archaic groups. These results are then contrasted with other lines of evidence to assess whether these differences can be associated with the biological differences between these groups. This chapter explores new perspectives regarding the cultural and biological diversity of Caribbean groups and presents new questions for future research.

## PALEODIETARY STUDIES IN CUBAN PREAGROCERAMISTS GROUPS: A BRIEF HISTORICAL REVIEW

The first paleodietary study in Cuba was performed in 1965 by José Manuel Guarch Delmonte at the archaeological site of Esterito de Banes in Holguin (Pino and Rodríguez, 1991). In this archaeological field season, Guarch Delmonte conducted a quantitative analysis of animal remains found at the site in order to evaluate the relative importance of different species of animals in the dietary practices of pre-colonial indigenous groups in Cuba (Pino and Rodríguez, 1991). Since then, different methods—focused exclusively on the analysis of macroscopic remains—have been proposed to reconstruct the subsistence strategies of Cuban indigenous groups (Alonso, 1991; Guarch Delmonte and Vazquez, 1991; Pino, 1980).

Although macroscopic remains are an important source of information for dietary resources of past populations, they have substantial limitations for reconstructing diet as a whole. For instance, since plant tissues degrade more easily than animal bone tissues, they are rarely recovered, especially in tropical environments, where animals are generally well represented in the archaeological record (Pestle, 2010; Mickleburgh and Pagán Jiménez, 2012). Since traditional paleodietary reconstructions of Cuban Archaic groups focused mainly on macroscopic remains, the importance of plants for Cuban indigenous communities was initially underestimated; resulting in these groups being recognized as hunters, fishers, and gatherers of molluscs, and possibly wild plants (Tabío and Rey, 1966; Tabío, 1984).

Additionally, most inferences about dietary practices of pre-colonial indigenous groups from Cuba were obtained from small scale excavations. This fact, along with the lack of regional studies, has led to a simplification of the wide spectrum of resources that were potentially exploited, to that of local faunal evidence found in reduced archaeological contexts. As a result, two aspects of these groups were underestimated: a) wild and domesticated plants that are not preserved properly in tropical environments and b) other faunal remains and artifacts that cannot be found unless more extensive excavations and regional studies are conducted.

Furthermore, the inferences about plant consumption in Cuba were constructed almost exclusively based on the typology of archaeological artifacts, the presence or absence of ceramics, and European chronicles (in the case of the populations who occupied the island during the contact and colonial period) (Oviedo, 1851; Las Casas, 1958). Based on those criteria, the beginning of agriculture as a cultural practice and systematic activity was attributed to late indigenous groups called “*Agroalfareros*,” following the notion that before their expansion, the indigenous groups from the Antilles were “fisher-hunter-gatherer” populations without pottery or agricultural production (Rouse, 1992; Wilson, 2007).

The absence of ceramic and agricultural production in Cuban Archaic groups was first questioned in the 1940s (Herrera Fritot, 1943; Pichardo Moya, 1949). This was mainly motivated

by the appearance of “simple ceramics” in association with the typical artifacts of Archaic Age groups. Consequently, a new group named “*Protoagricolas*” was created by Tabío (1984), which was understood to be a transitional group between Preagrocera-mist and Agrocera-mist populations (Tabío, 1984; Guarch Delmonte, 1990; Jiménez and Jiménez, 2009). In this way, Archaic Age populations continued to be construed as groups whose food came from the appropriation of animal resources (fisher-gatherer, fisher-hunter-gatherer or hunter-gatherer) with minimal management of (wild) plants. Fitting within the dominant evolutionist paradigm (Tabío and Rey, 1966; Tabío, 1984; Jiménez and Jiménez, 2009), the archaeological sequence assumed an inevitable progression from foragers to agriculturalists via a protoagriculturalist stage.

## CHANGING THE PARADIGM: THE EVIDENCE OF CULTIGENS AND THE DIVERSITY OF SUBSISTENCE STRATEGIES AND FOOD CONSUMPTION PATTERNS

In the last 20 years, macroscopic vegetable remains such as seeds from palms and other plants have been found in some Cuban archaeological sites (Hernandez and Navarrete, 1999; Delgado et al., 2000 Rodríguez Suárez et al., 2006). This finding opened up new inquiries into the role of plants for Archaic Age individuals’ diets. Furthermore, in the late 1980s, Roberto Rodríguez Suárez introduced the analysis of the relative importance of plants versus other resources in Cuban archaeological circles by performing trace elemental analysis at the archaeometry laboratory at the University of Havana (Ayala, 1993; Rodríguez Suárez et al., 2003; Rodríguez Suárez, 2004; Chinique de Armas et al., 2008). These first insights into the differential consumption of plants and other resources by indigenous groups, as well as the increasing evidence coming from Caribbean paleo-ethnobotanical studies (Veloz Maggiolo, 1992; Newsom, 1993; Newsom and Wing, 2004; Berman and Pearsall, 2008; Pagán Jiménez, 2009, 2011; Mickleburgh and Pagán Jiménez, 2012) led to more precise research aimed at understanding the diversity of subsistence strategies and food consumption patterns of Archaic Age populations in Cuba.

## THE NEW EVIDENCE: THE ROLE OF PLANTS IN THE ARCHAIC DIET

The archaeological site of Canímar Abajo in Matanzas (Figure 1) has been a key site in broadening our understanding of the subsistence strategies and food consumption patterns of Archaic Age populations in Cuba. The site consists of five stratigraphic levels (Rodríguez Suárez et al., 2006) and includes two cemeteries: the Old Cemetery dated to 1380–800 cal BCE (2a) and the Young Cemetery dated to cal 360–950 CE, with approximately 1 m thick shell-midden layer in between (Roksandic et al., 2015).

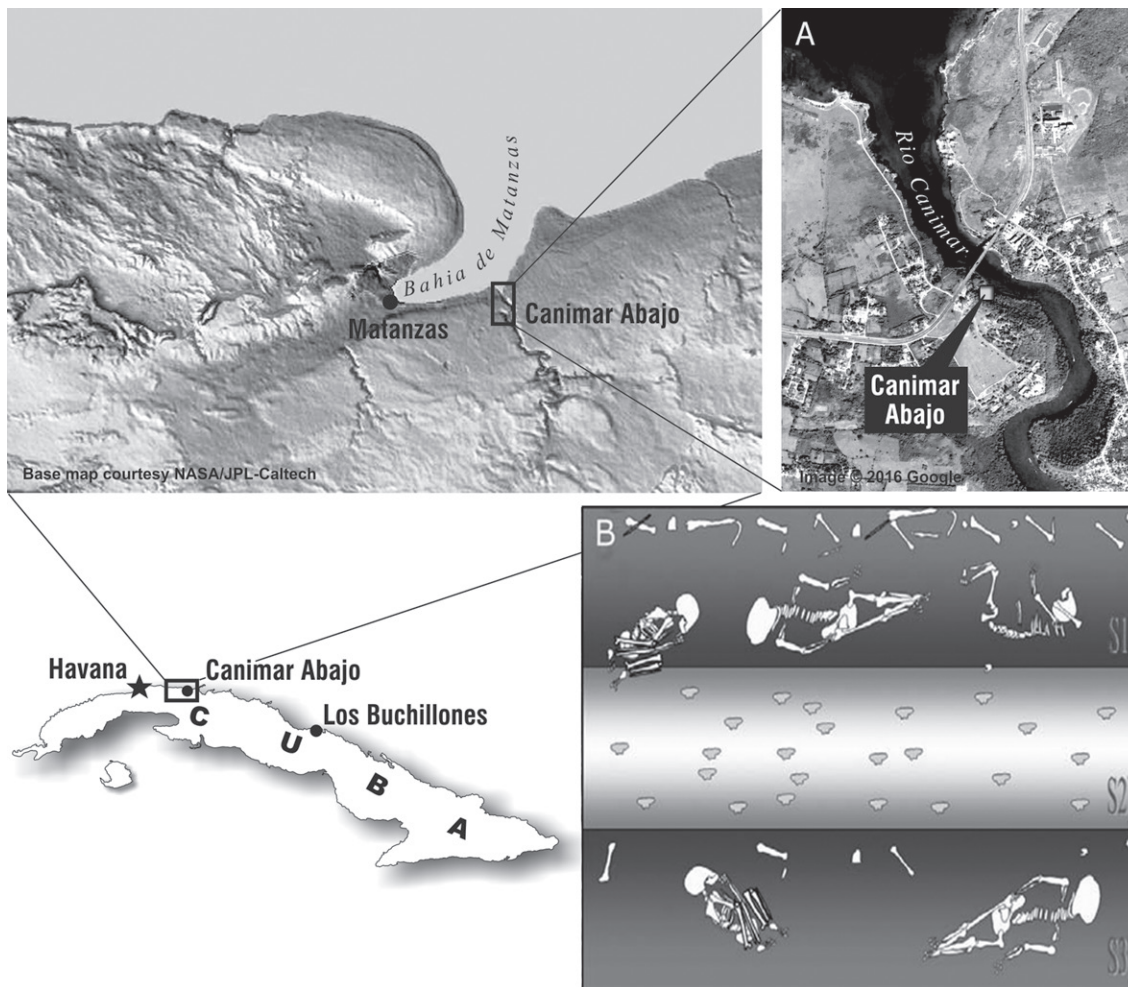


FIGURE 1. Age pyramids of Central and northwestern South American countries, with men and women pooled together: x axis = thousands of individuals; y axis = age group. Courtesy Joao Gabriel Martinez Lopez.

The first evidence for plant management came from the analysis of two grinding tools recovered from the site: one from the Old Cemetery, the other from a shell-midden layer separating the Old and the Young Cemeteries (Figure 1). The older tool provided evidence of maize (*Zea mays*), sweet potato (*Ipomoea batatas*), marunguey (*Zamia* sp.), and beach bean (*Canavalia* sp.). Starch grains identified as maize, bean, sweet potato, cocoyam (*Xanthosoma* sp.), and yam (*Dioscorea* sp.) were recovered from the more recent cemetery (Rodríguez Suárez, 2007).

Chinique de Armas et al. (2015) combined two different lines of evidence: starch analysis, and carbon and nitrogen isotopes analyses to assess the importance of plants in the Canimar Abajo populations. Dental calculus extracted from the individuals excavated from the Canimar Abajo cemeteries, indicates that they used “exotic” cultigens such as the common bean (*Phaseolus vulgaris*), maize (*Zea mays*), and sweet potato (*Ipomoea batatas*) (Chinique de Armas et al., 2015). Bean starches consistent with

*P. vulgaris* were identified in the dental calculus of individuals dated to 1380–800 BCE (Roksandic et al., 2015), providing direct evidence for the early use of this plant in the Greater Antilles (dental calculus and C<sup>14</sup> dates were recovered from the same individual) (Chinique de Armas et al., 2015). These results changed the traditional understanding that cultigens were absent in the diet of early Cuban populations and opened new discussions about the migratory pathways, economies, and lifestyles of ancient Caribbean groups.

### VARIATION IN SUBSISTENCE STRATEGIES AND FOOD CONSUMPTION PATTERNS

The inclusion of isotopic and starch analyses in the paleodietary reconstruction of Archaic Age groups revealed new evidence that supported the importance of plants in the diet, but

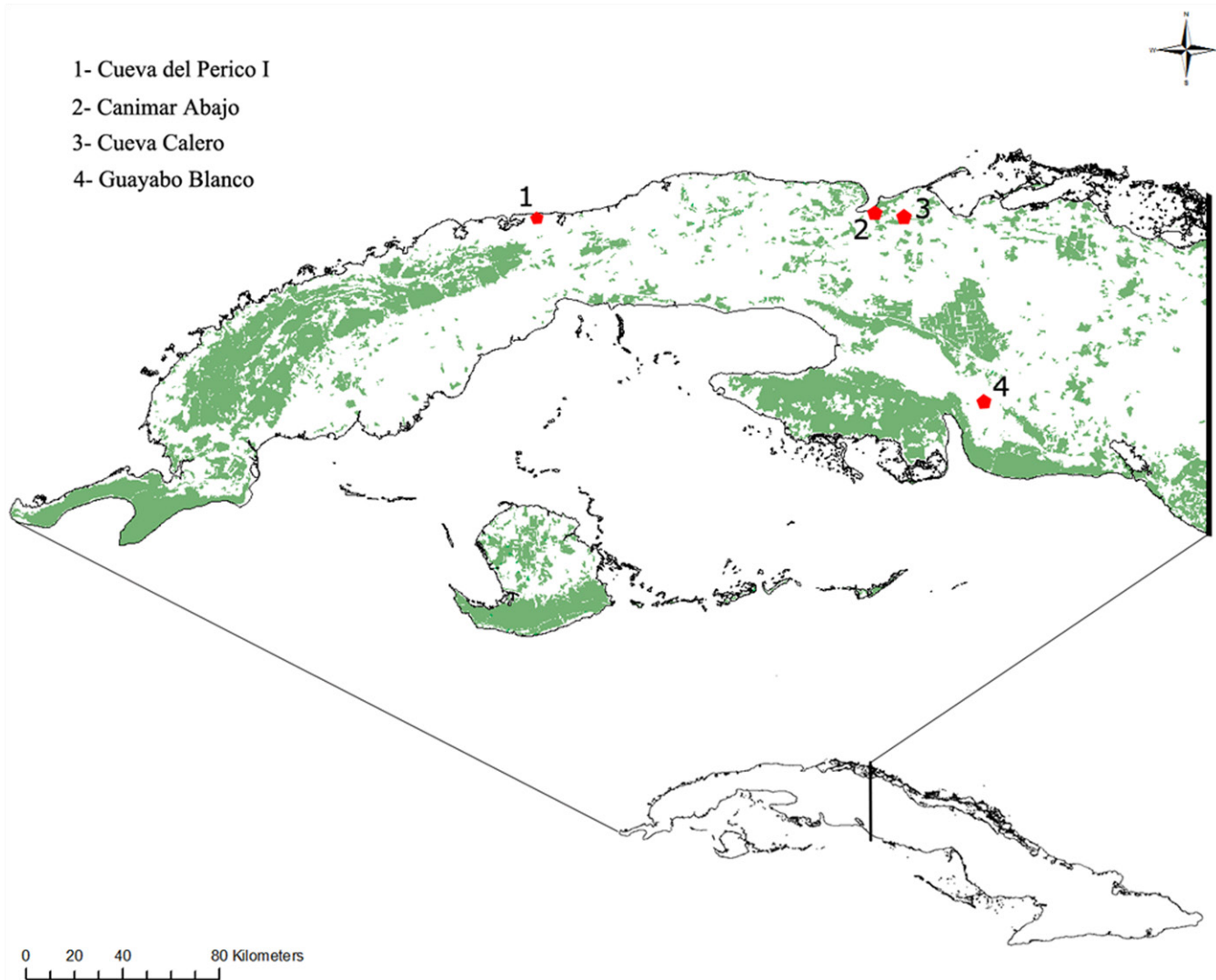
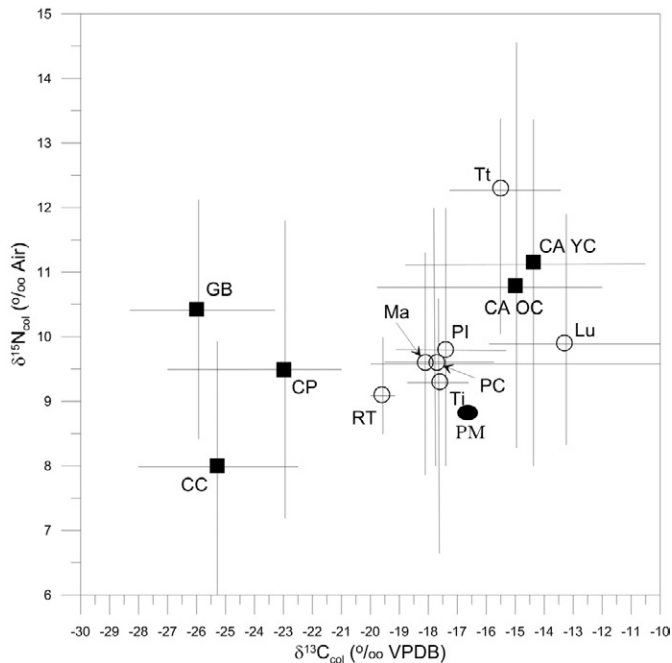


FIGURE 2. Locations of Cueva del Perico I (Pinar del Río), Guayabo Blanco (Matanzas), Cueva Calero (Matanzas), and Canímar Abajo (Matanzas) archaeological sites in Cuba. Courtesy Luis Manuel Viera Sanfiel.

also indicated dietary diversity among sites attributed to this period. Recently, we conducted an isotopic analysis of skeletal remains from the Cuban Archaic cemeteries of Cueva del Perico I (ca. AD 380–573) in Pinar del Río, and Cueva Calero (ca. AD 566–715), Guayabo Blanco (ca. AD 526–647) (Figure 2), and Canímar Abajo (ca. AD 360–950) in Matanzas (Chinique de Armas et al., 2016). This research examined whether the results obtained for Canímar Abajo could be easily transferred to fit other fisher-gatherer Cuban populations, or if alternatively, populations with different subsistence strategies and food consumption patterns coexisted within Western Cuba.

Isotopic evidence indicated that at least two different food consumption patterns coexisted among Archaic Age populations in Cuba: one mainly dependent on marine resources and  $C_3$  or  $C_4$

plants (e.g., Canímar Abajo), and another based predominantly on terrestrial resources and likely  $C_3$  plants (Chinique de Armas et al., 2016). Furthermore, the diet of the Canímar Abajo populations (both Old and Young Cemeteries) was found to be more similar to the pattern of Caribbean agricultural groups exemplified by the Tutu site in the U.S. Virgin Islands (Norr, 2002) and the *Lucayos* of the Bahamas (Keegan and DeNiro, 1988). The Canímar Abajo diet also more closely matched the isotopic composition of Puerto Rican sites such as Punta Candelerio, Paso del Indio, and Tibes (Stokes, 1998; Pestle, 2010), than the Cuban sites of Cueva del Perico I, Cueva Calero, and Guayabo Blanco, even when these sites demonstrated as high a dependence on marine/riverine resources as Canímar Abajo (Figure 3). These similarities seem to be correlated with the mixed patterns of  $C_3$  and



**FIGURE 3.** Comparison between the average mean values of  $\delta^{13}\text{C}_{\text{col}}$  and  $\delta^{15}\text{N}_{\text{col}}$  for Cuba and other Caribbean sites. CA OC: Old Cemetery at Canimar Abajo; CA YC: Young Cemetery at Canimar Abajo; CC: Cueva Calero; CP: Cueva del Perico I; GB: Guayabo Blanco; PC: Punta Candelerero, Puerto Rico; RT: Rio Tanamá, Puerto Rico; Ma: Maisabel, Puerto Rico; Ti: Tibes, Puerto Rico; PI: Paso del Indio, Puerto Rico; Lu: Lucayos, Bahamas; Tt: Tutu site, Virgin Islands. Taken from: Chinique de Armas et al. (2016).

$C_4$  plants that Chinique de Armas et al. (2015, 2016) described for this site. A recent paleodietary study at the archaeological site of Playa del Mango also showed a mixed pattern where both  $C_3$  and  $C_4$  plants were present, although individuals from the site seem to be more dependent on terrestrial resources (Chinique de Armas et al. in prep).

These results do not support the traditional evolutionist model of a unilinear transition from a fisher-gatherer economy toward an agricultural economy. Namely, the individuals from the Old Cemetery of Canimar Abajo (who lived at least 1,000 years before those from the other sites examined) had already cultivated plants as early as 1300 BCE and possibly earlier. They continued to do so throughout the occupation of the site, as evidenced by the isotopic results of the individuals from the Young Cemetery. In contrast, these latter Archaic Age sites—Cueva del Perico I, Cueva Calero, and Guayabo Blanco—showed a different pattern of subsistence in which maize was likely not present and certainly did not play an important role in nutrition (Chinique de Armas et al., 2016).

As the western portion of Cuba is narrow (Figure 2), different ecosystems are relatively close and access to different

food sources is possible within a relatively short walking distance. Communication between more distant places is easily accomplished through a network of navigable rivers that connect inland and coastal ecosystems. Therefore, a selective use of resources likely reflects food consumption preferences as a manifestation of cultural differences (Chinique de Armas et al., 2016). These results challenge the traditional paradigms about the homogeneity of subsistence strategies for fisher-gatherers in Cuba, opening up new debate about the cultural and biological diversity of some ancient pre-colonial Antillean groups since cultural and biological differences may be associated (Dillehay, 1997; Pucciarelli, 2004).

### OSTEOLOGICAL STUDIES IN PRECONTACT INDIGENOUS GROUPS OF CUBA: FUTURE DIRECTIONS

#### BIOLOGICAL DIFFERENCES BETWEEN ARCHAIC AGE AND "CERAMIC AGE" INDIGENOUS GROUPS OF CUBA: A BRIEF REVIEW

Most osteological studies of Cuban indigenous populations have focused on the determination of their stature and cranial morphometric traits (Rivero de La Calle, 1969; Travieso Ruiz et al., 1999; Valdés Pi, 2009; Bolufé, 2015). According to Rivero de La Calle (1966, 1994), "Ciboney" or Archaic Age people, as a group, had small and high skulls; wide to medium faces and eye orbits, average noses with a Leptorrhine nasal structure, and short palatine bones. The cranial capacity of male individuals was 1304 cm<sup>3</sup>, while for females the capacity was 1190 cm<sup>3</sup> (Dacal Moure and Rivero de La Calle, 1984). They had short to average stature (Table 1) and their physical characteristics fit with the general Amerindian traits (Dacal Moure and Rivero de La Calle, 1996). In contrast with late ceramic groups, these groups did not practice cranial deformation (Tabío and Rey, 1966).

More recently, statistically significant differences in cranial morphometric traits have been demonstrated between those grouped under the so-called term of "Taino" (Ceramic Age groups) and "Archaic" Age individuals (Valdés Pi, 2009). The hierarchical cluster analysis using Ward's method showed two easily distinguishable conglomerates with some subdivisions. One conglomerate grouped all the Archaic individuals ( $n = 17$ ), while the other separated the Agroceramists sample (Valdés Pi, 2009: 54). A recent study also reported marked differences between Archaic and late ceramic populations using radiographic cephalometry (Felipe, 2009). The Archaic individuals had less prognathism than late ceramic populations, with significant differences in length and width of the palatine bone, which was shorter in Archaic Age groups (Felipe, 2009; Rivero de La Calle, 1994).

In addition, previous studies had noted a dental morphological pattern remarkably different between Archaic Age and late

**TABLE 1.** Average stature for “Preagrocera-mist” populations from western Cuba. Statures were determined according to method proposed by Rivero de La Calle (2002).

Site	Location	<i>n</i>	Average stature (male)	Average stature (female)	Reference
Cueva de La Santa	Havana	M (1) F (1)	160.5 cm	147.0 cm	Torres and Rivero de La Calle (1970)
Cueva del Perico I	Pinar del Rio	M (2) F (5)	163.5±6.1 cm	157.4±6.45 cm	Travieso et al. (1999)
Canímar Abajo (Old cemetery)	Matanzas	M (6) F (1)	157.3±5.7 cm	157.3 cm	Bolufé (2015)
Canímar Abajo (Young cemetery)	Matanzas	M (15) F (10)	154.3±2.8 cm	146.5±2.92 cm	Bolufé (2015)
Cueva Calero	Matanzas	M (2) F (4)	158.5±3.2 cm	147.1±3.7 cm	Bolufé (2015)
Guayabo Blanco	Matanzas	M (3) F (3)	161.5±1.8 cm	149.7±4.64 cm	Bolufé (2015)

ceramic groups from Cuba (Coppa et al., 1995, 2003; Cucina et al., 2003). A larger study on the morphological variation of dental traits in skeletal populations from various Caribbean areas supports these differences (Coppa et al., 2008). In this study, principal components analysis (PCA) showed significant differences between Archaic Age (Ciboney) and late ceramic (“Taino”) populations. For instance, in the mandibular dentition, the trait number of cusps in the first molar (trait M1 cusp number) was more frequent in Archaic Age than in late ceramic individuals. Significant negative discriminating values characterized the number of cusps of the second premolar (2 vs. 3) and trait M1 cusp 7 was represented in very low frequencies within Archaic Age samples (as low as 0% in the archaeological site of Cueva del Perico I) in comparison with other Caribbean samples, including those of late ceramic populations. The number of roots in the second lower molar was the only trait that influenced the second component, with frequencies of 40–50% in Archaic Age groups in contrast to 15–25% in late ceramic groups (Coppa et al., 2008: 209). In the upper dentition, trait M1 cusp 5 was present in Archaic Age individuals in a frequency of 40–50%, while late ceramic groups presented much lower frequencies (10–15%). In addition, the mean measure of divergence (MMD) showed large distances between late ceramic and Archaic Age groups. This evidence supports the idea that these groups resulted from different migratory waves and that they are substantially different biologically, contrasting with previous mitochondrial genetic evidence that proposed a similar origin for both groups (Lalueza-Fox et al., 2003). Because the genetic variability within the Americas is low, being haplogroups A, B, C and D widely distributed, it is challenging to assess population origin based only on mitochondrial haplogroups.

#### DIFFERENCES WITHIN ARCHAIC GROUPS: DISCUSSING THE BIOLOGICAL EVIDENCE

The osteological evidence supports the notion that Archaic Age groups from Cuba differ from late ceramic groups elsewhere in the Caribbean (Coppa et al., 2008; Valdés Pi, 2009; Felipe, 2009), as well as from other skeletal populations from the circum-Caribbean region and South America (Ross et al., 2002). In contrast, less systematic osteological studies have been performed to understand the differences among populations grouped as “Archaic”. Most studies that compare Archaic and Ceramic Age populations homogenize all sites from non-ceramic populations (as Archaic, Ciboney) in order to obtain a bigger sample for comparisons. Taking into account that important dietary differences have been observed among populations grouped under this category (Chinique de Armas et al., 2016), the homogenization of the sample could mask biological differences within this group (i.e., Ross et al., 2002; Lalueza-Fox et al., 2003; Coppa et al., 2008).

For instance, the analysis of the mitochondrial DNA (mtDNA) of Archaic groups from Cuba performed by Lalueza-Fox et al. (2003) includes 37 samples from Cueva del Perico I (Pinar del Río), seven from Canímar Abajo (Matanzas), and three from Mogote La Cueva (Pinar del Río). Based on the traditional criteria that considered these Archaic Age groups to be similar biological populations, the sample was homogenized under the term “Ciboney.” From the initial sample, only 17 yielded positive amplifications and were sequenced. Although the paper does not offer any distinctions regarding how many samples from each site were included in the final assay, it is possible to identify that at least seven of them were from Cueva del Perico I, since this was

the number of samples with positive results from the first set that included only samples from Cueva del Perico I (Lalueza-Fox et al., 2003). This suggests that the microevolutionary history of Cueva del Perico I populations may have a bigger influence in the general conclusions that the paper makes about Cuban Ciboney groups. As a whole, the obtained sequences belonged to haplogroups A ( $n = 1$ , subgroup A2), C ( $n = 9$ ), and D ( $n = 5$ ) as deduced from their diagnostic nucleotide substitutions (Lalueza-Fox et al., 2003:101). The C and D sequences found in the sample are present in many Amerindian populations from both North and South America and are not specific to any of these geographic areas. According to the authors, although haplotype A2 found in one of the samples is most common in North America, it has also been found in indigenous populations from Chile and is closely related to a sequence found in Panamanian groups. The authors recognize that the phylogeographic association of Preagrocera-mists is difficult to determine due to the lack of diagnostic power of the amplified sequences. However, based on the haplogroup distribution and genetic affinities, they suggested a higher level of similarities between Archaic Age individuals and those from South America. Since these frequencies were determined based on a sample from different sites (that might present evidence of groups with different origins), this could have introduced a bias in the analysis of Archaic Age individuals migratory pathways. Most importantly, the contribution of Cueva del Perico I to the sample was large enough that it could have masked the genetic affinities of the Canímar Abajo and Cueva del Mogote sites. Future studies involving nuclear DNA analysis on a bigger sample size from the different Archaic Age groups from Cuba, along with genetic studies in ancient individuals from the Circum-Caribbean region, may shed light into this potential bias.

Two populations that have been included in most of the references consulted in this chapter, Cueva del Perico I and Canímar Abajo, illustrate well the necessity for the separate analysis of independent sites. The paleodietary evidence suggests marked differences in the subsistence strategies and food consumption patterns of these two archaeological skeletal samples (Chinique de Armas et al., 2016). The cultural differences between these two sites can be illustrated by dental modifications practiced at Canímar Abajo that have not been reported for Cueva del Perico I (Alarie and Roksandic, 2016; Roksandic et al., 2016). Recent osteological studies also confirm statistically significant differences between the stature of female individuals from both sites (Bolufé, 2015). In the study by Lalueza-Fox et al. (2003), haplogroup A was found in a low frequency (6.7%) within the total sample, while a recent study of the Canímar Abajo individuals reported values as high as 19% (Roksandic et al., in press). In accordance with Lalueza-Fox et al. (2003), higher frequencies in the Roksandic et al. (in press) study were observed for haplogroups C (57%) and D (29%) with a total absence of haplogroup B. As the specific sequences of haplogroups A, C, and D found in those populations were not included in the work by Roksandic et al. (in press), it is difficult to discuss geographic origins from diagnostic

sequences. The residual evidence of haplogroup A, along with the high frequencies of haplogroups C and D, led Lalueza-Fox et al. (2003) to suggest a South American origin for Cuban Archaic Age groups. However, the new frequency of haplogroup A together with the linguistic evidence discussed in Roksandic et al. (in press), may also link the population of Canímar Abajo to other areas such as Central America. In addition, haplotype A has been found in two samples from Marien 2 (Artemisa), possibly belonging to a mother and her child, representing 100% frequency at the site (Leonart et al., 1999). Although it is not possible, based on the current evidence, to state that Canímar Abajo and Cueva del Perico I are distinct biological populations, some comparative results may point in that direction. It seems clear that site-specific analyses of microsatellite (STRs: short tandem repeats), haplogroup sequences and their distribution should be performed to understand the biological diversity and the geographic affiliations of Cuban Archaic Age populations.

While some initial studies are trying to assess biological differences among Archaic Age populations (i.e., C. Alarie and M. Roksandic [University of Winnipeg], personal communication, 2016), problems associated with the number of samples and material preservation are challenging. Recently, Bolufé (2015) proposed at least two different phenotypes for Archaic Age groups based on their stature: one composed of Canímar Abajo and Cueva Calero and the other grouped the sites of Cueva del Perico I and Guayabo Blanco. Although these findings could provide some preliminary insights into the biological differences among these groups, various lines of evidence should be combined to overcome the effects of the small samples.

Currently, a joint Cuban-Canadian project between several Cuban institutions (including scholars from the Instituto Cubano de Antropología, Dirección Provincial de Cultura de Matanzas, Casa de la Nacionalidad de Bayamo and Fundación Antonio Núñez Jiménez de la Naturaleza y el Hombre) and the University of Winnipeg has among its goals to assess whether the cultural differences observed by Chinique de Armas et al. (2016) among indigenous groups of western Cuba are linked to biological differences. For this purpose, different lines of evidence, such as DNA analysis, nonmetric dental traits, and other osteological analyses will be performed. In addition, Archaic Age populations from eastern Cuba have been included to the project. This will complete the picture by contrasting what was described (based on the material culture) as Ciboney “Guayabo Blanco” (mentioned earlier in this paper) with the Ciboney “Cayo Redondo” type (Tabío and Rey, 1966; Rouse, 1992). The craniometric comparison conducted by Herrera Fritot (1957) found marked differences between individuals of these so-called “archaeological traditions.” However, Pospíšil and Rivero de La Calle (1968) reported insignificant differences in cranial morphometric traits between these two Archaic Age groups. The analysis of archaeological material from new sites, combining a variety of techniques will facilitate an understanding of the biological and cultural differences among Cuban Archaic populations, which will provide new insights into the origin of these groups, the



dynamics of the migratory processes, and the various ways indigenous groups interacted in the ancient Caribbean.

## FINAL CONSIDERATIONS: FUTURE DIRECTIONS

Recent evidence about the subsistence strategies and food consumption patterns of Cuban Archaic groups suggests greater diversity among these groups than previously acknowledged. The paleodietary reconstructions for the sites of Canimar Abajo, Cueva del Perico I, Cueva Calero, and Guayabo Blanco have changed some traditional assumptions regarding the use of plants and the differential consumption of other resources. It is possible to recognize at least two different plant consumption patterns among these groups: one dependent on a mixed diet composed of  $C_3$  and  $C_4$  plants (including cultigens such as maize), and another based mainly on  $C_3$  terrestrial resources, likely including only  $C_3$  plants. Given these differences, it is no longer possible to regard Archaic Age groups as homogenous.

Although there is a solid body of biological evidence that differentiates between Ceramic and Archaic Ages populations, the biological variation within the Archaic Age group has received far less attention. The assumed homogeneity is rooted in an outdated archaeological paradigm and has rarely been questioned. Although some studies have tried to assess these differences, the conclusions were hampered by small sample sizes and poor preservation of skeletal materials. As a result, most bioanthropological studies—whether on mtDNA, skeletal morphometric, stature estimation, or nonmetric traits—have analyzed the Archaic Age individuals as a whole sample, potentially masking the underlying biological differences. Future endeavors combining different lines of evidence, including nuclear DNA analysis, could help researchers understand site-specific variations within the Cuban Archaic Age populations. This approach is necessary to examine the early peopling of the Caribbean and the different points of origin these indigenous populations may have had. The evidence discussed in this chapter, although not conclusive, opens new perspectives for future analysis. It is very important to stress that the design of bioarchaeological research is dependent on the underlying archaeological evidence in a way that can bias our results (in this case by lumping together diverse Archaic Age samples). Understanding biological differences in the archaeological record requires an interdisciplinary approach that recognizes and overcomes this bias.

## ACKNOWLEDGMENTS

The authors would like to thank the members of the Canimar Abajo project. We would also like to thank Dr. Douglas Ubelaker and Dr. Sonia Colantonio for inviting us to contribute to this monograph. Thanks to Luis Manuel Viera Sanfiel, Joao Gabriel Martínez López, and Weldon Hiebert for providing Figures 1 and 2 and to Kathrin Nagele for her comments.

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# The History of Paleopathology in the Caribbean Archipelago

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**ABSTRACT.** The main objective of this chapter is to present a summary of paleopathological research performed on pre-Columbian and historical skeletal materials in the Caribbean archipelago and to shed light on past and current developments in the field of paleopathology in this geographical region. A historical overview is presented covering ethnohistorical accounts from the sixteenth century and research developed from the nineteenth to the first fifteen years of the twenty-first century. This last period of time covers approximately 166 years, and includes investigations that have contributed significantly to the field of paleopathology in the Caribbean archipelago.

**RESUMEN.** El principal objetivo de este capítulo es presentar un resumen de las investigaciones paleopatológicas realizadas sobre los materiales esqueléticos precolombinos e históricos en el archipiélago caribeño y arrojar luz sobre los acontecimientos pasados y actuales del campo de la paleopatología en esta región. Se presenta una revisión histórica general desde los documentos etnohistóricos del siglo 16 hasta las investigaciones desarrolladas desde el siglo 19 hasta los primeros quince años del siglo 21. Este último periodo cubre aproximadamente 166 años de investigaciones que han contribuido de manera significativa al campo de la paleopatología en el archipiélago caribeño.

**RESUMO.** O principal objetivo desse capítulo é apresentar, um resumo das investigações paleopatológicas executadas em materiais esqueléticos pré-colombianos e históricos no arquipélago caribenho e lançar luz sobre o passado e atuais desenvolvimentos no da Paleopatologia nessa região geográfica. Se apresenta uma revisão dos documentos etno-históricas do século 16 à pesquisa desenvolvida a partir do século 19 até os primeiros 15 anos do século 21. Esse último período inclui cerca de 166 anos de investigações que contribuíram significativamente para o campo de Paleopatologia no arquipélago caribenho.

## INTRODUCTION

Since the publication of *Studies of Paleopathology of Egypt* by Sir Marc Armand Ruffer in 1921 and *The Antiquity of Disease* by Roy L. Moodie two years later in 1923, the significant increase in paleopathological research worldwide is evident (Aufderheide and Rodríguez-Martin, 1998: 5–10). This research covers multiple topics, such as descriptions, identification, differential diagnoses of the pathological lesions present in both skeletal remains and mummies (Aufderheide, 2003; Aufderheide and Rodríguez-Martin, 1998; Campillo, 1993, 1994, 2001; Cockburn, et al., 1998; Mann and Murphy, 1980; Ortner, 2003; Roberts and Manchester, 2007; Steinbock, 1976; Waldron, 2009), theory, method, techniques, standardization of paleopathological data recording (Armela and Van Gerven, 2003; Buikstra and Ubelaker, 1994; Grauer, 2012; Pinhasi and Mays, 2008), and specific pathological conditions (Roberts and Buikstra, 2003; Powell and Cook, 2005).

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

Likewise, population studies have provided the opportunity to learn about the distribution and frequency of pathological conditions present in ancient populations in different geographic regions (Cohen and Armelagos, 1984; Cohen and Crane-Kramer, 2007; Ortner and Aufderheide, 1991; Owsley and Jantz, 1994; Rodríguez-Cuenca, 2006; Sotomayor and Cuellar-Montolla, 2007; Verano and Ubelaker, 1992; Webb, 1995). However, a review of this literature reveals the complete absence of studies from the region corresponding to the Caribbean archipelago.

This geographic region is relevant to paleopathology in the Americas, because the Caribbean archipelago was the first region of the New World where Europeans initially encountered Amerindian populations, with cultural, biological, and epidemiological consequences. Indeed, the early reports of some pathological conditions, their method of treatment, their importance in mythology, description of the practice of intentional cranial modification (deformation), and epidemic events present in the indigenous inhabitants of the Americas came from the early Spanish chronicles, written between the end of the fifteenth and the beginning of the sixteenth centuries in the Caribbean region.

Two published works discuss the history and development of osteological research in the Caribbean, covering approximately 166 years of analysis throughout the islands in the archipelago (Crespo-Torres et al., 2013; Goodwin, 1979). Both publications offer overviews of some paleopathological studies done in this geographic region.

### SIXTEENTH CENTURY: THE EARLY REPORTS

The first pathological condition described in the Americas by ethnohistorical accounts represents treponematosi (syphilis) in a pre-Colombian population, written by the Spanish chronicler Fray Ramón Pané, in 1498. In his work, Pané described the myths and ceremonies of the indigenous inhabitants of the Antilles, the Taínos. The following passage, recounting a Taíno myth, appears to describe an important mythological character called *Guahayona* who apparently suffered from a sickness identified by the chronicler as *mal francés* (The “French sickness or evil French,” that is, venereal syphilis):

“Dice que estando Guahayona en la tierra adonde había ido, vio que habia dejado en el mar una mujer, de lo cual tuvo gran placer, y al instante buscó muchos lavatorios para lavarse, por estar lleno de aquellas llagas que nosotros llamamos el mal francés” [“He says that when Guahayona was in the land where he had gone, he saw that he had left a woman in the sea, of which he had great pleasure, and at once he sought many lavatories to wash himself, for being full of those sores that we call French evil.”] (Pané 1991[1498]:11).

Later, in 1535, another Spanish chronicler, Gonzálo Fernández de Oviedo, indicated not only the presence of this infectious

disease, but also the treatment used by the indigenous inhabitants of the Antilles for this condition, and stated the following:

“Dos árboles hay muy notables y excelentes en estas islas e aún en la Tierra Firme. Porque, assi como es común el mal de las bubas en todas estas partes, quiere la misericordia divina que assi sea el remedio comunicado, é se halle para curar esta dolencia. Pero aunque en otras partes se halle esta enfermedad, el origen donde los chripstianos vieron las buas, y experimentaron é vieron curarlas y experimentar el árbol de guayacán fué en esta isla Española. El otro se llama palo sancto (*lignum vitae*), y este hay en la isla de Boriquen, llamada agora por los Españoles San Juan . . . Entre los indios no es tan recia dolencia ni tan peligrosa, como en España y en las tierras frías; antes estos indios facilmente se curan con este árbol. La qual cura es subjeta á mucha dieta é á beber del agua que hacen, cociendo este palo en ella, sin la cual dieta él no aprovecha, antes dañada.” [“Two trees are very remarkable and excellent in these islands and even in Tierra Firme. Because, as is common the syphilis in all these places, the divine mercy wants the remedy to be communicated, and to be found to cure this ailment. But although elsewhere this disease is found, the origin where the Christians saw the syphilis and experimented and found the cure from the guayacan tree was on this Española island. The other is called palo sancto (*lignum vitae*), and this one is on the island of Boriquen, called now by the Spaniards San Juan . . . Among the Indians, it is not as stiff ailment nor as dangerous, as in Spain and in the cold lands; these Indians easily heal with this tree. The cure is based on diet and the drinking water that they make by cooking this tree stick in it. Without this, the diet does not take advantage.”] (Fernández de Oviedo, 1959 [1535] Volumen 2, Libro 10, Capítulo II: 9).

Therefore, several authors clearly associate las búas, bubas, and mal francés (also known as mal indiano) with syphilis, but it is not certain whether these illnesses actually resulted from treponemal infections or were confused with other types of skin infections. However, we cannot discount the presence of this pathological condition in the pre-Colombian Antilles populations. Clear evidence of treponemal infection in skeletal remains from different pre-Columbian archaeological sites in the Caribbean Archipelago is reported later between the nineteenth and twenty-first centuries.

Likewise, the first documented New World smallpox outbreak occurred in the Caribbean between 1517 and 1518, and spread to areas of the Greater Antilles such as Puerto Rico (San Juan), Jamaica, and Cuba:

“Pero, así como se redujeron a pueblos, les sobrevivieron unas viruelas tan pestilenciales, que dejaron estas islas e las otras comarcas, Sanct Joan, Jamaica e Cuba, asoladas de indios, o con tan pocos, que pareció

un juicio grande del cielo. [“But, just as they were reduced to villages, they survived such smallpox, which left these islands and other nearby islands, San Juan, Jamaica and Cuba, ravaged, or with so few indians, that it seemed the Final Judgement.”] (Fernández de Oviedo, 1959 [1535]: Volumen 1, Libro IV, Capítulo II: 95).

At present, evidence of smallpox lesions in bone (variola osteomyelitis) is yet to be found in skeletal materials from the Caribbean archipelago (Aufderheide and Rodríguez-Martín, 1998: 202–207; Ortner, 2003: 332–336).

Fernández de Oviedo also described the therapeutic procedure used by the Tainos Indians to treat bone fractures. In relation to this, the chronicler mentions the following:

“Machacada las pencas deste árbol, quitadas las espinas primero, é tendido lo que assi se machacáre en un paño de lienço, a manera de emplasto. É ligada con ella una pierna o brazo quebrado, después que primero se hayan concertado los huesos rompídos, lo suelda é junta é afixa tan perfectamente como si nunca se quebraran, si bien se concertan primero los huesos de las tales quebraduras. E hasta que ha hecho su operación está tan asido el emplasto ó medicina ya dicha con la carne, que es muy dificultoso é penoso despegarlo, pero assi como ha curado é fecho su Buena operación, luego por si mismo se aparta é desecha el emplasto de aquel lugar, donde lo avían puesto.” [“Crushed the trunk of the tree, removed the thorns first, and stretched out this in a linen cloth, like a poultice. It linked to a broken leg or arm, after the broken bones have been arranged, welded and joined together as perfectly as if they never broke, although the bones of such breaks are first reconciled. And until its purpose is accomplished, the poultice is so gripped to the meat, that it is very difficult and painful to detach it, but even as it heals and finishes its mission, then by itself it moves away.”] (Fernández de Oviedo, 1959 [1535] Volumen II, Libro 10, Capítulo I: 8).

There is no doubt that the previous quote corresponds to the first, and maybe only, description we have found in the Americas of the use of a kind of “organic gypsum” by indigenous groups in the Antilles for the therapeutic treatment of fractured bones.

In relation to the practice of intentional body modification, early ethnohistorical accounts describe the presence in the Caribbean archipelago of intentional cranial modification (deformation). The first description of intentional cranial modification practice by the Amerindians came from Spanish chroniclers in the Caribbean. For example, Fernando Gonzalo de Oviedo described this practice among the indigenous population of La Hispaniola:

“Esta manera de frentes se hace artificialmente: porque, al tiempo que nascen los niños, les aprietan las cabezas de tal manera en la frente y en el colodrillo,

que, como son las criaturas tiernas, las hacen quedar de aquel talle: anchas las cabezas delante e detrás, e quedan de mala gracia.” [“In this way foreheads are made artificially: because, at the same time that the children are born, they squeeze their heads in such a way on the forehead and in the occipital bone, that, as they are tender creatures, they make them keep that size: the heads are wide front and back, and they remain of bad form.”] (Fernández de Oviedo, 1959 [1535]: Volumen I, Libro III, Capítulo V: 64).

As discussed later, evidence of this kind of body modification was reported and studied in pre-Columbian skeletal remains from different islands in the Caribbean archipelago since the nineteenth century.

Finally, some authors (Bates, 2002: 521–528, Fernández, 2015: 179; Spencer, 2003: 6) have mentioned the interesting case of Siamese conjoined twins born in the city of Santo Domingo in 1533 on the island of Hispaniola. The case was reported and the autopsy process meticulously described by Gonzalo Fernández de Oviedo (1959 [1535]: Volumen I, Libro VI, Capítulo XI: 170–172).

According to Bates (2002) the description by the Spanish chronicler is a probable case of omphalopagus twins. This type of conjoined twins involves fusion at the lower abdomen. The twins share a common liver, digestive system, diaphragm, and other organs. They present four arms, four legs, and two pelvises. At present, no modern paleopathological evidence of conjoined twins has been reported in the Caribbean region.

As mentioned above, during the sixteenth century the sources about some pathological conditions and therapeutic treatments observed in the ancient inhabitants of the Caribbean regions come exclusively from ethnohistorical accounts. Information about diseases and epidemic events that affected some Latin American countries during the seventeenth and eighteenth centuries is presented in different publications (Adames, 2000; Betrán, 2006; Hernández, 2004; Márquez, 1994).

The lack of information from the seventeenth and eighteenth centuries in the Caribbean region is evident. Therefore, it is necessary to consult documents from the historical archives in this region to reconstruct an epidemiological history during these two centuries.

However, it was not until the end of the nineteenth century that the first scientific study was conducted on pre-Columbian skeletal remains that show clear evidence of pathological conditions. The following presents the development of paleopathological studies in these geographic regions.

### **NINETEENTH CENTURY: THE FIRST CONTRIBUTIONS TO PALEOPATHOLOGY IN THE CARIBBEAN ARCHIPELAGO**

The first scientific contributions to Caribbean osteology came from the Bahamas (Brooks, 1888), Cuba (Montané 1874,

1877, 1885, 1887; Poey 1865) Dominican Republic (Llenas, 1821), and Jamaica (Duerden, 1895, 1897; Flower, 1891, 1895; Haddon, 1897). The predilection toward studies of the skull rather than other bones prevailed during this period. Descriptive studies with an emphasis on craniology and craniometrics were the principal interests. However, the first anatomical descriptions of intentional cranial modification present in skulls and some pathological conditions present in pre-Columbian skeletal remains were reported in Cuba by Felipe Poey (Goodwin, 1979: 464–473).

At the end of this century, the early contribution to the paleopathology of the Caribbean began, with the work of a British surgeon, Sir William Henry Flower (1895:607–608). In his reports on skeletal remains found in Jamaica, he noted a “remarkable” frequency of antemortem tooth loss, and the presence of two edentulous mandibles in a sample of twenty-two. The relatively great degree of dental attrition was noted; and he pointed out that the only caries present in the sample were in soon to be avulsed deciduous molars. In addition, deformation and enlargement of one femoral head and chronic rheumatic arthritis were described. In reality, either osteoarthritis or trauma-induced arthritis might be a better diagnosis, since rheumatic arthritis is usually of short duration and generally involves multiple joints (Ortner 2003).

Finally, Flower noted chronic periostitis of two tibiae, presumably from the same individual. Though the issue of a pathognomonic syphilitic lesion remains moot, there is no doubt that this is the first report in the paleopathology literature of the Caribbean of the sort of lesion one might expect to find in a case of syphilis. Flower’s presentation culminated in a plea stressing the importance of preserving and carefully examining prehistoric skeletal remains.

## **TWENTIETH CENTURY: GROWTH OF RESEARCH IN CARIBBEAN PALEOPATHOLOGY**

Basically, during the first half of the twentieth century, systematic archaeological research began in some Caribbean islands (Aitken 1917, 1918; Alegría, 1947; Alberti, 1932; DeBooy, 1919; Fewkes, 1907; González de Campo, 1933; Herrera-Fritot and Leroy, 1946; Rainey, 1940; Royo, 1939, 1940). Nevertheless, with one exception (Tacoma, 1959) the interest in artifacts did not extend to human skeletal remains.

The second half of the century witnessed a continuation of craniological studies that characterized the preceding period, such as those conducted in Cuba. The distinctive characteristics of this period were the pursuit of craniometry, craniotrigonometry, and the study of intentional cranial deformation (Herrera-Fritot 1964, 1965; Rivero de la Calle, 1949, 1960; Royo, 1943).

With the influence of “cultural ecology” (Meggers 1954; Steward, 1955) in archaeological research, scholars became increasingly aware that the relationship between man and environment was a systemic one. This information provided a new reason for looking at human remains recovered from archeological

contexts. Skeletal data could be integrated with other sets of archaeological data to facilitate more accurate reconstructions of prehistory. Osteology could in fact benefit archaeology (Goodwin, 1979: 481).

This inter-disciplinary symbiosis is present in most of the research done during this period in the Caribbean archipelago. Interest in parts of the skeleton other than the skull, and an awareness of ecology benefited paleopathology. A disease cannot be understood apart from its ecological setting. The relationship of host to pathogen is a complex one involving a variety of environmental factors such as climate. When humans are the host, cultural variables—such as diet and patterns of personal hygiene—can greatly influence the incidence of disease.

Since the 1960s, paleopathology research usually comprises one of two alternate approaches: a) a report on a single pathological condition, or b) a descriptive catalogue and discussion of analyses of skeletal series obtained either from a museum or through archaeological excavations. Both of these approaches have been pursued in the Caribbean archipelago.

Pathological conditions such as treponematosi, osteomyelitis, osteoarthritis, bone trauma, dental diseases, lead poisoning as well as intentional cranial and dental modifications were reported in skeletal materials from both pre-Columbian and historical archaeological sites in the Caribbean archipelago (Corruccini et al., 1987a, 1987b; Crespo-Torres, 1994, 1998; García-Godoy, 1978; Goodwin and Walker, 1975; Handler et al., 1982; Jacobi et al., 1992; Morbán, 1976, 1980; Rodríguez, 1980; Stewart and Groom, 1968; Tacoma, 1964; Versteeg et al., 1990; Torres and Rivero de la Calle, 1972; Vento, 1984, Vento and González 1999).

Without doubt, during this period of time in the Caribbean region, figures like Adelaide Kendal Bullen, a physical anthropologist from the United States (1908–1987), Manuel Rivero de la Calle (1926–2001), a physical anthropologist from Cuba (Fleitas, 2003: 111–119), and Fernando Luna Calderon (1945–2005), an anthropologist from the Dominican Republic (Taváres, 2006:110–117), were the principal researchers in the area of human osteology with particular interest in paleopathology.

The inter-disciplinary symbiosis mentioned above was first achieved in the Caribbean area by Adelaide Bullen (1964: 13–17) on pre-Colombian human skeletal remains from the Savanne Suazey site on the island of Grenada. In addition to the osteological study of the remains, Bullen introduced a comparative analysis of dental caries between specimens from Grenada and skeletons from coastal Florida. The author noticed a high frequency of dental caries in the Grenada sample, whereas caries is rare in prehistoric skeletal series from Florida. In one such Florida series, with over 100 adult individuals, no carious lesions were observed (Bullen, 1964: 16–17). She suggested that the high frequency of dental caries in the Grenada sample could be explained as a result of the habitual consumption by indigenous groups during the colonial period of foods favored by the Europeans, such as refined sugar. Later, in another work (Bullen, 1968: 45), she suggested that multiple factors, such as genetics, physiology, hygiene, and the environment interact in the high



incident of caries. She proposed more studies to make a comparative and spatial distribution of caries incidence in the pre-Columbian and historic inhabitant of the Caribbean. However, cariogenic lesions are reported in skeletal samples from different pre-Columbian sites in the Caribbean (Crespo-Torres, 1994; García-Godoy, 1978; Morban, 1980; Torres and Rivero de la Calle, 1972). Before the introduction of sugar cane by the Europeans, two important crops consumed by the pre-Columbian inhabitants of the Caribbean were manioc (*Manihot esculenta*) and maize (*Zea mays*), both with a high carbohydrate content.

Bullen's 1964 report on Granada was the first archaeological monograph on the Caribbean to recognize the importance of osteology and paleopathology. She was a trained physical anthropologist, well-versed in the knowledge of method as well as theory, and the use of non-metric and pathology data in synthesis with metric data. In a study conducted on a pre-Columbian burial from the island of Saint Lucia (Bullen, 1970: 45–60), she described the presence of a healed fracture on the right fibula and evidence of osteoarthritis that was also more prevalent on the right side of the individual. Bullen hypothesized that the sidedness in osteoarthritis was due to overcompensation for the injured leg, including the possible use of a crutch.

According to Goodwin (1979: 482), the most significant aspect of Bullen's reports was her attempt at the explanation and use of the comparative method. She identified possible causalities for the observed phenomenon, and placed emphasis on diet and pathology, rather than simply describing the pathological conditions present in the skeletal sample.

Beginning in the 1970s, new methodological and technical approaches were used in the analysis of pathological conditions present in Caribbean skeletal samples. The use of differential diagnosis applied to the gross study of skeletal lesions, and the use of radiographic techniques to complement the diagnosis, facilitated precision and helped to exclude other pathological conditions, syndromes that cause the same bony change, or pseudopathologies caused by taphonomic processes (Campillo, 2001: 77–99; Ortner, 2003: 45–64; Roberts and Manchester, 2005: 7–10). This approach is also present in the studies performed by two recognized Caribbean paleopathologists, Manuel Rivero de la Calle and Fernando Luna Calderon.

In Cuba, interest in the area of paleopathology began with the work of Manuel Rivero de la Calle (1987, 1990; Rivero de la Calle and Vento 1987). In a monograph published in 1987, Rivero de la Calle reported different paleopathological conditions present in the indigenous peoples of Cuba, such as: osteoarthritis, infectious diseases (perostitis, osteomyelitis), congenital anomalies of the skull (macrocephaly), hematological disorders (*criba orbitalia* and porotic hyperostosis), bone trauma, and dental and maxillo-facial pathologies (Rivero de la Calle, 1987: 475–498). In addition, he reported cases of dental modification in skeletal remains from two African slave cemeteries (Rivero de la Calle, 1973). Indeed, the cases of dental modification reported in the Caribbean region are related to skeletal remains associated with individuals who were brought from Africa as slaves between the fifteenth and nineteenth centuries, rather than the

pre-Columbian inhabitants (Crespo-Torres, 2010a, Handler et al., 1982, Schroeder et al., 2012, Stewart and Groom, 1968).

In the mid-1970s, Fernando Luna Calderón published a Spanish language textbook on paleopathology. This atlas (Luna, 1976) basically used illustrations of skeletal materials from collections at the United States National Museum (the Smithsonian Institution). This is an important contribution, because the atlas was not only used in the classroom as a textbook, but also as a guide for archaeologists and researchers interested in paleopathology.

Likewise, Luna (1974, 1977a, 1977b, 1998) also reported similar paleopathological conditions present in skeletal remains from different archaeological sites in the Dominican Republic. In addition, he reported two new paleopathological conditions not previously mentioned in osteological studies of the pre-Columbian inhabitants of the Caribbean. One of these conditions was a possible case of amputation found in the skeleton of a juvenile female from the island of Gonave, Haiti. The amputation was localized at the distal ends of the left tibia and fibula (Luna, 1980: 213–227). The other new condition he reported consisted of vertebral lesions associated with tuberculosis in skeletal remains found at Cueva María Sosa in the Dominican Republic (Luna, 1982).

In relation to the bone fractures, Luna points out that many of the cases reported showed therapeutic treatment, as the Spanish chronicler Gonzalo de Oviedo described in his sixteenth century account. He also mentioned the presence of possible cases of treponematosis in pre-Colombian human remains (Luna, 1977a). This revived the debate about the geographical origin of this pathological condition, since Flower (1895) suggested the possible presence of pre-Columbian treponematosis on the island of Jamaica in the late nineteenth century.

The analysis of dental wear, associated with the use of teeth as tools or for various habits, is reported by some authors in skeletal material from pre-Columbian and historic archaeological sites in the Caribbean region. A particular dental wear pattern associated with a high frequency of caries—known as lingual surface attrition of maxillary anterior teeth or LSAMAT (Turner and Machado 1983; Turner et al., 1991)—was first discovered at the pre-Columbian site of Punta Candelero on the island of Puerto Rico (Crespo-Torres, 1994), and later in the U.S. Virgin Islands (Larsen, 1997: 260–261). This kind of wear is associated with the use of teeth as tools during the preparation of manioc. In addition, some indications of pipe smoking were reported by Handler and Corruccini (1983) in two skeletons from Newton Plantation (1660–1820) on the island of Barbados.

## **TWENTY-FIRST CENTURY: A BIOARCHAEOLOGICAL APPROACH TO PALEOPATHOLOGY STUDIES IN THE CARIBBEAN**

The multidisciplinary perspective present in a bioarchaeological research design integrates biological, cultural, and

environmental variables in the study of human remains from an archaeological context. The integral studies of mortuary practices, ethnohistorical accounts, biological profile (sex, age at death, stature, and morphological characteristic), nutrition, health and activities indicators (paleopathology), intentional body modification, dental morphology, and chemical and biochemical analyses (stable isotope strontium, and DNA), all contribute to the biocultural reconstruction of ancient societies (Buikstra and Beck, 2006; Larsen, 1997).

In many Caribbean islands, the start of the 1990s witnessed a growth in both academic research and cultural resources management (CRM) projects involving the excavation of human remains. During this period, multidisciplinary studies combining the biocultural and bioarchaeological approaches bring a new dimension to the analysis of human skeletal remains from archaeological contexts (Crespo-Torres et al., 2013: 443–445).

Since the early twenty-first century, two events have created opportunities to evaluate more paleopathological conditions present in the pre-Columbian and colonial period inhabitants of the Caribbean archipelago. First, important archaeological sites with multiple human remains have been systematically excavated in different islands such as: Tutu in the U.S. Virgins Island (Sandford et al., 2002; Sandford, 2005; Larsen et al., 2002); Punta Candelero (Crespo-Torres, 1994), Paso del Indio (Crespo-Torres, 2000, 2005a), Río Tanamá (Antón, 2008), Jacana (Espenshade et al., 2014), and Punta Mameyes (Muñoz-Guevara, 2014, 2016) in Puerto Rico; Anse à la Gorde in Guadeloupe (Hoogland and Panhuysen, 2003), and on the island of Saint Martin (Schroeder et al., 2012). Second, skeletal samples from previously excavated sites, or collections housed in academic, private, and government facilities, have been reevaluated in Cuba, the Dominican Republic, Jamaica, Puerto Rico, Trinidad, and the continental United States (Armstrong, 2012; Campillo, 2009; Crespo-Torres, 2010a, 2010b, 2008a, 2008b; Drew, 2009; Mickleburgh, 2012, 2013; Mickleburgh and Pagán, 2012; Muñoz-Guevara, 2013; Roksandic, 2016; Renschler, 2007; Rothschild et al., 2000; Santos et al., 2002, 2012; Schats, 2011). Most of these reports involve the application of standard methods and advanced techniques used in paleopathological analysis to obtain the most accurate differential diagnosis of the lesions present in the skeletal material under study. Such techniques include DNA analysis, stable isotope analysis, paleobotanical studies, and scanning electron microscopy.

Stable isotopes and paleobotany studies have established the principal food sources present in pre-Columbian artifacts, as well as in human skeletal remains associated with various chronological periods in the Caribbean region (Chinique et al., 2016; Mickleburgh and Pagán, 2012; Norr, 2002; Pagán, 2013; Pagán and Oliver, 2008; Pearsall, 2002; Pestle, 2010, 2013; Stokes, 1998, 2005). For example, these studies have established that the high incidence of tooth decay and calculus accumulation exhibited by the ancient inhabitants of the Antilles was due to the consumption of two carbohydrate sources, maize (*Zea mays*) and manioc (*Manihot esculenta*), in addition to marine and terrestrial proteins.

In 1990, a pre-Columbian site known as Tutu was discovered in a central valley on the island of Saint Thomas (U.S. Virgin Islands). A total of 42 human burials from different temporal contexts, identified as early period (Saladoid 450–960 A.D. and late period (Ostionoid 1170–1535 A.D., 2 sigma), were detected at this important archaeological site (Righter, 2002).

A paleopathological study of skeletal remains from Tutu (Sandford et al., 2002: 209–229) indicated that 26 individuals (17 adults and 9 subadults) showed evidence of pathological conditions. Conditions such as the inflammatory processes associated with treponemal infections, metabolic conditions (*Cribra orbitalia* and porotic hyperostosis), osteoarthritic change, bony neoplasm (button osteoma), and antemortem trauma were detected. No evidence of intentional cranial deformation is present in the remains from this site.

An analysis of dental health conditions in these individuals (Larsen et al., 2002: 230–249) detected dental caries (associated with the consumption of manioc), calculus, enamel defects, dental wear (associated with the type of diet and the use of teeth as tools), and activity-related pathology (enthesopathy). According to this study, the Tutu population had relatively poor oral health.

According to the authors of these two studies, the frequency and distribution of bone and dental pathologies present in the skeletal sample from the Tutu archaeological site evolve slightly from the early period (Saladoid) to the late period (Ostionoid). Results suggest that they are associated with dietary and ecological changes.

An important pre-Columbian site known as Paso del Indio is located on the west bank of the Indio River in the northern town of Vega Baja, Puerto Rico, 5 kilometers south of the Atlantic coast, and 156 kilometers west of the Tutu Site. Between 1993 and 1995, a large-scale data recovery excavation was conducted at Paseo del Indio (Walker, 2005). A total of 151 human burials from a chronological context identified as Ostionoid (633–1356 A.D. as detected at this site (Crespo-Torres, 2000; Pestle, 2010). Nevertheless, only 129 individuals (62 adults and 67 subadults) were available for osteological analysis.

A paleopathological study of the skeletal materials from Paso del Indio (Crespo-Torres, 2000, 2005a, 2008b), revealed most of the same pathological conditions reported from the Tutu site. A total of 41 individuals (23 adults and 18 subadults) showed clear evidence of dental diseases, inflammatory processes, treponemal infections, metabolic conditions, osteoarthritis, activity-related pathology (enthesopathy), and antemortem trauma. However, unlike the Tutu sample, intentional cranial deformation is present in the ancient inhabitants of Paso del Indio.

The frequency and distribution of pathological conditions and high mortality rate in subadult samples at Paso del Indio are strongly associated with the conditions of drastic environmental change that affected the site in different periods. A geomorphological study done at Paso del Indio (Clark et al., 2003) confirmed that periodic floods constituted the major depositional process at the site, and that the frequency and intensity of flooding varied during different periods of occupation.

Clark and his colleagues state that the flooding probably did not endanger many lives, but they feel that during those periods when flooding was more frequent it probably caused substantial damage to residence, loss of property, severe disruption of village life, and interruptions to subsistence activities such as agriculture (Clark et al., 2003: 646). Without doubt, the destructive effects of these catastrophic flood events on cultivated crops promoted the physiological stresses observed in the teeth and bones of the inhabitants of Paso del Indio, specifically in the subadult sample (Crespo-Torres, 2000: 189–190; 2008b: 20).

In 1986 and 1987, major excavations were conducted under the direction of the Cuban archaeologist José Guarch Delmonte at the site known as El Chorro de Maíta (Guarch Delmonte, 1996). This important archaeological site is located in the province of Holguín in eastern Cuba, approximately 4 kilometers from the Atlantic coast.

According to archaeological research, El Chorro de Maíta was populated from the thirteenth century to the first half of the sixteenth century. Recovered artifacts, mortuary practices, and radiocarbon dating indicate that the individuals buried in this archaeological site lived and died under the Spanish encomienda system (Weston and Varcárcel-Rojas, 2016). In other words, it is an important and unique archaeological site in the Caribbean region, where the skeletal samples represent the indigenous people who had direct contact with the first Europeans to arrive in the Americas.

The El Chorro de Maíta skeletal population consists of 133 individuals (83 adults and 50 subadults). Forty-two individuals showed signs of skeletal pathology, included non-specific inflammation or infection, degenerative joint disease, trauma, congenital conditions, neoplasm, and activity-related pathology (enthesopathy) (Weston and Varcárcel-Rojas, 2016: 92–95). On the other hand, 82 individuals (66 adults and 16 subadults) with preserved teeth and jaws demonstrated some form of dental pathology, including antemortem tooth loss, caries, calculus, periodontal disease, enamel hypoplasia, supernumerary teeth, hypercementosis, and extreme wear (Weston and Varcárcel-Rojas, 2016: 95–96).

According to Weston and Varcárcel-Rojas (2016:104), the examination of bones and teeth revealed no evidence of trauma, and no systematic evidence of wide-spread malnutrition in the skeletal sample. This contradicted the paradigm that the indigenous were victims of violence, overwork, poor nutrition, and disease due to their subjugation by the Europeans during the colonization process, at least, at the El Chorro de Maíta archaeological site.

It is clear that most of the pathological conditions present in the three archaeological sites mentioned above are endemic from the pre-Columbian period to the first decade of European colonization in the Caribbean archipelago.

Finally, it is important to point out that the lack of bony response seen in the majority of individuals from Tutu, Paso del Indio, and El Chorro de Maíta, indicates they died as a consequence of pathological conditions that leave no evidence on the

skeleton. I agree with Weston and Varcárcel-Rojas (2016: 103) that this is the hallmark of the “osteological paradox,” where individuals without bony lesions are considered less healthy or weaker, and those with lesions are considered healthier because their immune systems were able to sustain a response to the disease (Wood et al., 1992). This suggests that new methodologies are needed for the analysis and interpretation of health conditions in ancient populations (Byers and Roberts, 2003; Van Schaik et al., 2014).

## CONCLUSIONS

The principal aims of this chapter are to present the hallmarks of paleopathological research, and the experts who made important contributions to the paleopathological studies of human skeletal materials from the pre-Columbian and historic periods in the Caribbean archipelago. According to this review, interest in the health conditions of the indigenous inhabitants in this geographic region began 40 years ago and continues to grow. This review also highlights the absence of paleopathological studies from Haiti, which is most probably associated with the turbulent social and economic history that the country has suffered since its independence.

Evidence of different pathological lesions has been reported since the nineteenth century, such as: non-specific and specific infectious diseases (periostitis, osteomyelitis, treponematosi, and tuberculosis) (Figures 1 and 2), joint disease (osteoarthritis) (Figure 3), metabolic disease (porotic hyperostosis, *criba orbitalia*, osteoporosis) (Figure 4a,b), congenital disease (spina bifida and macrocephaly) (Figure 5), dental diseases (Figure 6), trauma (bone fracture and amputation), and intentional body modification (cranial and dental) (Figures 7 and 8).

The number of paleopathological studies performed in the Caribbean region is relatively small when compared to other geographic areas, but they make the international scientific community aware of the pathological conditions affecting the pre-Columbian and historic populations of the Caribbean archipelago.

It is important to point out that the identification of bone pathologies is not an easy task, especially in the Caribbean region, because, taphonomical events are one of the best enemies to the preservation of ancient skeletal material. In the Caribbean region, these include soil and rock acidity, root modification, and bioturbation. This situation requires the practitioner to have vast experience, trained eyes, and the knowledge of methods and techniques employed in paleopathological analysis to avoid diagnostic errors (pathology versus pseudopathology).

Finally, future discoveries of skeletal remains and reevaluations of skeletal collections could contribute to the development of more comparative studies in the area of paleopathology, in order to reconstruct diachronic and synchronic regional similarities or to differentiate between the pre-Columbian and historic period inhabitants of the Caribbean archipelago.



FIGURE 1. Osteomyelitis in left tibia. Adult male. Paso del Indio site, Puerto Rico (600–1200 A.D.).



FIGURE 2. Treponematosi. Cranial vault exhibit granulomatous lesions or *caries sicca*. Adult female. Paso del Indio site, Puerto Rico (1102 A.D.).



FIGURE 3. Osteoarthritis. Note porosity and eburnation of joint surfaces of the left radius. Adult male. Puerto Ferro site, Puerto Rico (1900 B.C.).



FIGURE 4. (a) Porotic hyperostosis; (b) *Cribræ orbitalia*. Subadult. Paso del Indio site, Puerto Rico (600–1200 A.D.).



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FIGURE 5. Spina bífida. Adult male from Puerto Rico (eighteenth century).

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FIGURE 6. Caries, periapical abscess, dental wear, and antemortem tooth loss. Adult male. Paso del Indio site, Puerto Rico (600–1200 A.D.).

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FIGURE 7. Frontal-occipital intentional cranial modification. Adult male. Paso del Indio site, Puerto Rico (600–1200 A.D.).



FIGURE 8. Two cases of intentional dental modification from Puerto Rico (eighteenth–nineteenth centuries).

## ACKNOWLEDGMENTS

I would like to express my deep gratitude to Sonia E. Colantonio and Douglas H. Ubelaker for the invitation to contribute to this volume and also to the reviewers for their editing and comments on the manuscript. Special thanks to my anthropology student Iulianna Rosario for the translation of the abstract into Portuguese.

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# 16

## Biodemography of the Caribbean Populations

*Vanessa Vázquez Sánchez*

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**ABSTRACT.** Biodemography, a subfield of biological anthropology, has seen a surge in research activity during the last few years, fundamentally in the United States and Europe, and somewhat less in the Caribbean. This chapter provides an overview of the discipline and its two main branches: biomedical demography and biological demography, along with the historical development of the field at the international level. The demographic transition in some Caribbean countries is described, with an emphasis on Cuba, with analysis of fertility and mortality rates. As an example of biodemographic research, the chapter also offers a case study of biological fitness in the population of the Plaza de la Revolución, an urban municipality in the capital city of Havana. This study describes the chances of natural selection over two generations and demonstrates how the practice of abortion negatively influences both the reproductive health and the viability of the population.

**RESUMEN.** La Biodemografía es uno de los campos de la Antropología biológica con un aumento de las investigaciones en los últimos años, fundamentalmente en Estados Unidos y Europa, siendo menos frecuentes en el Caribe. En el capítulo se abordan las generalidades de la biodemografía, con sus dos ramas principales: la demografía biomédica y la demografía biológica, así como el desarrollo histórico de esta disciplina a nivel internacional. Se describe la transición demográfica en algunos países del Caribe, con énfasis en Cuba y se analizan las tendencias de las tasas de fecundidad y mortalidad. Finalmente se expone un ejemplo de investigación biodemográfica en Cuba, con un estudio de caso sobre eficacia biológica de población residente en el municipio urbano Plaza de la Revolución, en La Habana, donde se aborda además la intensidad de acción de la selección natural en dos generaciones. Los resultados evidencian la influencia de la práctica de aborto provocado en la baja fecundidad y eficacia biológica de dicha población.

**RESUMO.** Biodemografia é um dos campos da Antropologia biológica com um aumento das investigações nos últimos anos, fundamentalmente nos Estados Unidos e Europa, sendo menos frequente no Caribe. No capítulo são abordadas as generalidades do biodemografia, com os dois principais temas: a demografia biomédica e a demografia biológica. Também se descreve o desenvolvimento histórico desta disciplina a nível internacional. A transição demográfica é descrita em alguns países de Caribe, com ênfase em Cuba e as tendências das taxas de fecundidade e mortalidade são analisadas. Finalmente um exemplo de investigação de Biodemografia está exposto em Cuba, com um estudo de caso sobre na efetividade biológica de população a municipalidade Plaza de la Revolución, em Havana onde também é chegado a intensidade oportunidade da ação da seleção natural com uma análise geracional. Os resultados comprovam a influência da prática de aborto induzida na baixa fecundidade e efetividade biológica desta população.

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

### **OVERVIEW OF BIODEMOGRAPHY: HISTORICAL DEVELOPMENT**

Biodemography is a modest subfield of biological anthropology; however, the level of research activity has increased in recent years. This chapter will explore the two main branches of biodemography: (1) biomedical demography, which includes investigations

directly related to health, and (2) biological demography, or research that involves a close relationship between demography and biology (Carey and Vaupel, 2005).

The area of biomedical demography links demography and epidemiology. Demographers focus on the way diseases affect the structure and dynamics of populations, while epidemiologists are concerned with the etiology, prevention, and cure of diseases. On the other hand, biological demography is an interdisciplinary view that integrates biological concepts with demographic approaches from an evolutionary and ecological perspective. Those topics include fertility, migration, and mortality, with an emphasis on issues such as aging and longevity.

Biological demography reconstructs the genetic structure of present and past populations, the mechanisms which have influenced their structure and their change through time. It is based on information provided by demography, integrating statistical data with a biological explanation of population dynamics (Sánchez Compadre, 2001, Colantonio and Fuster, 2006). Scientific contributions were few before 1960. Research has addressed mainly the growth and distribution of populations. In terms of processing data, a pioneering study by Valls (1960) concerned the degrees of consanguinity and kinship in Spanish regions.

Before 1970 there was sparse literature addressing the integration of biology and demography. Some works related to population studies have linked demography with ecology (Frank, 1959), anthropology (Spuhler, 1959), and genetics (Kallmann and Rainer, 1959). Carey and Vaupel (2005) performed a historical analysis of the main biodemographic studies pursued in the United States. In turn, Sánchez Compadre (2001) conducted a review summarizing the main investigative efforts in Europe, principally in Spain and Portugal. This author underscores the fact that the more focused topics are: fertility, marriage patterns, effective family size, mortality, incidence of multiple pregnancies, longevity, sex ratio, migration, and the estimation of natural selection and genetic drift. Such studies have been performed on both historical and modern populations.

A focus on biomedical demography has emerged in recent decades. Research is based on the accumulation of data such as physical measurements (weight and height), physiological traits (blood pressure, cholesterol levels), nutritional status, and physical and genetic markers derived from DNA analysis. These measurements have been used as variables in demographic analysis, along with other economic, social, and cultural variables.

In particular, there is a growing interest in the use of genetic information, both in medical and demographic investigations, to determine the genetic structure of a population and to make inferences about the influences of migration and inbreeding. The main objective of those “molecular demographic studies” is to identify genetic polymorphisms affecting morbidity, mortality and fertility. Other emerging areas in biodemographic research are: evolutionary demography, genetic and genomic demography, ecological demography, and paleodemography. Carey and Vaupel (2005) summarized the major sub-areas of biodemographic research in three levels of biological organization: molecular and physiological, individual and cohort, and population

and evolutionary processes. These levels indicate the complexity of the fields and the potential synergies of interdisciplinary research.

In summary, both branches of biodemography, biomedical and biological, are areas of increasing growth and development. Not only can demographers learn from biologists and epidemiologists, but they can also contribute to research about population health.

## CARIBBEAN BIODEMOGRAPHY

In the Caribbean region, biodemography has not developed along the same lines as those that Carey and Vaupel (2005) present for the United States and Sánchez Compadre (2001) demonstrates for Europe. Caribbean research efforts have been of a pure demographic nature, like the Demographic and Health Survey (DHS) which was conducted in several Caribbean countries, such as Haiti and the Dominican Republic.

Funded primarily by the U.S. Agency for International Development (USAID), the DHS is administered by Macro International, Inc., based in Maryland, USA. One of the most significant contributions of the DHS program is the creation of an internationally comparable body of data comprising the demographic and health characteristics of populations in developing countries. This data set includes specific topics such as contraceptive knowledge, use, and sources, maternal and child health, and other issues related to sexual and reproductive health. The DHS compiles data from women aged 15–49 years old and tracks them along with their descendants (Curtis and Neitzel, 1996).

In Cuba, in the late 1980s, an interest in biodemographic studies began to emerge due to academic exchanges with European researchers. Since 1988, the Physical Anthropology Symposia in honor of Luis Montané have been conducted in Havana. After 1998, these symposia were conducted in 2001, 2003, 2005, 2007 and then every four years, in 2011 and 2015. At the last three sessions, topics have expanded, and the international convention “Anthropos” has convened simultaneously at the Palace of Conventions in Havana. The evolution of biodemographic topics covered in these Caribbean symposia is described below.

In the second Symposium on Physical Anthropology in honor of Luis Montané in 1990, more genetic approaches were introduced focusing on endogamy, inbreeding, and isolation in a Cuban population who live in the mountainous region of Yateras, Guantánamo province, in the eastern part of the country. The population reflected in the study had high endogamy and a rate of inbreeding higher than 2% (Tejedor et al., 1990). In the third Symposium in honor of Luis Montané, a demographic anthropology session was held, in which the research of Tejedor et al. (1992) correlated marriages and geographical distances with the birth places of mates in three Cuban parishes during the eighteenth and nineteenth centuries.

For the first time, in 1998, two sessions of biodemography were presented and included presentations from Brazil, Argentina, Mexico, Uruguay, Easter Island, and Spain, but none from

the Caribbean. The same applies to the two sessions devoted to the genetics of Latin American populations, which included investigative reports from Brazil, Venezuela, Uruguay, Costa Rica, and Argentina.

In the international convention “Anthropos 2011,” a session on anthropology, biodemography, and reproduction was arranged, in which several presentations covered topics of sexual and reproductive health in neighborhoods of Havana (Díaz, 2011; Acosta and Vázquez, 2011; Vázquez et al., 2011a). Also discussed were relationships in two rural communities in Cuba, both showing high rates of endogamy and inbreeding, and additional male immigration (Rodríguez, 2011)

In addition to the papers presented at the symposia in Cuba, a few articles that referred to the biodemography of Caribbean islands were published. Brittain (1991) studied child-to-woman ratios in Saint Vincent and the Grenadines reporting low child-to-woman ratios, with an increase in the loss of children related to migration.

In the last fifteen years, *Biodemography and Social Biology*, the official journal of the Biodemography and Social Biology Society of the United States, has published only three studies from the Caribbean, all from Puerto Rico. These included Oropesa et al. (2001), on poverty, prenatal care, and child health; Gorman et al. (2001), on poverty and childcare; and Palloni et al. (2005), which addresses the relationship between health conditions and nutrition in childhood, and the prevalence of obesity, diabetes, and cardiovascular disease in adulthood. These articles may be classified as biomedical demography, and all are based on the use of surveys.

The population of Haiti has been studied by many researchers from a demographic point of view. Inquiries emphasize poverty, infant mortality, consensual unions and marriages, cultural barriers to contraception, and other factors (Maynard, 1996). Another widely discussed issue is the migration of Haitians to various Caribbean and Latin American countries.

Although there are few biodemographic publications in the Caribbean, there are considerable demographic data available provided by various international institutions such as the Latin American Demographic Center (CELADE), the Economic Commission for Latin America (CELAC), and the Pan American Health Organization (PAHO), among others. For example, the Statistical Yearbook for Latin America and the Caribbean, published by the United Nations and CELAC, provides valuable data organized by country: social statistics, population, employment, education, health, housing and basic services, poverty and distribution income, gender, and other economic and environmental statistics. This information can be used by researchers to conduct biodemographic research.

## DEMOGRAPHIC TRANSITION IN THE CARIBBEAN

Demographic transition is a process that takes place between two extreme conditions: the first is an initial phase of

low population growth coupled with high rates of mortality and fertility, and the second is the final phase of low population growth, but with low rates of fertility and mortality. We can identify two main stages: first, the decline in mortality, and then a subsequent decline in fertility. The extent to which these changes affect the rate of population growth will depend on the speed and time it takes for mortality and fertility to begin to decrease. In developed countries, the transition related to health improvement, technological development, and scientific-technical development took place first, in relation to modernization (Chesnais, 1986).

Caribbean countries have experienced profound demographic changes over the past century. Rapid population growth has given way to the gradual decline in mortality and fertility as expressions of an accelerated process of demographic transition. The Latin American Demographic Center proposes a classification of Caribbean countries by mortality levels, measured from life expectancy at birth (E0) and fertility, in relation to the total fertility rate (TFR), as shown in Table 1.

Haiti is the lagging country in terms of demographic transition. At the opposite end of the spectrum are Cuba and Barbados with the best indicators, followed by Guadalupe, Puerto Rico and Martinique, which have low fertility and mortality with low population growth (CELADE, 2008). Cuba is the most advanced country in terms of demographic transition, compared to other Latin American and Caribbean countries, mainly due to fertility levels that have fallen below replacement since 1978, that is, due to a TFR lower than 2 children per woman.

Cabrera (2011) conducted an analysis of demographic transition from 1950 to 2010 in some Caribbean countries, selected according to the availability of statistical data. This author concludes that the total fertility rate has a marked downward temporal trend, which began to register in most countries starting in the 1970s. In the case of the Dominican Republic, from 2005 to 2010, women had 2.55 children on average. Cuba, Trinidad and Tobago, and Puerto Rico, at the end of this period, show fertility rates below replacement level. In terms of life expectancy at birth from 1950 to 1955, Cuba, Jamaica, and Barbados had values over 55 years; the values for Suriname and Saint Lucia were around the same, while the Dominican Republic lagged behind with a value close to 45 years of age.

The child mortality rate is perhaps the best indicator of disparities in the area. The period of 1995–2000 shows values of 41.3 and 41 deaths per 1,000 live births in the Dominican Republic and Granada, respectively. At the same time, Cuba and Puerto Rico had better levels (below 10 deaths on average). The other countries oscillated between 28 (Saint Vincent and the Grenadines) and 13 deaths (Barbados). The 2005–2010 period continued showing disparities, although it is important to note that values decreased in all countries considered.

Demographic transition theory is applicable to the countries of the Caribbean, but one must keep in mind that each of them presents different historical, economic, and social conditions. The most outstanding feature of these processes in the region is the great heterogeneity in terms of incomes, health systems, and

TABLE 1. Caribbean countries according to levels of total fertility rate, life expectancy at birth, and natural growth rate 2005–2010.<sup>a</sup>

Total fertility rates (TFR)	Mortality levels E <sup>0</sup> = life expectancy at birth			
	Low E <sup>0</sup> <66	Moderate 66=< E <sup>0</sup> <71	Intermediate 71=< E <sup>0</sup> <76	High 76=< E <sup>0</sup> <81
Moderate 4.5>TFR=>3.5	Haiti, 1.85			
Intermediate 3.5>TFR=>2.5			French Guyana, 2.02; Dominican Republic, 1.75	
Low 2.5>TFR>1.5		Suriname, 1.26; Guyana, 0.87; Trinidad and Tobago, 0.67	Jamaica, 1.28; Saint Lucia, 1.25; Netherland Antilles, 0.46; Bahamas, 0.11	Guadalupe, 0.84; Puerto Rico, 0.57; Martinique, 0.48
Very low TFR=<1.5				Barbados, 0.40; Cuba, 0.29

<sup>a</sup>Source: Centro Latinoamericano y Caribeño de Demografía Latin American and Caribbean Demographic Center [CELADE] (2008).

educational levels, that is reflected in the different rates of fertility, child mortality, and life expectancy.

### THE DEMOGRAPHIC TRANSITION IN CUBA

The low fertility rate in Cuba has affected population growth, and is related to a population of seniors who have aged beyond 60 years old. The decrease in fertility which started in 1978 continues today. The country serves as an example of progress in education, health, safety, and welfare, along with profound changes in the status of women, who have been integrated into the labor market. This exemplifies an unprecedented process among developing countries and particularly within the Caribbean region. In turn, this process has been accompanied by a high incidence of abortion (Alfonso, 2006).

Cuba is 1 of 35 countries with birth rates between 10 and 14 births per 1,000 inhabitants, along with European and other Latin American countries, including Argentina, Chile, and Uruguay. Cuban population growth in recent years has shown rates below 1%. Other related factors are the presence of a negative migration balance and low rates of child mortality, below 5 deaths per 1,000 live births (Gran and López, 2003)

According to the most recent population and housing census, conducted in 2012, the TFR in Cuba was 1.69 children, with 18.3% of the population over the age of 60 years old (ONEI, 2014a). The census also emphasized a high life expectancy, with figures of 80.45 years for women, and 76.5 years for men during the 2011–2013 period (ONEI, 2014b). Those factors

demonstrate that Cuba is one of the most advanced countries in Latin America and the Caribbean in terms of demographic transition.

### BIODEMOGRAPHY IN CUBA: A CASE STUDY ON BIOLOGICAL FITNESS IN THE RESIDENT POPULATION OF PLAZA DE LA REVOLUCIÓN, HAVANA

The Center for Demographic Studies (CEDEM) at Havana University was established on February 9, 1972. In this academically acclaimed center, investigations regarding the composition and dynamics of the Cuban population are conducted, addressing relationships between development, population, and environment. CEDEM maintains its national leadership and has also achieved a prominent position in demographic circles in Latin America and the Caribbean region, but no biodemographic research is conducted there. This work is carried out by the Montané Anthropological Museum (overseen by the Faculty of Biology) at Havana University.

In most countries, biodemographic research focuses on regions with certain geographic isolation. However, in the case of Cuba, the biodemographic perspective was introduced in the urban municipality Plaza de la Revolución, in the capital city of Havana, which has the lowest fertility rate and highest percentage of population over the age of 60 in the country (ONEI, 2014b).

This area has received special attention since the early 1970s. In 1972, a fertility survey in the region was conducted,



in which 1,751 women aged between 15 and 54 years old were interviewed. A comparison of their fertility rates with those of women in various Latin American cities revealed that fertility was lower in Plaza de la Revolución than in all considered cities (1.84 children per woman between 20 and 54 years old), with the exception of Buenos Aires (Argentina), where the TFR was 1.49 children per woman between 20 and 54 years old (Álvarez and Rubén, 1973, 35).

The decline in the birth rate in Plaza de la Revolución has been sustained overtime. Thus, the rate of 10.2 births per 1,000 reported in 1997 dropped to 6.33 in 2007 (ONE, 1998; ONE, 2008a). Cuba's National Statistics Office has conducted an analysis of the typology in provinces and municipalities according to their total fertility rate in the 2005–2007 period. The fertility rate in Plaza de la Revolución was extremely low, with a TFR of 1.04 children per woman, the lowest throughout Cuba (ONE, 2008b).

Specific biodemographic research was introduced in Cuba by Vázquez (2010) with the main objective of characterizing the biological fitness of the population residing in Plaza de la Revolución. Information was obtained through interviews about reproductive history, conducted between March 2007 and October 2008, as part of a retrospective, descriptive, and transversal methodology. The interviewees represented a cohort of 1,200 resident women born in the period between 1942 and 1953, aged between 55 and 64 years. The age range was chosen to ensure that they were all post-menopausal. The sampling method was random and stratified women into seven municipal clinics.

The study showed that 1,200 women yielded 4,579 pregnancies but only 2,276 were born alive. The pregnancy rate in women was 3.81 with a rate of only 1.89 live births, an approximate 50% decrease due to the high frequency of abortions. On average, 1.83 children per woman survived to age 15. Compared with the initial number of pregnancies, this implies that the biological fitness of this population is low due to the small number of offspring that reach reproductive age, because 61% of women underwent abortions.

One aspect that has been addressed in biodemographic research is the estimation of the intensity of natural selection (Luna and Moral, 1990). This aspect has been under-investigated in Caribbean population research. To measure the intensity of natural selection in Plaza de la Revolución, Vázquez et al. (2011b) used: the Crow (1958) selection index (I), the selection index corrected (Ic) (Johnston and Kensinger, 1971), which takes into account prenatal mortality (spontaneous miscarriages and fetal deaths), and a corrected selection index (I<sub>tc</sub>), which includes abortions. The results show that natural selection acts more on differential fertility, which is consistent with low fertility (1.89 live births). Moreover, low levels of child mortality diminish the effect of the mortality after birth.

The post-partum probability of survival to reproductive age is very high. The opposite occurs with the pre-birth statistics since abortion increased prenatal mortality. Genetic transmission became complex, so the intensity of natural selection increased

considerably. The use of abortion as a birth control method, and its recurring practice, is evident in other Cuban population studies (Gran et al., 1996; Castañeda and Molina, 1999; Gran, 2005; Rodríguez, 2013).

Vázquez and Daudinot (2014) compare indexes for natural selection in two generations of women living in Plaza de la Revolución, in order to analyze the impact of low fertility on the viability of the population with a generational perspective. Data were obtained from interviews about the reproductive history of two cohorts: one of 22 women, between 58 and 64 years old, and the other, their 25 menopausal daughters, who were older than 44 years of age. Data were also collected concerning mortality and surviving offspring, from the first embryonic stages until the age of 15. Both the Crow index and the corrected index proposed by Johnston and Kensinger (1971) were used. According to the Crow index, in both generations, natural selection acts more through the differential fertility rate in conjunction with the drop in fertility, due to the practice of birth control. The index proposed by Johnston and Kensinger shows that daughters depend more on the use of abortion than their mothers, and as a consequence, have a higher value on the corrected selection index. Thus, the intensity of natural selection is also linked to high prenatal mortality as a result of abortion. The use of contraceptives, as well as the voluntary interruption of pregnancy, affects both fertility and prenatal mortality. Postnatal mortality contributes less to natural selection, because most of the deaths take place prior to birth.

Finally, it is difficult to compare Cuban biodemographic investigations with those of other Caribbean countries because such studies are not abundant outside of Cuba, and because it is difficult to obtain records and statistical data since abortion is legal and unrestricted only in Puerto Rico, French Guyana, Guyana, and Barbados (Guillaume and Lerner, 2007). In Cuba, abortion is legal and has been performed safely since 1965. This contributes to the lower fertility rate and helps to explain why Cuba is one of the most advanced countries in demographic transition in the region. An emphasis on biodemographic research continues to be important in Cuba, in order to analyze the impact of abortion in population replacement and genetic transmission.

## FINAL THOUGHTS

Despite the intensification of research in biodemography, such studies are uncommon in the Caribbean, where purely demographic investigations and biomedical and epidemiological views predominate. In Cuba, anthropological research has emphasized historical demography, specifically in studies using parish registers from the seventeenth, eighteenth, and nineteenth centuries, and in others focused on genetics and population structure. In the twenty-first century, investigations have considered fertility, abortion, and marriage in contemporary populations. It is necessary to promote further research in biological

demography in this region to better understand the dynamics and structure of present and past populations.

#### ACKNOWLEDGMENTS

This chapter could not have been possible without the guidance and translation assistance of Douglas Ubelaker, Sonia Colantonio, and Michael Schnepf (University of Alabama). Many thanks to all of them.

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# History of Population Genetics in Northwestern South America

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**ABSTRACT.** This chapter will address the most important aspects of the history and development of population genetics in the northwestern region of Latin America, which includes the countries of Colombia, Ecuador, Peru, and Venezuela, and will focus exclusively on the use of genetic polymorphisms. The approach is based on the evolution of laboratory techniques to detect polymorphisms at different biological levels: immunological techniques and electrophoresis, to detect phenotypic polymorphisms of blood groups and proteins, and molecular techniques, to detect variability at the DNA level. This chapter summarizes the incorporation of both types of techniques in the research of these different countries to describe their populations. The information was obtained from the most relevant and pioneering scientific publications in each country. The review concludes that the technical requirements of these studies have been better confronted by Colombia, where a greater number of research groups, modernly equipped, have appeared which has allowed an autonomous development of population genetics. In Ecuador, Peru, and Venezuela, advancement in population genetics research has been slower and less generalized, with occasional external collaborations. However, efforts are being made in these countries to accommodate the new trends in population genetic research.

**RESUMEN.** Se presenta una revisión histórica sobre el desarrollo de la genética de poblaciones en Colombia, Ecuador, Perú y Venezuela, que conforman el nor-occidente de Suramérica. El enfoque se hace a partir de la evolución de las técnicas de laboratorio que permiten detectar polimorfismos a diferentes niveles biológicos: técnicas inmunológicas y de electroforesis para detectar polimorfismos fenotípicos de grupos sanguíneos y proteínas, y técnicas moleculares, que detectan la variabilidad directamente en el ADN. Se resume sobre la incorporación de ambas técnicas en los diferentes países para describir genéticamente sus poblaciones. La información se obtuvo a partir de las publicaciones científicas pioneras y las más resaltantes en cada país. La revisión realizada permitió concluir que las exigencias técnicas de este tipo de estudios han sido mejor enfrentadas por Colombia, donde se ha desarrollado un mayor número de grupos de investigación modernamente equipados, que ha permitido un desarrollo autónomo de la genética de poblaciones. En Ecuador, Perú y Venezuela, el ritmo de las investigaciones ha sido más lento y menos generalizado, con colaboraciones externas ocasionales; sin embargo, se han hecho esfuerzos en acompañar las nuevas tendencias de este tipo de estudios.

**RESUMO.** Uma revisão histórica do desenvolvimento da genética de populações na Colômbia, Equador, Peru e Venezuela, que formam a noroeste da América do Sul é apresentado. A abordagem baseia-se na evolução das técnicas de laboratório para detectar polimorfismos em diferentes níveis biológicos: técnicas de eletroforese e imunológicas, que detectam polimorfismos de fenótipos de grupos sanguíneos e proteínas, e técnicas moleculares, que detectam a variabilidade direta

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

no ADN. Se resume a incorporação destas técnicas em diferentes países para descrever suas populações. As informações foram obtidas a partir das publicações científicas pioneiras e mais relevantes em cada país. A revisão levou à conclusão de que os requisitos técnicos de tais estudos têm sido melhor enfrentados na Colômbia, que desenvolveu um maior número de grupos de pesquisa modernamente equipados, o que permitiu um desenvolvimento autônomo da genética de populações. No Equador, Peru e Venezuela, o ritmo das pesquisas tem sido mais lento e menos generalizado, com colaborações externas ocasionais; no entanto, foram feitos esforços para acompanhar as novas tendências neste tipo de estudo.

## INTRODUCTION

The development of population genetics as a scientific discipline in Latin America can be approached from two different points of view: the use of genetic polymorphisms or the use of inbreeding studies. This chapter will address the most important aspects that describe the history and development of population genetics in the northwestern region of Latin America, which includes the countries of Colombia, Ecuador, Peru and Venezuela. Discussion will focus exclusively on the use of genetic polymorphisms, due to important technological developments in the last decade.

Enhancements in the description and understanding of human genetic variation since the development of cell biology techniques have led to research combining population genetics and biological anthropology. Immunological techniques marked the beginning of such studies. The prospect of studying evolutionary theories and describing the distribution of alleles of different blood groups drew the attention of geneticists from the United States, who became interested in studying the native populations of South America. Thus, population genetics in Latin America has its formal beginning in the mid-twentieth century. This gave rise to a combined effort between anthropologists and geneticists in different countries, who conducted hundreds of expeditions to study many indigenous communities, resulting in the subsequent discovery of important genetic variability in these populations. Between the years 1940–1965, numerous South American indigenous populations were investigated, especially in the Amazon basin and the Andean region.

## THE BEGINNINGS

The first population genetics studies in northwestern South America were reported in the 1940s, and they targeted the indigenous communities of Colombia. These studies were focused on blood groups and protein polymorphisms and they not only mark the beginning of population genetics in that country, but also in the region (Arcila, 1943; Duque, 1944; Páez and Freudenthal, 1944; Reichel-Dolmatoff, 1949). However, the zenith in this first phase of development of population genetics occurred in Venezuela. Pioneers and leading representatives of this scientific discipline—the researchers M. Layrisse, Z. Layrisse, and

T. Arends from the Venezuelan Institute for Scientific Research (Instituto Venezolano de Investigaciones Científicas, IVIC), and A. Diaz Ungría from the Central University of Venezuela, in collaboration with Americans J. Wilbert, H. Gershowitz and J. Neel, described allele frequencies for different blood groups and proteins in the indigenous communities of the Venezuelan Amazon, in indigenous groups along the border with Colombia (in the state of Zulia), and in a few mestizo (descendants of people with different ethnic origins) populations (Layrisse and Layrisse, 1959; Layrisse et al., 1958, 1960, 1961, 1973; Díaz Ungría, 1963, 1966). An important discovery that marks genetic studies at that time is the Di\*A allele of the Diego blood group, reported in a descendant of a Venezuelan indigenous group by Layrisse et al. (1955). This new antigen was associated with Native American ancestry and, after numerous studies on indigenous peoples throughout the Americas and on individuals from other continents, it was concluded that this was a genetic marker of Asian origin for Native Americans (Layrisse and Wilbert, 1999). On the other hand, Arends became a pioneer in the study of abnormal hemoglobins in the northwestern region of South America, directing his research to the Venezuelan mestizo populations (Arends, 1961b; 1963a; 1971; Arends et al.; 1990) and collaborating significantly with researchers from other countries, including A. Restrepo of Colombia (Arends, 1963b; Restrepo, 1965; 1971; Salzano and Bortolini, 2002).

The first studies based on Amerindians from Ecuador and Peru were published in the 1960s (Matson et al., 1966a; 1966b; Johnston et al., 1969). However, these cannot be considered hallmarks of the beginning of population genetics in these countries, since these investigations were conducted by foreign groups. In Colombia, after the pioneering studies of the early 1940s, reports are scarce (Arends, 1961a; Kirk et al., 1974), and it can be stated that a new stage in population genetics begins in Colombia with studies in abnormal hemoglobins led by A. Restrepo (Restrepo, 1965; 1971).

The first graduate programs in human genetics in the region (although they were primarily medically oriented), were created in the late 1970s. This marked the beginning of institutional training for professionals in Colombia under the direction of E. Yunis, and in Venezuela under the direction of S. Arias. Subsequently, in Colombia, other centers arose where population genetics was studied, such as those established at the University of Antioquia (Bravo, 1995; Bravo et al., 1994; 1996), the National University of Colombia in Bogotá (Yunis et al., 1995a, 1995b; 1996a; 1996b; 1996c) and the Pontifical Javeriana University. This last institution led the foundation of the “Human Expedition” national project (1983–1993), directed by J. Bernal in collaboration with other institutions, including the Los Andes National University, the University of Caldas, and the Universidad del Rosario. The main results of this project were published in genetics journals, the Colombian journal *América Negra* and the series *Libros terrenos de la gran Expedición Humana*, edited by J. Bernal. In 1993 and 1994, the Institute of Genetics at the National University of Colombia in Bogotá and the Molecular

Genetics Group (GENMOL) at the University of Antioquia were created; the latter with the support of the Colombian geneticist Andrés Ruiz-Linares, who is now at University College, London, UK. Both events mark an important development in molecular genetics in this country, with a significant influence on the genetic studies of Colombian populations.

Through the years 1960–2000, though with a more modest development than that of Colombia, several studies appear in Venezuela, Ecuador, and Peru concerning admixed populations. In Venezuela, the field of population genetics developed at the Venezuelan Institute for Scientific Research (IVIC). Important studies include those conducted by Z. Layrisse in admixed populations with the major histocompatibility complex (HLA) (Layrisse et al., 1976; Mickelson et al., 1982; Simonney et al., 1985; Makhatadze et al., 1997; Rivera, 1998), and the genetic studies of African-derived populations of D. Castro de Guerra in collaboration with M. C. Bortolini and F. Salzano from the Department of Genetics, Federal University of Rio Grande do Sul, Brazil (Castro de Guerra et al., 1993; 1996; Bortolini et al., 1995). In 2001, Rodríguez-Larralde et al. published a comprehensive study on estimation of admixture in different geographical regions of Venezuela. These results represent the first attempt to understand the process of genetic makeup in different regions of this country and show the existence of an inter-regional genetic heterogeneity (Rodríguez-Larralde et al., 2001). In Ecuador, population genetics as a scientific discipline has had poor development in the late twentieth century. Some studies were conducted by local researchers (Guderian and Vargas, 1986), while others, such as the study of some indigenous groups and groups of African descent, were conducted by researchers at the University of Rome, Italy (Martínez-Labarga et al., 1999). Finally, in Peru, studies about the ABO and Rh blood groups were reported in Lima but conducted by researchers in biochemistry from different institutions outside of Peru (Gonzalez Vallarino, 1958; Valdez, 1965; Balarezo et al., 1969), which we believe do not represent the beginning of population genetics as a scientific discipline in that country.

In the last third of the twentieth century, the prevalent research consisted of admixture studies performed by testing the

blood groups, proteins, and HLA of individuals from semi-isolated populations. These groups were ethnically classified, according to their historical origins, as having either African or European ancestry. Genetic investigations of American mestizo populations arise from the desire to understand the processes of admixture that resulted in these populations. Research regarding the distribution of alleles of different blood groups and proteins in the indigenous populations of South America provided the necessary information for reference frequencies to estimate parental contributions of European and African gene flow. The finding of alleles, such as the Amerindian population marker Di\*A, and the African markers HB\*S, RH\*cDe and FY\*O, facilitated the estimation of admixture, and the use of different methods increased their accuracy. More details about these methods can be found in Sans (2000) and Salzano and Sans (2014). Due to the particular history and heterogeneous admixing process that led to the current Latin American populations, many researchers identify or classify populations according to their ethnic origin. The genetic characterization of groups claiming African ancestry had an important moment in the final decade of the last century.

Table 1 summarizes the main findings in relation to the estimates of the Amerindian, European, and African components in the populations of Colombia, Ecuador, Peru, and Venezuela. These estimations differ in the number of genetic systems and methods used. In this portion of South America, the populations of African descent show important differences in their genetic makeup. In all, African ancestry predominates (50–80%), with variable Amerindian and European components. There are no estimates reported for Peru based on blood groups and proteins. In the other three countries, it can be said that the populations of African descent differ in the degree of isolation and preservation of the initial gene pools.

Regarding populations with European ancestry, there are no estimates reported for Colombia through blood groups and proteins. We draw attention to the results reported by Salzano and Bortolini for Peru (2002), estimated from data published by Mourant et al. (1976). Populations classified as having European ancestry in this publication, have an almost absolute

**TABLE 1.** Estimates of admixture (%) in northwestern South America, based on blood groups and proteins,<sup>a</sup> and listed according to ethnic classification. INA = information not available.

Population	Urban/mestizo			African descent			European descent		
	European	African	Amerindian	European	African	Amerindian	European	African	Amerindian
Colombia	0–42	18–84	16–47	13	71	16	INA	INA	INA
Ecuador	53	27	25	11–14	58–75	14–28	67	7	26
Peru	21	32	47	INA	INA	INA	0	3	97
Venezuela <sup>b</sup>	33–85	0–39	39–46	0–43	54–79	0–26	78–100	0–14	0–8

<sup>a</sup> Salzano and Bortolini (2002).

<sup>b</sup> Castro de Guerra et al. (2011).

Amerindian component (97%); this value may be highly influenced by the decision to use only the GC and TF genetic systems. In Venezuela and Ecuador, individuals with European ancestry have maintained a high degree of isolation and have mixed only with Amerindians. Finally, the urban populations of these countries (nonrural populations and without a defined ethnic origin) show a significant heterogeneity, and no clear trend was observed regarding the prevalence of a particular ethnic component; however, Venezuela seems to have more tendencies towards the predominance of a European component in its urban populations.

At this early stage, which is characterized by the use of genetic markers identified from immunological and electrophoretic tests (blood group and HLA proteins), Colombia displays an autonomous development of population genetics, manifested through studies in different research centers. In Venezuela, population genetics is bolstered by the influence and participation of American and Brazilian researchers, and the main center where it thrives is the Venezuelan Institute for Scientific Research (IVIC). In Ecuador, foreign influence is also observed, however, population genetics does not take root as an established field of study in this country. In Peru, we cannot say that population genetics emerges as a scientific discipline at this stage, since the few studies conducted were exclusively with ABO and Rh blood groups and were focused on clinical and epidemiological results.

## THE MOLECULAR ERA

In the last decade of the twentieth century, population genetics studies based on DNA polymorphisms or molecular markers were initiated. In northwestern South America, the rise in molecular-genetic studies has its earliest beginning and its highest expression in Colombia. Researchers at the National University of Colombia in Bogotá and the University of Antioquia in Medellín, among others, have established an important development in the research of population genetics. Numerous reports on the genetic characterization of different native and mestizo populations in Colombia, using autosomal and Y-chromosome STR polymorphisms, SNP-AIMs, and *Alu*-indels were published (Yunis et al., 2000; 2005; 2013; Alonso and Usaquén, 2013). The distribution of mitochondrial haplogroups and the Y-chromosome in indigenous and mestizo groups across most of Colombia has been described by researchers from different institutions (Mesa et al., 2000; Carvajal-Carmona et al., 2000; Keyeux, et al., 2002; Rodas et al., 2002; Salas et al., 2008; Avila et al., 2009; Rojas et al., 2010; Usme-Romero et al., 2013; Yunis and Yunis, 2013). This information has facilitated the reconsideration of the genetic affinities between Colombian indigenous groups and even the notion of probable migration routes the various groups used to reach Colombia. Also, new estimates of genetic admixture in urban populations, and the occurrence of directional mating between European men and Indian women in the colonial period, were published.

In the first decade of the twenty-first century, the creation of national and multinational projects stands out in Colombia. At the National University of Colombia, Institute of Genetics, the Identification and Population Genetics Group, coordinated by William Usaquén, created an approximation of a genetic map of Colombia in order to describe the genetic diversity, population structure, and migration patterns of the Colombian population. The information used originated from paternity and identification tests of 3,500 individuals from 23 departments of the Andean region and the Atlantic and Pacific coasts, carried out between 2000 and 2003. The polymorphisms used were forensic STRs and mitochondrial DNA (mtDNA) (Rojas et al., 2013, Alonso and Usaquén, 2013).

Moreover, the GENMOL group at the University of Antioquia, directed by G. Bedoya, in collaboration with Ruiz-Linares at University College, London, initiated a project called CANDELA (Consortium for the Analysis of the Diversity and Evolution of Latin America), which aims to evaluate the interaction of genetic, phenotypic, and sociocultural characteristics in several Latin American countries: Brazil, Chile, Colombia, Mexico, and Perú. Polymorphisms used in this project correspond to 30 AIMs that were tested in 7,342 individuals from the participating countries. Relevant to this chapter, the Colombian sample included 1,659 individuals from Medellín, while that from Peru included 906 from Lima. The first results were reported in 2014 (Ruiz-Linares et al., 2014). The genetic information from Colombia that is gathered and consolidated through these projects is undeniable. In Peru, the alliance made between the Universidad Peruana Cayetano Heredia and the CANDELA project significantly expanded the knowledge about the relationship between Peruvian phenotypic characteristics and admixture. Another important partnership that has encouraged the development of Peruvian population genetics was established between the Centre for Research in Genetics and Molecular Biology, University of San Martín de Porres, headed by A. Fujita, and the Genographic Project (a joint venture between National Geographic and IBM), coordinated in South America by Fabrizio Santos, from the University of Minas Gerais, Brazil. The products of these cooperative endeavors are several recently published studies that characterize Peruvian indigenous groups and describe the process of admixture in that country (Sandoval et al., 2013a, 2013b). Prior to these two multinational projects, some molecular studies of populations had been published, with a primarily forensic emphasis (Pérez et al., 2003; Martínez et al., 2008; Barletta et al., 2013) and several postgraduate studies in human genetics were completed.

In Ecuador, the main avenues of research in the molecular era were medical and forensic genetics; however, indigenous and mestizo urban groups were also investigated. One of the initial findings of great importance was the identification of a sequence of mtDNA which defined a new Amerindian haplogroup named D4h3, initially called Cayapa, for the group where it was discovered. However, this important discovery was reported by researchers at the University of Rome who had not collaborated

with any Ecuadorian scholars (Rickards et al., 1999). In the first decade of this century several indigenous, rural, and urban populations were characterized molecularly using autosomal and Y-chromosome STRs. Most of these investigations were conducted by F. González-Andrade (Laboratory of Molecular Genetics, Metropolitan Hospital in Quito and Science and Technology Department, Ministry of Public Health) in collaboration with Martínez-Jarreta, from the University of Zaragoza, in Spain (González Andrade et al., 2003; 2006; 2007; 2008; 2009; Baeta et al., 2012; 2013).

In Venezuela, molecular studies have been conducted mainly with rural and urban populations, and very little has been done with Amerindians. The main centers of population genetics studies are the Laboratory of Human Genetics of the Venezuelan Institute for Scientific Research (IVIC) and the Genetics Unit, Faculty of Medicine, University of Zulia (La Universidad del Zulia, LUZ). Both research groups have characterized and studied admixture using autosomal and Y-chromosome STRs, mtDNA, and Y-chromosome haplogroups. The IVIC research group, headed by Castro de Guerra and Rodríguez-Larralde, has focused its studies on urban populations with African or European ancestry in the central and eastern regions, in some cases in collaboration with Vivenes de Lugo from Eastern University (UDO) (Castro de Guerra et al., 2003; 2009; 2012; Vivenes de Lugo et al., 2003; Acosta-Loyo et al., 2004; Martínez et al., 2007; Simmons et al., 2007). A study which summarizes the parental genetic components in different regions of Venezuela and in populations with European, African, or mestizo ancestry, was conducted by Castro de Guerra et al., (2011). Especially noteworthy is the support of the Federal University of Rio Grande do Sul, through M. C. Bortolini and F. Salzano, in the molecular studies initiated by IVIC (Castro de Guerra et al., 1997; Araujo da Silva et al., 1999; Bortolini et al., 1999). Western Venezuela, including some indigenous groups, has been studied mainly by LUZ, headed by L. Pineda Bernal and L. Borjas, who have also received foreign support from A. Carracedo at the University of Galicia, Spain (Pineda Bernal et al., 2000; 2003; 2006; Borjas et al., 2008; Zabala et al., 2005; Quintero et al., 2009; Gómez-Carballa et al., 2011).

Researchers from other Venezuelan universities have also contributed to research in population genetics (Chiurillo, et al., 2003; Lander et al., 2008; Nuñez-Bello et al., 2009).

Genetic studies conducted with mestizo populations in northwestern South America reveal an important heterogeneity and stratification consistent with historical information. In all, there is a significant predominance of Amerindian mitochondria, while the Y-chromosomes are European. A synthesis of these results is presented by Salzano and Sans (2014). Table 2 summarizes the main findings in relation to the estimates of the Amerindian, European, and African components in the four countries considered based on molecular markers. There are no estimates reported for populations classified as European descendants. The African component dominates only in populations of African descent in these four countries and is the least important in other mestizo and/or urban populations throughout the region, where European and Amerindian components are variable. Peru and Ecuador seem to be the countries where the Amerindian component has been preserved in a greater proportion, more than 70%, while in Colombia and Venezuela, there is great heterogeneity. However, the European genetic component appears to be the most important in the main urban centers and shows differences by socioeconomic strata, as reported in Caracas, Venezuela (Martínez et al., 2007).

## CONCLUSIONS AND PERSPECTIVES

Advances in molecular techniques improved the level of specificity in population genetics studies. It is possible to use more accurate genetic markers to characterize populations, describe their variability, estimate genetic affinity, and even trace migratory routes by sex. A new era in the research of indigenous groups has been encouraged, with a review of the theories about the peopling of the Americas and a better understanding of the dynamics of admixture. The new theoretical analysis and increasingly complex bioinformatic approaches, as well as the demand for very expensive laboratory techniques, such as real time

**TABLE 2.** Estimates of admixture (%) in northwestern South America, listed according to ethnic classification, and based on molecular markers<sup>a</sup>: a = SNPs; b = AIMS; c = STRs; d = *Alu* indels; e = VNTRs; INA = information not available.

Population	Urban/mestizo				African descent			
	European	African	Amerindian	Markers	European	African	Amerindian	Markers
Colombia	20–79	0–28	16–75	a,b,c,d	0–28	44–89	11–33	a,b,c,d
Ecuador	19	8	73	c	16	56	28	c
Peru	1–31	1–3	67–98	b	INA	INA	INA	INA
Venezuela	33–75	4–38	17–40	c	15–26	55–70	6–26	c,e <sup>b</sup>

<sup>a</sup>Salzano and Sans (2014).

<sup>b</sup>Bortolini et al. (1999).

PCR, microarrays, next generation sequencing, etc., make the development of this discipline in countries with scarce economic resources difficult. The technical requirements of these studies have been better confronted in Colombia, where a greater number of modernly equipped research groups have appeared. This has allowed an autonomous development of population genetics, independent of the constant support the group in Medellín has received from University College, London. In Ecuador, Peru, and Venezuela, the advancement in population genetics research has been slower and less generalized, with occasional external collaborations. However, efforts are being made to keep up with the new trends in this field of research, not only with the use of AIMs for the estimation of admixture, but also by studying their association with diseases and pharmacogenetics. Several examples of this type of research are found in Colombia (Chacón-Duque et al., 2014), Ecuador (Sinúes et al., 2008; Soriano et al., 2010; Vicente et al., 2014), and Venezuela (Chiurillo et al., 2009; 2013; Castro de Guerra et al., 2013).

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# A Brief History of Pre-Hispanic Skeletal Collections in the Northern Andes of Colombia, Venezuela, and Ecuador

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**ABSTRACT.** Human skeletal remains collected from archaeological excavations have always been an important source of information for archaeologists and physical anthropologists. A detailed review of pre-Hispanic human skeletal remains reported in the archaeological and anthropological literature of Colombia, Ecuador, and Venezuela between 1945 to 2014 reveals: 1) reports of excavations and current locations, 2) contextual analysis, 3) osteological analysis (sex, age, height), and 4) specialized analyses (deformation, craniometry, paleopathology, dental morphology, DNA, and others). The study of human skeletal remains in the northern Andes has provided an important bank of information to contribute to the understanding of the three major problems of bioarchaeology: diet, diseases, and patterns of migration and settlement.

**RESUMEN.** Los restos óseos que provienen de excavaciones arqueológicas han sido siempre una fuente importante de información para los arqueólogos y antropólogos físicos. Se realizó una revisión detallada de los hallazgos de restos óseos humanos prehispánicos reportados en la literatura arqueológica de Colombia, Ecuador y Venezuela entre 1945 y 2014 incluyendo: 1) Reporte de excavaciones y ubicación actual, 2) Análisis del contexto del esqueleto, 3) Análisis osteológicos (sexo, edad, estatura), 4) Análisis especializados (deformación, craneometría, paleopatología, morfología dental, ADN, entre otros). El estudio de restos óseos en el norte de los Andes ha brindado un banco de información importante para contribuir a la comprensión de los tres principales problemas de la bioarqueología: dieta, enfermedades, y patrones migratorios y de poblamiento.

**RESUMO.** Os restos ósseos que vêm de escavações arqueológicas sempre foram uma importante fonte de informação para arqueólogos e antropólogos físicos. Uma análise detalhada dos restos humanos pré-históricos relatados na literatura arqueológica da Colômbia, Equador e Venezuela entre 1945 e 2014 foi realizada incluindo: 1) Relatos de escavações e localização atual, 2) Análise contextual, 3) Análises osteológicas (sexo, idade, altura), 4) Análises específicas (deformação, craneometria, paleopatologia, morfologia dental, DNA, etc.). O estudo de restos de esqueletos do norte dos Andes tem fornecido informações importantes para a compreensão dos três principais problemas da bioarqueologia: dieta, doenças e os padrões de migração e de povoamento.

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*Manuscript received 28 April 2016; accepted 10  
November 2017.*

## INTRODUCTION

The term bioarchaeology is very general. In some Latin American countries, such as Colombia, Ecuador, and Venezuela, it is often confused as a synonym for osteology or physical anthropology applied to archaeological contexts. No doubt bioarchaeology is a concept that originated in these sciences, though it has become much broader.

From the point of view of archaeology, it can be defined as a methodological concept composed of three sources of different biological analysis: archaeobotany (the analysis of botanical remains), zooarchaeology (the analysis of faunal remains), and osteology (the analysis of human skeletal remains).

This definition indicates that those anthropologists who produce bioarchaeologic texts should consider a wide range of data sources, bring together research teams from different biological specialties, and manage a theoretical framework sufficiently solid to interpret all relationships between the biological information and its cultural context.

Bioarchaeology can also be defined by avenues of investigation such as: diet (production, conservation, processing, intake, nutrition, and waste), diseases (genetic or environmental), population studies (growth, structure, social differentiation, and conflict), modification of the body (intentional and unintentional), and biological relationships (origin, contacts, migration, and familial relations). As such, the specialties of bioarchaeology are not differentiated because they remain in an applied technical dimension (Walker, 2001; Spencer, 2002; Collins-Cook, 2006).

These parameters were explored in the composition of a historical text on the development of bioarchaeology in the northern Andes. Through the research and evaluation of the advancement of this science in Latin America, it becomes possible to identify existing gaps and propose strategies that improve teaching and professional applications in different regional universities that teach anthropology. Such an understanding will also help raise awareness about the need to establish laws for the protection of archaeological heritage, including the biological remains, particularly in this region of South America.

## METHODOLOGY FOR THE REVIEW OF LITERATURE

In Colombia, from the end of the nineteenth century to the early twenty-first century, there has been considerable progress in the advancement of bioarchaeology, for academics as well as professionals, through the recognition that the analysis of human remains must be considered in association with the archaeological context. It was difficult to perform a proper literature review due to the circumstance that much of the archaeological studies in Latin America are consigned to graduate theses or unpublished research reports that are difficult to access.

For this review, the most relevant documents on the subject of archaeology in Colombia were researched. Also reviewed

were the major serial journals, with an emphasis on articles that mention and describe bone and dental specimens. The following Spanish language journals and books were consulted, in order, for the period from 1945 to 2014:

1. Books published by the Fundación de Investigaciones Arqueológicas Nacionales del Banco de la República (FIAN).
2. *Boletín de Arqueología de la Fundación de Investigaciones Arqueológicas Nacionales.*
3. *Revista Colombiana de Antropología.*
4. *Boletín de Antropología de la Universidad de Antioquia.*
5. *Boletín del Museo del Oro.*
6. *Revista de Arqueología del Área Intermedia SCAR-ICANH.*
7. *Revista de Arqueología de Estudiantes de la UNAL.*
8. *Revista Inversa de Estudiantes de Antropología UNAL.*
9. *Boletín de Arqueología del Servicio Arqueológico Nacional.*
10. *Revista Maguaré de la Universidad Nacional de Colombia.*
11. *Revista Cespedia del Instituto para la Investigación y la Preservación del Patrimonio Cultural y Natural del Valle del Cauca.*
12. *Revista de Antropología y Arqueología de la Andes.*

Literature from other countries, such as Venezuela and Ecuador, has also been reviewed. There are, however, major differences between them, because the literature from Venezuela is very sparse (two journals of general anthropology: *Boletín Antropológico* from Universidad de Los Andes–Merida and *Revista de Antropología Forense* from Universidad Central de Venezuela), whereas for Ecuador, there are many well referenced journals. This makes a meaningful regional comparison and final synthesis difficult.

## MID-TWENTIETH CENTURY

During the 1940s, the archaeologist J. E. Silva-Célis recorded the morphology of *chibcha* skulls (Silva-Célis, 1945a, 1946, 1947). Since then, the archaeological studies that have analyzed skeletal remains from burials, funeral urns, or reference collections are proportionately few. An investigation of at least 118 individuals from the pre-Hispanic cemetery of Sogamoso was carried out and Silva-Célis made an extensive analysis of the age at death and the population distribution, as well as the percentages of positioning of the bodies in the burials, and the orientation of the skulls. He also determined the sex of some individuals (Silva-Célis, 1945b).

From the end of the 1940s until the end of the 1960s, archaeology reports are numerous in Colombia, but they do not mention the precise findings of human skeletal remains.

In Ecuador there are few studies. All of them refer to the morphological description of the skull. The study of the Punin skull by Sullivan and Hellman (1925) is an early example. Subsequently, similar studies were conducted on the skulls from Cochasqui (Santiana, 1953), Punin–Paltacalo (Santiana, 1962),

and Imbabura (Santiana, 1964). Salvador (1968) conducted a descriptive study of several bone collections of Ecuador. There are no reports from Venezuela.

### THE 1970s

In 1970, an archaeological investigation in Laguna de La Herrera on the south side of the montane savannah, Sabana de Bogotá was carried out. Unidentified human skeletal remains were described at sites 3, 7, 9 and 13 (Broadbent, 1971).

Subsequently, in 1974, the discovery of human bones was recorded under the archaeological rescue program in Pupiales, Department of Nariño. It refers to the recovery of some long bones (femora and tibiae) in one of the tombs looted by the residents of the sector (Perdomo, 1974). That same year, a Muisca cemetery located in the Sabana de Bogotá, on the site of the Aca-cias, was investigated, and paleopathological and craniometric analyses were performed (Correal, 1974).

In 1975, a study of archaeological excavations in the area of the Panches, Department of Cundinamarca, described the presence of human skeletal remains for at least six individuals (registering isolated bones). Sex and age were analyzed for each individual, and the teeth provided some information about diet and wear (Perdomo, 1975).

In 1978, Silva-Célis mentioned the scattering of human bones (fragments of bones, such as humeri femora, and tibiae) as a result of the previous looting in a rectangular excavated area where the monoliths of the sacred field are located in the archaeological site Infiernito (Silva-Célis, 1978).

In 1979, G. Correal described skeletal remains found in excavations of the Nemocón and Sueva rock shelters. Some funeral aspects, such as dispersion of skeletal materials associated with the specified minimum number of individuals, are mentioned for the Nemocón site. In addition, some taphonomic aspects (such as cremation or partial calcination of vertebral fragments), some pathological lesions, and a high level of dental abrasion were identified. Sueva skeletal and dental remains are recorded in several stratigraphic units excavated to a lesser extent, with some cranial indices presented (Correal, 1979).

In Ecuador there was a nascent interest in osteological analyses. These include cranial deformation studies by Munizaga (1976), studies about Valdivia by Klepinger (1979), and investigations regarding skeletal evidence for habitual kneeling posture by Ubelaker (1979). There are no reports from Venezuela.

### THE 1980s

In 1980, Chavez and Puerta carried out a research study on the primary burials of Tierradentro, encompassing the towns of Inzá and Belalcázar in the Department of Cauca, Colombia. Despite excavating 29 tombs in this sector, only bone fragments were found, rather than complete skeletons. A detailed description of

the pottery associated with each burial is recorded, but the bones are not considered in the analysis (Chavez and Puerta, 1980).

In 1981, C. Angulo described the presence of many damaged fragments of human skeletal remains in some primary and secondary burials and urns associated with the Malambo cultural complex. This study makes a slight mention of the general state of paleopathological conditions and some cranial indexes (Angulo, 1981). That same year, G. Cadavid and A. M. Groot conducted an archaeological survey in the Sierra Nevada de Santa Marta in northern Colombia. This survey described the presence of cemeteries in five sites of the area. It refers to the presence of individual burials containing fragments of jaws and teeth, but this minimal osteological data does not influence the interpretation of the site (Cadavid and Groot, 1981).

In 1982, a craniometric study of three pre-Hispanic skulls and a jaw from the Guabas region in the Valle del Cauca Department was carried out. It described the procedure for determining the age and sex of each individual and taking cranial measurements (Rodríguez-Cuenca, 1982).

In 1983, Rodríguez-Cuenca recorded carvings on necklace beads made from animal bones, including those of deer, rabbits, iguanas, and fish (Angulo, 1983). This same year, the discovery of human skeletal and faunal remains was registered in Zipacón, Department of Cundinamarca. This study presented the distribution of the human skeletal remains as they were found, determined the minimum number of individuals, and described the cremation state of skeletal fragments, as well as some dental (severe attrition) and vertebral anomalies (Correal and Pinto, 1983). In 1983, during reconstructions of tables A and B from archaeological sites in San Agustín, the discovery of cremated human bone fragments was mentioned (Duque and Cubillos, 1983). Similarly, the discovery of human bone fragments, possibly of an adult from Quinchana, was described (Llanos and Duran, 1983).

In 1984, excavations in the preceramic site of Sabana de Bogotá, yielded human skeletal remains (Ardila, 1984). In that report, Appendix 5 is entirely dedicated to the study of human skeletal remains, describing the poor preservation of the samples. It was possible to study only two of the skulls, which presented severe dental wear, cephalic indexes, and tooth decay. Osteoarthritic injury in long bones was also detected (Ardila, 1984). The same year, another study described aspects of physical anthropology on human skeletal remains found in primary burials from Tunja. It describes the minimum number of individuals, the pattern of their funerary context, sex, and age at death, as well as paleopathological features, mainly in skulls and teeth (Castillo, 1984). Also, cranial and skeletal fragments of seven tombs excavated in the archaeological sites of Colorados and Mayaca in the middle Magdalena region are described. The presence of bone material was noted, but no description of their condition was recorded (Castaño and Davila, 1984).

In 1986, after a series of excavations carried out on preceramic sites in Sabana de Bogotá, G. Correal described the presence of primary and secondary human burials. He described

the position and orientation of the skeletons, as well as their treatment prior to burial (Correal, 1986a). Subsequently, Correal carried out a new study on the human bones found in the Trementina Cave in the Department of Cesar. The examined sample included five skulls and fragmented long bones, as well as a partial skeleton, and isolated teeth. This study presented a detailed description of the conventional cranial diameters and concluded that the skeletons represented an indigenous population (Correal, 1986b).

In 1987, the intentional deformation of a pre-Hispanic skull from the municipality of Balalaica, in the Department of Nariño, was recorded by Correal. He recorded the sex, age at death, cranial measurements, and pathologies of the individual, emphasizing in particular the oblique, tabular deformation that the skull presents (Correal, 1987). Primary individual and collective burials of human skeletal remains also were recorded in a wider region, ranging from the Hoya de La Miel River in the Department of Caldas to where it joins the Magdalena River. In this study, the skeletons were mentioned only to register that individuals had been buried in the tombs (Castaño, 1987; Bruhns, 1990). In this same year, archaeological research carried out in the valley of the Laguna de Samaca, in the Department of Boyacá, recorded anthropological features, such as the minimum number of individuals for each burial, sex, age, position and orientation of the skeletons inside the graves, body treatment, and state of preservation in fifteen excavated tombs. It also refers to the process of recovery of the bones, as well as craniometrics compared with other samples from the region. Some pathological descriptions of the teeth, vertebrae, and phalanges are conducted at the end of the text (Boada 1987a). That same year, investigations at the Marin archaeological site were recorded. Within the funerary practices outlined in this study, the presence of human skeletal remains is mentioned and the sex, age at death, cranial deformation, position and orientation of the skeleton, body treatment at the time of the burial, and cultural elements associated with the funerary offerings are described (Boada, 1987b).

In 1988, human skeletal remains at two deposits in northern Colombia, one primary and the other secondary, were described. The report only mentioned probable age and sex (Angulo, 1988). N. Castillo excavated tombs in the western part of the Department of Antioquia, in the municipality of Sopetrán. The report mentions collective burials and the dispersion of the skeletal remains of children and adults in the tombs. Evidence of partial calcination in a row of 32 human skulls associated with the skulls of horses (Castillo, 1988) is also mentioned. Consequently, examination of the Marin samples presented indicators of various injuries, such as degenerative joint diseases, spinal fusions, scoliosis, osteoporosis, septic arthritis, and bone fractures. The teeth presented severe occlusal wear, caries, and enamel hypoplasia (Boada, 1988). Finally, Duque and Cubillos described the presence of numerous tombs discovered in the Alto de Lavapatas at the archaeological site of San Agustín. Their investigation yielded traces of human skeletal remains and isolated teeth from 29 tombs (Duque and Cubillos, 1988).

In 1989, Correal performed one of the most complete studies ever developed in the country on preceramic skeletal remains from Aguazuque, in the Altiplano Cundiboyacense region. The remains, mostly of primary and secondary collective burials, constitute one of the better recovered bone samples in the country. In his report, a whole chapter is dedicated to the osteological analysis of these samples, specifically craniometrics and stable isotope analysis. Chapter 10 describes the incidence of multiple paleopathological lesions, some dental abscesses, severe wear, and decay (Correal, 1989). This same year, some fragmented skeletal remains also were recorded in the excavation of a pre-Columbian cemetery in the Tenza Valley, in the same region described above (Lleras, 1989). Also that year the anthropologist T. Gahwilder-Wälde performed an archaeological study of the types of burials and burial patterns in the region of Pavas and La Cumbre in the Department of Valle del Cauca. Gahwilder-Wälde described the presence of some human skeletal remains and indications of the position of the skeleton in the majority of tombs, including the staining of the earth where the skeleton was positioned, known regionally as "pudre" (rotten), which is considered evidence of a burial. Despite its extensive review of mortuary sites in the region, the report does not mention human skeletal remains (Gahwilder-Wälde, 1989). Regarding the territory of the Viejo Caldas, which currently comprises the departments of Caldas, Risaralda, and Quindío, archaeologist A. Valencia made an ethnohistorical tour and frequently mentioned the presence of fragments of human skeletal remains in the tombs. Unfortunately, the records of looting and sales to private collectors do not describe the major features of the skeletons (Valencia, 1989). There was also an archaeological discovery in Las Delicias, a neighborhood south of Bogotá. There, despite photographic records of the bones of an infant buried in an oval niche, these bones are not referenced in the text nor are they analyzed (Enciso, 1989). Finally, an archaeological project was conducted in the village of Tajumbina, in the municipality of La Cruz, Department of Nariño. The report described the presence of human skeletal remains from some excavated tombs. The distribution and preservation status of the bone fragments is described, including the position and orientation of some individuals (Cadavid, 1989).

In Ecuador, there is a surge in osteological studies during this decade, thanks in large part to the research of D. Ubelaker about skeletal collections from Cotacollao (Ubelaker, 1980a), Santa Elena (Ubelaker, 1980b), Ayala (Ubelaker, 1981), Guan-gala (Ubelaker, 1983), La Libertad (Ubelaker, 1988a), La Tolita (Ubelaker, 1988b), and the Jama-coaque culture (Ubelaker, 1986). Also noteworthy are the studies of the skull of Punin (Brothwell and Burleigh 1980; Bonifaz et al., 1983). There are no reports from Venezuela.

## THE 1990s

One of the few molecular studies on prehistoric human bones was undertaken by Van der Hammen et al. in 1990. It

corresponded to the stable isotope analysis carried out on 19 individuals from the preceramic excavations of Tequendama and Aguazuque, near Bogota City. Van der Hammen and his colleagues described the concentration of  $C^{13}$  and  $N^{15}$  in these samples, making inferences about diet and food changes over a period spanning 4,000 years (Van der Hammen et al., 1990).

A study carried out by archaeologist M. Groot in the municipality of Nemocón, noted the presence of several human burials, but no further information was provided on the bones or any respective analysis that may have been performed (Groot, 1990).

Rodríguez conducted an archaeological study at the pre-Hispanic cemetery of Almacafé in the municipality of Buga in the center of the Department of Valle del Cauca. The resulting report described the presence of several bones representing individuals whose sex, age, and height were determined (Rodríguez, 1990).

Sixteen burials were excavated at the archaeological site of Palogordo in the Department of Santander, revealing the presence of thirteen individuals. The study considered variable foci such as the age at death, sex, and some pathologies which were included in the interpretation and discussion (Lleras and Vargas, 1990).

In 1991, H. M. Correcha described the discovery of human bone fragments corresponding to a skull and 16 teeth obtained from the excavation of a tomb of the Suaza River Valley in the Department of Huila (Correcha, 1991). Another archaeological study conducted in 1991 identified the presence of human bones in the middle of the Bogotá River basin. Annex 2 of this research presents an analysis of the remains with an emphasis on the minimum number of individuals, age, and sex. A dental evaluation yielded information about caries, attrition, periodontal disease, and enamel hypoplasia. It also refers to the size, position, color, and shape of the dental fragments. In general terms, the information supplied is imprecise regarding chronology and context (Peña, 1991).

C. A. Rodríguez and D. Stemper conducted an archaeological study in the municipality of Palmira, Department of Valle del Cauca. They described the excavation of four tombs, in which bone materials were found. It mentions the presence of bone fragments corresponding to skulls, long bones, and isolated teeth (Rodríguez and Stemper, 1992). This same year, a study was performed describing the presence of tombs and burials with human bones under the sidewalk of Tajumbina, in the municipality of La Cruz in the Department of Nariño. This research described the presence of bones that were used to determine sex, age at death, and stature in the majority of cases. Despite the bone analysis, bone information is not integrated into the archaeological interpretation (Cadavid and Ordoñez, 1992). Groot noted preceramic human skeletal remains in Checua, describing their funeral orientation, age at death, sex, and some pathologies. This corresponds to a preceramic sequence and constitutes a very important bone sample for the region, (Groot, 1992).

Pradilla and her colleagues carried out a detailed description of the bones found in the excavations of the Cercado Grande de los Santuarios site in the town of Tunja. They described the position of the bones in the tomb, their orientation, the types

of bones, sex, age at death, and other features, such as cremation and conditions of bone deterioration. It should be noted that this analysis also considered the bones in their archaeological context, in relation to the type of tomb, stratigraphy, and spatial location. The report also included a significant number of cranial measurements and dental pathologies, such as caries and antemortem tooth loss, and consulted the Carious-Sealed-Loss (Cariados-Obturados-Perdidos, or COP) index applied frequently in dentistry (Pradilla et al., 1992). C. O. Bernal and G. Orjuela carried out an archaeological survey in the municipality of Turbana, Department of Bolívar, recording the presence of human skeletal remains in some burials. The osteological analysis allowed them to record the age at death and sex in some cases, as well as the presence of dental pathologies and cranial deformation. Some noncontextual skeletal remains are described in the same way as the contextual ones. The analyzed individual's possible cause of death is referred to in general terms (Bernal and Orjuela, 1992). At La Sorga Farm, near the Cauca River Canyon in the municipality of Jerico (Department of Antioquia), an archaeological study was conducted in 1992. The report described the presence of human skeletal remains from five burials found in rock shelters. They are described as charred remains consigned to urns, whose dental analysis allowed the researchers to identify a minimum number of three individuals with their respective ages at death (Otero, 1992).

In 1993, Rodríguez and his colleagues recorded the presence of at least 11 human burials described as children, women, and men associated with the Malagana culture in the Department of Valle del Cauca (Rodríguez et al. 1993). Later, primary collective burials containing human skeletons were recorded in the same sector. Despite the description of the position and orientation of the skeletons, no further information is provided about the biological characteristics of these individuals (Cadavid, 1993).

In 1995, A. Martinez carried out a study in the municipality of Gigante, Department of Huila. The excavated cemetery yielded three complete skeletons (two male and one female) for whom the age at death, sex, and cranial deformation were determined. This information is included briefly in the interpretation of burial patterns for the region (Martinez, 1995). In this same year, a number of skulls with intentional cranial deformation from these same excavations were analyzed, and were used as evidence to interpret the processes of pre-Hispanic social differentiation in the region.. Three hypotheses emerged from extensive analyses suggesting that the intentional cranial deformation was due to either horizontal social differentiation, vertical social differentiation, or belonging to another ethnic group. This report was one of the first truly bioarchaeological studies in the country (Boada, 1995). Archaeologist A. Botiva conducted a study in the municipality of Suarez in the Department of Tolima, describing in detail a tomb with human skeletal remains. Despite the verification of the bones in one of the photographs, there is no osteological analysis. It should be noted that the skeleton is used as a reference to record the exact location of multiple necklaces and necklace beads buried around the individual (Botiva, 1996).

In 1997, a set of tombs of the Bolo-Quebrada Seca cultural complex was found in the Ciudad Jardín neighborhood near the city of Santiago de Cali, Colombia. The presence of fragmented human bones in Grave 2 and in the dome of Tomb 4 is described. It is an interesting study, with recovered dental parts classifying the minimum number of individuals and age of each (possibly 3 infants), as well as the presence of caries and enamel hypoplasia (Blanco, 1997).

M. Sanchez carried out archaeological research in Guenqueles Cave along the Saija River in Cauca, near the Pacific coast. Human burial sites yielding information about the funerary practices in this region of Colombia were found in this cave. Analyses were performed on the dental remains recovered from the funerary urn using data for the minimum number of individuals (approximately 17 individuals) with their corresponding age at death, wear, and decay (Hernandez, 1998). In southwestern Colombia, investigations of human skeletal remains from Bolo-Quebrada Seca cultural contexts demonstrated the first attempts to experiment beyond osteological analysis, by applying methods and techniques used commonly in medicine (histopathology and DNA) to identify cases morphologically associated with tuberculosis (Díaz et al. 1999; Martinez and Rodríguez, 1998). Finally, an investigation on the Dardanelos Farm, in the town of Obando in the Department of Valle del Cauca, identified burials associated with the Quimbaya culture. The report included a detailed description of the burial forms and noted the presence of bone fragments and teeth (Rodríguez and Rodríguez-Cuenca, 1998).

In 1999, the presence of human skeletal remains from the archaeological site of San Agustín in Llanura de Matanzas was described (Llanos, 1999). Cardale and her colleagues studied the largest recorded archaeological site in the region. They described the location and composition of some human burials with the presence of skeletal remains which were only partially preserved (Cardale et al., 1999). Similarly, an archaeological study carried out in the Sierra Nevada del Cocuy, Department of Boyacá, revealed human skeletal remains. Material from five burials was examined to determine the sex, age at death, some cranial measurements, and height. Most of the samples were sacrificed to obtain dates using collagen (Pérez, 1999).

In Ecuador, analyses were carried out on the osteological collections from Cumbayá (Ubelaker, 1990), Guangala (Ubelaker, 1993), the hospital of San Juan de Dios (Ubelaker and Rousseau, 1993), Tumaco-La Tolita (Ubelaker, 1997), and the San Francisco Church (Ubelaker, 1994; Ubelaker and Ripley, 1999). There are no reports from Venezuela.

## BEGINNING OF THE TWENTY-FIRST CENTURY

Salgado and Gomez (2000) recorded the presence of teeth and bones in Tumbas de Cancel (a type of tomb lined with stone slabs) excavated in the municipality of Cajamarca, Department of Tolima. This study determined the sex, age at death,

antemortem tooth loss, gum disease, tooth decay, severe occlusal wear, cranial deformation, traces of occupational stress, and partial cremation. That same year, R. Salas and M. Tapia recorded the presence of human skeletal remains in an archaeological site called Tibacuy, located between the plateau and the middle Magdalena River valley. The osteological analysis of four individuals from funeral urns determined sex, age at death, and some dental traits such as wear and pathologies. A brief reference was made about the robustness of the crania and appendicular skeletons, particularly noting the features of cranial deformation (Salas and Tapias, 2000). Also in 2000, a detailed study was made on the incidence of dental caries in tooth samples recovered from the Dardanelos Farm, in the municipality of Obando in the Valle del Cauca. This study describes the prevalence of caries using Arizona State University (ASU) methodology (Rodríguez-Flórez et al., 2000). During the year 2000, there were few new discoveries of human skeletal remains reported in Colombia. Some analyses of previously recovered skeletal remains were carried out. A pre-Hispanic sample representing the Bolo-Quebrada Seca culture, which had been excavated years ago by J. C. Cubillos at the Morro de Tulcán site in Popayan, was tested, and the DNA from *Mycobacterium tuberculosis* was successfully extracted. This study is the first example of ancient DNA extraction in Colombia (Díaz and Rodríguez, 2000; Díaz et al., 2000a, 2000b; Rodríguez, 2001). Dental pathologies were analyzed using ASU methodologies on two samples from the Dardanelos Farm (Rodríguez-Flórez et al., 2001a) and the pre-Hispanic cemetery of Guacanda in the municipality of Yumbo, Valle del Cauca (Rodríguez-Flórez et al., 2001c). Finally, a morphological analysis of tooth cusps was performed to obtain biological indicators of familial relationships on a set of skeletal remains from a Bolo-Quebrada Seca cultural context (Rodríguez-Flórez et al., 2001b).

A study in 2002 on human skeletal remains recovered in El Salado, Salamina, along the lower Magdalena River, was conducted in which five burials containing six individuals were analyzed to determine the basic data of sex, age, and height. Reference was made to the possible presence of treponematosi in these samples (Rodríguez-Cuenca and Rodríguez-Ramirez, 2002). Also in 2002, dental remains from the cemetery of Obando were analyzed to establish familial relationships among the individuals found in four tombs spanning 700 years (Rodríguez-Flórez and Gavilanes, 2002).

In 2003, an extensive analysis was conducted with samples of human skeletal remains that had been recovered between the years 1994 to 1995 at the Hacienda Malagana in the Department of Valle del Cauca. The report details the procedures used to determine sex, age, and height. It also describes the presence of intentional cranial deformation and dental pathologies, such as caries and enamel hypoplasia (Correal et al. 2003).

In 2004, a study of the dental remains recovered from 21 tombs in the pre-Hispanic cemetery of Guacanda in the Valle del Cauca was published. The report offered an analysis of 33 individuals to establish the chronological range of biological



affiliation within the population that practiced the Sonsoide cultural tradition (Rodríguez-Flórez, 2004).

In 2005, human skeletal remains were discovered in a formative site confined to the Laguna de la Herrera, in the Department of Cundinamarca. The sample corresponded to eleven individuals (ten of them disarticulated), from which it was possible to determine biological attributes such as sex, age, and height, as well as taphonomic considerations. It was determined that they were robust and dolichocephalic individuals with a low rate of caries and some evidence of treponematosi (possibly indicating syphilis) (Rodríguez-Cuenca and Cifuentes, 2005). Finally, a survey was conducted on the dental samples of 27 individuals recovered from the pre-Hispanic cemetery of Guacanda in the Valle del Cauca (Rodríguez-Flórez, 2005).

In 2006, the presence of human skeletal remains was recorded from archaeological excavations in the Hacienda Genoa, in the municipality of Pereira. This project described fragments of skeletal remains found in four tombs. No more information is provided (Restrepo, 2006). This same year, a book was published on the excavations carried out in the Cacicazgo de Guabas, in the Department of Valle del Cauca. There is an interesting analysis of recovered skeletal and dental remains. The report offers a description of numerous dental and bone pieces found in almost all excavated tombs. A craniometric comparison was conducted against previously published osteological series from pre-Hispanic Colombia. Other population aspects such as the mortality rate, the osseous and dental pathologies, cranial deformation, and aspects of morphological robustness in the skull and long bones also were described (Rodríguez et al., 2006).

In 2007, only two studies of prehistoric skeletal remains in Colombia were recorded. The first one refers to an important craniometric analysis carried out on 17 pre-Hispanic samples, recording a set of 65 variables using European standards of measurement. It attempts to establish connections between Colombian specimens and specimens from elsewhere in the Americas, Asia, and Oceania, mainly addressing the problem of the origin and dispersal of the first inhabitants of Colombia (Rodríguez-Cuenca, 2007). The second was an analysis of bilateral asymmetry in dental samples from 6 late archaeological sites in Colombia. In this study, some nonmetric dental traits have high rates of asymmetry and affect the taxonomic value of biological distances calculated between fragmented pre-Hispanic populations in Colombia (Rodríguez-Flórez and Colantonio, 2007).

In 2008, human bones were discovered in several tombs excavated in the area of Porce in the Department of Antioquia. The description of the bones complements the information about the funerary structure. The methodology and recording systems for basic skeletal data such as age and sex are not described (Cardona and Montoya, 2008).

In 2009, finds recovered from the archaeology project in the Baja basin of La Luisa River, in el Guamo, Tolima were published, and the analysis of bone and dental specimens were detailed in Annex 3 of the study, including basic skeletal data and the minimum number of individuals. It is striking how important

dental material can be in the determination of biological parameters (Salgado et al., 2009).

Finally, in 2010, a comparative analysis of 19 pre-Hispanic samples was published, using the Arizona State University Dental Anthropology System (ASUDAS) for the analysis of nonmetric dental traits. The report revealed patterns of genetic mobility between late societies in Colombia that reflect biological affiliations and affinities in their processes of migration, contacts, and displacements in the past. These patterns explain the wide biological diversity of these societies during the 1000 years preceding European contact (Rodríguez-Flórez, 2012).

In Ecuador, the work on the collections of La Florida mainly should be highlighted (Ubelaker, 2000), as well as a study of the Early Formative period remains from Real Alto (Ubelaker, 2003). Other studies describing human skeletal remains, including diseases and osteometrics, were later conducted by C. D. Rodríguez-Flórez and Ernesto Leon Rodríguez on material from the Oleoducto de Crudos Pesados del Ecuador (OCP) project, directed by the Instituto Nacional de Patrimonio Cultural del Ecuador (INPC) between the years 2002 and 2004. The resulting research reports are on file with the INPC in Quito. There are no reports from Venezuela.

## CONCLUSIONS

By assuming that research is a permanently dynamic process, this chapter is considered by the author to be incomplete and must be updated in the future. Of a total of 196 references about funerary archaeology in Colombia, Ecuador, and Venezuela, 109 presented descriptions of prehistoric human skeletal and dental remains (Table 1). Many of the publications mention skeletal and dental remains among the archaeological finds from funerary contexts. These specimens are kept in university laboratories and museums. In 2015, a publication revealed the osteological collections that are actually available for study in Colombia (Rodríguez-Flórez and Colantonio, 2015).

Regional bioarchaeological research began expanding in the 1970s. Most of the archaeological reports from this period only describe the presence of skeletal and dental evidence. A small selection describes aspects of basic osteological data such as age at death, sex, and height. In very few cases, the findings are associated with bioarchaeological analyses. In these, paleopathological results are most common, followed by paleodemographic data.

To a lesser extent, morphological analyses such as craniometry and odontometry are conducted, including studies of inherited dental morphology associated with inferences about the past genetic mobility of some pre-Hispanic populations in the west and center of the region. As mentioned by Rodríguez-Flórez (2008), Colombian archaeologists have demonstrated a growing interest in solving problems based on biological evidence. Funerary biology, as a concept which brings together all the biological evidence recovered from tombs and urns, including mummified remains, propels further research and exploration into the

**TABLE 1.** Colombian samples included in this research, grouped by period. Abbreviations: BP = years before present; N = number of samples. Dating method and locations are defined in table footnotes.

Samples (Code)	Colombian Province	Chronology (BP)	Culture	Dating method <sup>a</sup>	Location <sup>b</sup>	N
<b>Early Holocene Period</b>						
Checua (1)	Cundinamarca	7800	Preceramic	C <sup>14</sup>	LabUNAL	14
Guavio (2)	Cundinamarca	9360	Preceramic	C <sup>14</sup>	ICNMUNAL	39
Nemocon (3)	Cundinamarca	7530	Preceramic	C <sup>14</sup>	ICNMUNAL	7
San Pedro de Gachala (4)	Cundinamarca	9360	Preceramic	C <sup>14</sup>	ICNMUNAL	2
Sueva (5)	Cundinamarca	10090	Preceramic	C <sup>14</sup>	ICNMUNAL	1
Tequendama (6)	Cundinamarca	9740	Preceramic	C <sup>14</sup>	ICNMUNAL	8
<b>Total Early Holocene samples</b>						<b>71</b>
<b>Middle Holocene Period</b>						
Chia III (7)	Cundinamarca	5040	Preceramic	C <sup>14</sup>	ICNMUNAL	2
Aguazuque (8)	Cundinamarca	5030	Preceramic	C <sup>14</sup>	ICNMUNAL	82
Mosquera–Vistahermosa (9)	Cundinamarca	3410	Pre-Herrera	C <sup>14</sup>	ICNMUNAL	4
Zipacon (10)	Cundinamarca	3270	Pre-Herrera	C <sup>14</sup>	ICNMUNAL	5
<b>Total Middle Holocene samples</b>						<b>93</b>
<b>Late Holocene Period (3rd Millennium)</b>						
Apuló (11)	Cundinamarca	2400	Herrera	C <sup>14</sup>	ICNMUNAL	3
Malagana (12)	Valle del Cauca	2500	Yotoco	C <sup>14</sup>	MN-ICANH	13
Cerrito (13)	Valle del Cauca	2000	Ylama	RM	LabUNAL	10
Coronado (14)	Valle del Cauca	2000	Ylama	RM	LabUNAL	42
Hacienda Santa Barbara (15)	Valle del Cauca	2000	Ylama	RM	LabUNAL	16
Estadio Deportivo Cali (16)	Valle del Cauca	2000	Ylama	C <sup>14</sup>	LabUNAL	10
<b>Total Late Holocene (3rd millenium) samples</b>						<b>94</b>
<b>Late Holocene Period (2nd–1st Millenia)</b>						
Guacanda (17)	Valle del Cauca	1000–500	Sonso	C <sup>14</sup>	MAUnivalle	30
Dagua (La Granja) (18)	Valle del Cauca	1000–500	Sonso	RM	MAUnivalle	3
La Escopeta 14 (19)	Valle del Cauca	1000–500	Bolo	RM	MAUnivalle	27
Obando (Dardanelos) (20)	Valle del Cauca	1000–500	Quimbaya	C <sup>14</sup>	MAUnivalle	93
Guacari (21)	Valle del Cauca	1000–500	Quimbaya	RM	LabUNAL	17
Jamundi (22)	Valle del Cauca	1000–500	Bolo	RM	MAUnivalle	13
Tierradentro, Corinto, Arrayanes, Cauca (23)	Cauca	1000–500	Bolo	RM	MHNUCAUCA	16
Morro de Tulcan (24)	Cauca	1000–500	Bolo	RM	MHNUCAUCA	9
Tambo–Alto del Rey (25)	Cauca	1000–500	Bolo	RM	MHNUCAUCA	21
Palestina (26)	Caldas	1000–500	Quimbaya	C <sup>14</sup>	PAAerocafe	105
Quindío ICANH (27)	Quindío	1000–500	Quimbaya	RM	UCaldas	4
Autopista del Café (28)	Quindío	1000–500	Quimbaya	RM	UCaldas	3
Las Delicias (29)	Cundinamarca	1000–500	Muisca	C <sup>14</sup>	MN-ICANH	12
Candelaria La Nueva (30)	Cundinamarca	1000–500	Muisca	C <sup>14</sup>	MN-ICANH	33
Soacha Portoalegre (31)	Cundinamarca	1000–500	Muisca	C <sup>14</sup>	MN-ICANH	84
Marín (32)	Cundinamarca	1000–500	Muisca	C <sup>14</sup>	MN-ICANH	15
Nemocon (Ubaque) (33)	Cundinamarca	1000–500	Muisca	RM	MN-ICANH	2
Soacha Portoalegre (34)	Cundinamarca	1000–500	Muisca	C <sup>14</sup>	ICNMUNAL	4
Boavita (35)	Cundinamarca	1000–500	Muisca	RM	ICNMUNAL	1
Funza (36)	Cundinamarca	1000–500	Muisca	RM	ICNMUNAL	1
Abra (37)	Cundinamarca	1000–500	Muisca	RM	MN-ICANH	2
Cueva La Trementina (38)	Cesar	1000–500	Tamalameque	RM	LabUNAL	3
Curumani (39)	Cesar	1000–500	Tamalameque	RM	ICNMUNAL	2
Gamarra (40)	Cesar	1000–500	Tamalameque	RM	ICNMUNAL	2
Cueva de Sasaima (41)	Santander	1000–500	Guane	RM	ICNMUNAL	1
Cueva del Indio (42)	Santander	1000–500	Guane	RM	ICNMUNAL	1
Cueva del Santuario (43)	Santander	1000–500	Guane	RM	ICNMUNAL	5
Cutiri (44)	Santander	1000–500	Guane	RM	ICNMUNAL	1

TABLE 1. (Continued)

Samples (Code)	Colombian Province	Chronology (BP)	Culture	Dating method <sup>a</sup>	Location <sup>b</sup>	N
Malpaso (45)	Santander	1000–500	Guane	RM	ICNMUNAL	1
Perlas de Cuba (46)	Santander	1000–500	Guane	RM	ICNMUNAL	1
Turbay (47)	Santander	1000–500	Guane	RM	ICNMUNAL	1
Manauere (48)	Guajira	1000–500	Wayuu	RM	ICNMUNAL	1
Tierranueva (49)	Guajira	1000–500	Wayuu	RM	ICNMUNAL	1
Aranda (50)	Nariño	1000–500	Piartal–Tuza	RM	MAUnivalle	2
Botanilla (51)	Nariño	1000–500	Piartal–Tuza	RM	MAUnivalle	7
Catambuco (52)	Nariño	1000–500	Piartal–Tuza	RM	MAUnivalle	4
Jamondino (53)	Nariño	1000–500	Piartal–Tuza	RM	MAUnivalle	2
Las Marianas (Maridiaz) (54)	Nariño	1000–500	Piartal–Tuza	C <sup>14</sup>	UMarianas	11
Nariño ICANH (55)	Nariño	1000–500	Piartal–Tuza	RM	MN-ICANH	4
Tolima (56)	Tolima	1000–500	Tolima	RM	ICNMUNAL	1
Copey (57)	Cesar	1000–500	Sierra Nevada	C <sup>14</sup>	PCFGaia <sup>c</sup>	122
<b>Total Late Holocene (2nd–1st millennia) samples</b>						<b>668</b>
<b>Total Colombian samples</b>						<b>926</b>

<sup>a</sup>Dating methods: C<sup>14</sup> = radiocarbon method; RM = relative method.

<sup>b</sup>Locations defined as follows:

LabUNAL: Laboratorio de Antropología Física, Universidad Nacional de Colombia, Bogotá.

ICNMUNAL: Instituto de Ciencias Naturales y Museo, Universidad Nacional de Colombia, Bogotá.

MN-ICANH: Museo Nacional e Instituto Colombiano de Antropología e Historia, Bogotá.

MAUnivalle: Museo Arqueológico, Universidad del Valle, Cali.

MHN Cauca: Museo de Historia Natural, Universidad del Cauca, Popayán.

UCaldas: Universidad de Caldas.

PAAeroCafe: Proyecto Arqueológico AeroCafe, Palestina, Caldas.

UMarianas: Universidad Las Marianas, Pasto.

PCFGaia: Proyecto Copey Fundación Gaiga, Medellín.<sup>c</sup>

<sup>c</sup>Human skeletal remains were reburied in the archaeological site at the request of the indigenous communities.

behavior of ancient populations in the region. Despite this, a thorough review of references on the subject leaves us some gaps with regard to five distinct problems of bioarchaeological areas (Rodríguez-Flórez, 2012): 1 *low accessibility*, 2 *nonapplicability*, 3 *noncomparability*, 4 *uncertain chronology* and 5 *unclear culture*. In this research, all problems are present, but two of them have been identified as major problems through a review of the literature from Colombia, Ecuador, and Venezuela. These two major problems include the others.

The first major problem is *low accessibility* (Rodríguez-Flórez, 2012), and refers to the circumstance that incomplete archaeological provenance of the samples often hinders or prevents the observation of morphological traits of interest to anthropologists. *Low accessibility* directly exacerbates the *noncomparability* of samples, limiting the statistical comparison within and between different samples, because the number representative of an archaeological culture is often very small. Colombian bioarchaeologists are forced to solve this problem in three different ways: The first option involves using transformation coefficients of frequencies that correct the normal distribution of limited data (for example,

the Anscombe transformation or Freeman-Tukey transformation) (Anscombe, 1948; Freeman and Tukey, 1950; Rodríguez-Flórez, 2012). A second approach involves combining several small samples from the same region or period, in order to make the tested sample large enough to be statistically relevant. The disadvantage of this option is that it eliminates local variations present within each sample, and therefore, the differences that may exist among them. The third option is a last resort—the bioarchaeologists choose to delete the problematic samples from their analyses.

Many of the skeletal and dental samples referenced here either (a) do not have a clear location today or (b) an *unclear cultural* affiliation. The largest and most well-documented collections in Colombia are curated at the National Museum of Colombia (La Casita), where stored materials are preserved by the Institute of Natural Sciences and the Laboratory of Anthropology (ICAHN) of the Universidad Nacional de Colombia. Other minor collections are distributed in laboratories and private collections across the country although some of them are difficult to access (Table 1). In Ecuador, the collections are mainly preserved in the INPC.

A second major problem is identified as *noncomparability* and refers to the impossibility of comparing samples because the data are minimal or have been extracted using different methodologies (*nonapplicability*) (Rodríguez-Flórez, 2012). Despite observing a large number of attributes or describing the palaeopathological condition or basic skeletal data, there is no standard methodology for observation and description employed from report to report. For this reason, it is difficult to compare skeletal data from Colombia with osteological series from other Latin American countries. This problem limits the spectrum of population comparison on the continental and regional scale because it reduces the number of susceptible features in the comparative analysis. Only in the last 20 years have morphological data been extracted using internationally recognized standards, and in the majority of cases, been shown to correspond to known and re-screened samples. Despite this, the comparisons made so far from the perspectives of palaeopathology and population have provided insights into the processes of health, disease, and population structure in some societies of the central and western parts of Colombia (Rodríguez-Cuenca, 2005). However, detailed studies on the spatial-temporal distribution of particular diseases, their origin, patterns of dispersal, and microevolution during 12,000 or more years have not been addressed consistently because of the problem of *noncomparability*. One example refers to a study presented in 2010 at the Congress of Archaeology in Colombia in the city of Santa Marta that reported a number of publications describing the presence of dental caries in pre-Hispanic populations of the northern Andes, including those in Colombia, Ecuador, and Venezuela. The results from this study are unreliable because original publications reported the prevalence of this disease in multiple ways. The presentation of data also brings together incompatible components such as the following. (1) Individual presence with decay; (2) number of individuals classified with tooth decay by age cohort; (3) number of decayed teeth; (4) presence of caries in tooth types; (5) types of molars with decay; (6) tooth surface caries; (7) depth or sector of occurrence of caries; and (8) data combined with other oral pathologies. Thus, I have come to the conclusion that the comparisons can only be solved using the same registration systems for all publications in a particular country, or failing that, exhibiting the same type of trait frequencies to facilitate comparisons. This is because, in some cases, the published data do not include the total number of individuals or the number of individuals that were affected by dental caries, but only the direct percentages (Rodríguez-Flórez, 2012).

The few comparative studies carried out in the northern Andes to date have been the result of analyses of limited collections, primarily because these collections were created by only a few researchers during the course of many years. This problem can be called the *unclear culture* problem. The availability of samples is affected not by the state of preservation of the skeletal and dental material, but instead by the lack of records. A book published by Springer on the archaeology of South America is proof of this (Silverman and Isbell, 2008). In this publication,

the description of the stage of physical inactivity during the Formative period in northern South America refers to issues involving the paleo diet, but with regard to Colombia, describes this process in little more than half a page without referencing any osteological or dental evidence. The relationships between problems addressing population distribution, diet, and diseases do not appear visible in this type of encyclopedic text.

One might consider that the *noncomparability* of data and samples in the northern Andes region is affected by the development of local or regional problems of archaeological research, which do not relate to anthropological research elsewhere in Latin America. This one major problem—*noncomparability*—should be discussed in the appropriate archaeological research centers because the standardized representation of skeletal and dental specimens is important in the solution of such problems.

Finally, it should be noted that the issue of *nonapplicability* can be improved with the use of standardized methodologies for the recovery, treatment, conservation, and analysis of human skeletal remains, and increasing the number of samples for multiple regions in Latin America. These advances will make it possible to address broader archaeological research problems that allow us to integrate more arguments about the biological past of indigenous populations in the northern Andes and their relationships with other Latin American zones.

## ACKNOWLEDGMENTS

This chapter is dedicated to Miriam Flórez Gil, who died on April 7, 2013. I am grateful to the following institutions that facilitated my research: Instituto Colombiano de Antropología e Historia, Biblioteca Luis Ángel Arango, Universidad del Valle, Universidad de Antioquia, Universidad Nacional de Colombia, Universidad del Cauca, and Universidad de Caldas. This article is a compilation of four presentations made years ago. A first version was presented in the First Cycle of Scientific Talks at the Museum of Natural History at the University of Cauca, Popayan, Colombia, in 1999 under the title “Advances in Dental Anthropology in the Department of Cauca.” A second presentation was given at the Fifth National Conference of Biological Anthropology held in Puerto Madryn, Chubut province, Argentina, held 23–26 October 2001. The document was presented as a free communication under the title “Status of research in dental anthropology in Colombia” (Rodríguez-Flórez, 2001). A third version was presented in the Permanent Seminar “Archaeology, Culture, and Society” organized by the Banco de la República and the Universidad del Valle in Cali, Colombia, in 2003 under the title “Pre-Hispanic Anthropology in the Valle del Cauca.” The fourth and final version was presented in November 2008 during the celebration of the Fifth Congress of Archaeology in Colombia at the University of Antioquia, Medellín, under the title “The concept of funerary biology and its importance in the understanding of the population structure of ancient societies: three case studies for Colombia” (Rodríguez-Flórez, 2008).

Finally, the text within this chapter is drawn from work in the doctoral program in biological sciences at the National University of Córdoba, Argentina, especially chapter 2 of the dissertation titled “Biological relationships among Pre-Hispanic human populations of Colombia through nonmetric traits of dental morphology” (Rodríguez-Flórez, 2012).

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# Paleopathology in Northwestern South America (Venezuela, Colombia, Ecuador, and Peru)

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**ABSTRACT.** The northwest region of South America demonstrates great potential for paleopathological research featuring many excavated osteological series and the multiple contexts in which ancient populations interacted. This has made the generation of analyses of different processes of adaptation and disease manifestations possible. This chapter presents a historical overview of the origins and development of paleopathology in the four diverse countries that compose the region: Venezuela, Colombia, Ecuador, and Peru. Their geographical, historical, and cultural differences have produced unique interests and trends in the discipline of paleopathology.

**RESUMEN.** El Noroeste de Suramérica representa una región con gran potencial en la investigación paleopatológica, dada la amplia cantidad de series osteológicas excavadas y los múltiples contextos en los que las poblaciones antiguas interactuaron. Esto ha posibilitado el estudio sobre diversos procesos de adaptación y las diferentes manifestaciones de las enfermedades. Este capítulo hace un recorrido histórico de los orígenes y desarrollo que ha tenido la paleopatología en los cuatro países que componen la región: Venezuela, Colombia, Ecuador y Perú. Sus diferencias geográficas, históricas y culturales han producido intereses y tendencias disímiles en la disciplina paleopatológica.

**RESUMO.** O noroeste da América do Sul é uma região com grande potencial para pesquisa na área da Paleopatologia, devido ao grande número de séries osteológicas escavadas e os diversos contextos em que interagiam os povos antigos. Isso permitiu uma análise dos processos de adaptação e das diversas manifestações patológicas. Este capítulo faz uma síntese histórica das origens e do desenvolvimento que tem levado as pesquisas em Paleopatologia em quatro dos diferentes países que compõem essa região: Venezuela, Colômbia, Equador e Peru; suas diferenças geográficas, históricas e culturais produzem diferentes interesses e tendências na disciplina paleopatológica.

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

## INTRODUCTION

In the nineteenth century, the first observations regarding diseases revealed in the bones of ancient populations were made by medical experts and historians to explain the conditions of health, therapeutic procedures, and interactions these groups had

with their environment. In this sense, paleopathology is defined as the study of diseases in antiquity (Lovell, 2000; Ortner, 2003). In the beginning, the field was primarily concerned with past populations from Egypt, Europe, and North America (Lovell, 2000); but in the first half of the twentieth century, skeletal remains from South America started to gain recognition (Hrdlička, 1943; MacCurdy, 1923; Moodie, 1930; Newman, 1943, 1948; Reiss and Stübel, 1887; Tello, 1929; Verano, 1997). Particularly important were those remains related to war injuries and trephination in ancient Peru (Stewart, 1958 cited in Angel, 1981), as well as mummified Peruvian material which required the application of innovative diagnostic techniques (Buikstra and Cook, 1980).

New instruments and technologies that have expanded research in this field have emerged since then, but the discussions around the origins and development of paleopathology as a discipline have been quite scarce. For example, Angel (1981) reviewed the work of some pioneers who were interested in bone lesions and gradually incorporated several tools for analysis giving rise to discussions concerning the origin of diseases such as syphilis, other treponematoses, and tuberculosis, as well as the proposal of paleopathological models to explain osteoarticular diseases and nutritional stress. In this work, Angel (1981:513) distinguished three stages of development in paleopathology, each one responding to the particular interests of its production contexts. The first phase corresponded to the nineteenth century with a descriptive view of the lesions present in bone structures. Subsequently, in the early decades of the twentieth century, an analytical perspective formed; and, between the 1930s and 1970s, paleopathology tended to be synthetic and specialized.

There is also a relatively new stance on how the manifestations of disease and the impact on populations of the past must be analyzed. In this way, researchers discuss how to describe the lesions and employ a model of differential diagnosis, integrating the systems of data recording and analytical techniques by proposing frameworks of interpretation at the population level (Rodríguez, 2006:31). This interdisciplinary stance persists to this day; but in recent years, it has been complemented by a tendency to demonstrate the socio-cultural dynamics around the diseases of ancient populations; in other words, how diseases are perceived, studied, and treated.

Nevertheless, in recent years (1996–2000), Armelagos and Van Gerven (2003) have recognized an important shift in paleopathology towards the old question of differential diagnosis, as well as a return to description through the application of new techniques and technology on ancient material.

The history of paleopathology in South America followed the global trajectory, transitioning from the description of individual cases to the paleoepidemiology of populations, and finally, to the resolution of questions about human adaptation (Verano, 1997). However, in discussions about the development of research in bioanthropology, bioarchaeology, and paleopathology, South American scholars find that the main difficulties are the challenges in financing research projects, the need to strengthen programs of academic training, and the need to

reach a wider international audience with their theoretical and methodological proposals (Rodríguez, 1996). These discussions have largely taken place at events organized in the region, such as the Congress of the Latin American Association of Biological Anthropology, or ALAB (Rodríguez, 2010), and the Paleopathology Association Meeting in South America, or PAMinSA (Rojas-Sepúlveda and Perafán, 2013).

However, in Latin America, topics about the analysis of ancient diseases have gained popularity, due mainly to the rapid development of technology and information systems. Despite the fact that this has enabled South American researchers to access academic studies in North America and Europe, it seems that such research does not take the inverse direction very frequently (Salager-Meyer, 2008).

On the other hand, there is a tendency to collaborate with other disciplines, such as biomedical sciences, dentistry, and social sciences, among others (Mitchell, 2012; Wanek et al., 2012; Zimmerman, 2012). This has enriched frameworks of paleopathological interpretation, giving rise to an interdisciplinary perspective that permits deeper analysis.

The region explored here, northwestern South America, is a very diverse area from a geographic, biological, and cultural point of view. Such diversity makes it very challenging to analyze a discipline like paleopathology. The history of the discipline in each of the four countries in this region is very different, and consequently, the current state of paleopathological research is quite unique in each country.

Paleopathology depends upon different sources of data to study disease such as ethnohistory, ethnography, artistic representations, and skeletal remains (Ortner, 2003; Verano, 1997). Nevertheless, this chapter will focus on the most direct evidence of health in the past: the skeletal remains. A crucial factor for the study of skeletal remains is the imbalance in the rates of preservation within the archaeological context. For instance, some desert areas and some highland environments in Peru offer good conditions for the preservation of organic archaeological evidence (Lozada, 2014; Verano, 1997). Some contexts in Ecuador are also good (Ubelaker, 2014), but this is not always the case in Colombia (Rojas-Sepúlveda, 2014) or in Venezuela (Scaramelli and Scaramelli, 2014).

A very brief summary of the history of paleopathology in each country will be presented; this will be followed by the current state of research and methodologies that are usually applied in the context of the discipline. Finally, some perspectives for future research in paleopathology in the region will be discussed.

## **HISTORY OF PALEOPATHOLOGY IN VENEZUELA, COLOMBIA, ECUADOR, AND PERU**

### VENEZUELA

According to Díaz-Ungría (1993), Venezuelan anthropology began with the European perspective, which was focused

on biological anthropology. Ernst, Vernier, Kate, Marcano, and Virchow performed some osteological studies by the end of the nineteenth century, with an emphasis on cranial deformation, osteometry, and cranial capacity (Díaz-Ungría, 1993; Scaramelli and Scaramelli, 2014). Although these studies in osteology were the first physical anthropology studies in the country, they did not have the expected impact needed to establish the field (Díaz-Ungría, 1993). However, the case of Venezuela is interesting because the Universidad Central de Venezuela has offered a course in Anthropology since 1896 (Rodríguez, 1996:83; Scaramelli and Scaramelli, 2014:238), but it was not until 1953 that the Department of Sociology and Anthropology opened at the school, formalizing the training and practice of bioanthropology. In this decade, collaborative work began among professionals of different areas with several research centers in order to concentrate efforts to strengthen the field in Venezuela (Rodríguez, 1996). While cranial deformation and craniometric comparisons between groups were undertaken by researchers such as Dupouy, Cruxent, Briceño, Requena, Dettein King, Kate, Barras de Aragón, Fleury Cuello, de Arechabaleta, Castillo, Peñalder, Méndez, and Mancera (Díaz-Ungría, 1993; Scaramelli and Scaramelli, 2014), Garaycochea studied craniometry and osteometry for forensic purposes (Rodríguez, 1996). Unfortunately, these studies are not easily accessible. Some osteological research has been produced by the Universidad Central de Venezuela, and a considerable quantity of material has been recovered and catalogued in several Venezuelan museums, particularly those in Aragua and Carabobo (Díaz-Ungría et al., 1993). In both Aragua and Carabobo, several osteological series have been established as a result of archaeological excavations supported by the Fundación Lisandro Alvarado. Some of them have provided material for dental and craniological studies (Díaz-Ungría et al., 1993).

Different studies were produced related to health and disease in native Venezuelan groups, particularly in relation to the epidemiology of tropical diseases. The work of scholars from the medical and anthropological fields shows that the health of these populations has degraded during the last fifty years (Díaz-Ungría et al., 1993).

Nevertheless, paleopathological studies from a bioanthropological perspective are scarce in Venezuela, and consequently, very few studies in paleopathology have been published in Venezuela. This could be explained in part by the theories of Sanoja and Vargas-Arenas (1993), who suggest that elites there have shown very little interest in the historical and cultural ancestry of the country, while scholars are more concerned with global trends than research on the local or national level. Another factor is the stagnation of international and interdisciplinary collaborations in the 1990s (Rodríguez, 1996).

#### COLOMBIA

During the eighteenth and nineteenth centuries, especially from 1940 to 1970, several studies were performed on osteological material in Colombia (Rodríguez, 1996). To analyze the case of Colombia, Rodríguez (1996:88) proposed three stages

in the development of bioanthropology. During the first period, at the end of the eighteenth century and in the first years of the nineteenth century, an interest arose in collecting materials that could feed the growing museum collections in Europe. Simultaneously, the achievement of independence in 1810 inspired the Colombian nation to build a history and create a national identity. In this process, several European researchers explored the country—especially French scholars, such as Bollaert, Broca and Brettes—making records of the morphological variability of the skulls of pre-Columbian groups, with a clear typological trend based on traditional ideas leftover from the colonial period (Rodríguez, 1996; 2006).

In the second period, the first half of the twentieth century, the civil wars affected scientific activity in the country. However, European researchers were still doing their work, emphasizing ethnocentric and deterministic interpretations with a clear racial influence. The visits of these specialists were also crucial to the consolidation of the first ethnological and archaeological museum (1931) as well as in the teaching of the first courses about these areas (1939), through the *Escuela Normal Superior*. Researchers, such as José Pérez de Barradas from Spain, expanded their studies to include bioarchaeology in several regions of Colombia. Also, with the opening of the National Ethnological Institute (Instituto Etnológico Nacional) in 1941, the first Colombian anthropologists were trained in accordance with the guidelines of Paul Rivet from France, and Justus W. Schottelius from Germany, who taught the first courses in bioanthropology. In this period, they began to analyze the remains of hunter-gatherer groups from the eastern Andes in Colombia, which formed the basis for the studies carried out in the 1980s (Rodríguez, 2006:35).

Between 1940 and 1970, Correal and Silva Celis worked on material from the central territory, discovering new information about the health of past populations (Rodríguez, 1996; Rojas-Sepúlveda, 2014). In this period, training programs in anthropology opened at several universities: the Universidad de los Andes in 1963, the Universidad Nacional de Colombia in 1966, the Universidad de Antioquia and the Universidad del Cauca in 1970 (Rodríguez, 1996). The period from 1970 to 1990 was a critical time for anthropology, and particularly for biological anthropology. After these decades, a “renaissance” in bioanthropology began, with the return of specialists trained in other countries, such as José Vicente Rodríguez and Felipe Cárdenas, as well as contributions from the medical field, for instance, those made by Hugo Sotomayor (Rojas-Sepúlveda, 2014). The importance of forensic anthropology (Rodríguez, 1996), as well as the training in the universities, brought new relevance to physical anthropology in Colombia (Rojas-Sepúlveda, 2014).

The objectives in the study of osteological series and mummified remains have been very diverse, leading researchers to expand models of interpretation about the health conditions, diseases, and diet of pre-Columbian populations in the eastern Andes and southwestern Colombia (Rodríguez, 1996). In addition, they integrate several lines of evidence from Spanish chronicles, ethnohistory, and archaeology with elements

of material culture, including some depictions of diseases, such as those associated with the Tumaco and La Tolita groups in southwestern Colombia (Sotomayor Tribín, 1990, 1999, 2007). According to Rodríguez (1996), bioanthropology has developed around archaeology in Colombia; but additionally, in the 1990s, interdisciplinary work with dentists began. This collaboration facilitated the study of dental morbidity in prehistoric groups, from hunter-gatherers until the late periods of several indigenous cultures (Rodríguez, 2006:35). There was also an interest in recording cranial deformation in the pre-Columbian populations of the eastern Andes, an aspect which has been addressed from a descriptive point of view, while being attentive to the social differentiation of these peoples (Boada, 1995).

At this stage, paleopathology evolved from being descriptive to having an analytical and interpretative understanding about the conditions of health and disease in populations of the past. Paleopathological models were also constructed in an attempt to explain how the lifestyles and environments of these groups influence the manifestation of bone lesions. For example, scholars discussed the frequency of osteoarthritis and its relationship to the physical activities of these groups, or the presence of infections associated with treponematosi and tuberculosis as evidence of changes in the lifestyles of these populations (Correal-Urrego, 2012; Rodríguez, 2006). Similarly, the application of new techniques for analysis such as imaging allowed researchers in the 1990s to identify lesions compatible with tuberculosis as Pott's disease. This diagnosis was supplemented in the next decade with the application of DNA analysis (Sotomayor Tribín, 2007:145).

#### ECUADOR

Paleopathology in Ecuador has been characterized by research in a broad context, ranging from prehistory to the colonial period, and from coastal areas to the Andean highlands. However, much of the work has been developed by foreign researchers like Douglas Ubelaker, who has made important investigations since the 1970s into the conditions of health, diseases, and diet of the indigenous populations and the transition to the established model by the Spanish conquest and colonization (Ubelaker, 2005). Ubelaker began his investigations in Ecuador in 1973 with the aim of performing a comparative analysis with osteological series from the eastern United States. In later years, he provided a systematic approach to the understanding of the health status of these populations from a regional perspective (Ubelaker, 2005), considering also the peculiarities of different historical periods.

Munizaga worked on deformation and cranial morphometrics while Ubelaker studied stress indicators and funerary patterns in several skeletal series from 8300 B.P. until the contact period along the coast and in the highlands (Rodríguez, 1996), as well as in the colonial period (Newson, 1993; Ubelaker, 2014). Recent decades have witnessed several archaeological excavations from which skeletal collections were assembled and easily dated

according to the associated cultural material. Several studies based on these collections have facilitated the reconstruction of the local temporal trends of morbidity and mortality (Ubelaker, 1984; 2014). Ubelaker has participated in the excavation and analysis of more than ten archaeological funerary sites (Ubelaker, 2014). The biological characteristics studied, like craniometry, non-metric variation, stature, trauma, infectious disease, porotic hyperostosis, degenerative changes, congenital anomalies, population density, dental anomalies, demography, and changes associated to activity, have demonstrated a clear reduction in health conditions through time (Ubelaker, 1979; 1984; 2005; 2014). Moreover, Ubelaker and his colleagues (1995) introduced stable isotope analyses in the 1990s that identified differences in the diets of ancient populations related to social status.

#### PERU

The particular conditions under which bioarcheology has developed in Peru are characterized by local and foreign researchers working with extensive osteological series and mummified remains of mainly pre-Columbian populations. These studies have driven the development of paleopathology in the central Andes.

According to Altamirano (2013), paleopathology in Peru has passed through four phases: descriptive (1850–1910), the domain of the medical field and of foreign researchers (1911–1970), new archaeology and modern paleopathology or the break from foreign influence (1971–2000), and demarcation, or interdisciplinary paleopathology (2001–2013).

Pioneering works on pathology, dental anomalies, cranial deformation, trephination, and nutrition were developed by Virchow (Reiss and Stübel, 1887), Lastres, Marroquin, Pezzia, Quevedo, Salazar, Tello, Valdivia, Weiss, Newman (Rodríguez, 1996), Moodie (1921, 1928, 1930), MacCurdy (1923), Stewart (1943), Rogers (1938), Newman (1943, 1948, 1954), and Hrdlička (1943).

Virchow analyzed deformed skulls from the central coast site called Ancón, beautifully described by Reiss and Stübel (1887). Besides the deformation, Virchow observed *Arthritis deformans*, hyperostosis, Wormian bones, trauma, developed muscle attachments, caries, and abscesses (Reiss and Stübel, 1887).

Newman (1943, 1948) considered that the reconstruction of Peruvian “racial history” was challenging at the time because few physical anthropologists had worked there, physical anthropology in Peru was just then entering the stage of rigorous scientific method, few archeologically documented skeletal series existed, and high frequencies of cranial deformation masked “racial characters.” Aleš Hrdlička studied material from northern and central Peru in order to clarify the affinities between ancient populations, and by doing so, he observed cranial deformation. Some other researchers, such as Kroeber and Stewart, also analyzed this material, and their various studies concluded that deformation became less frequent in later periods along the coast as well as in the mountains (Newman, 1948). These studies were reviewed by Weiss in the 1960s and 1970s. He expanded

the typology of cranial deformation and also considered cultural aspects around this practice (Cocilovo et al., 2011).

Comparisons of data from previous works allowed Newman (1948) to conclude that from the Formative to the Regional Classic stages, the valleys supported near-optimum populations. Newman (1948) considered that careful anatomical research should be done, particularly in mummies and about trephination, in order to complete Tello's and Stewart's works on these subjects. In 1954, Newman reported that skeletal material from the central coast showed very few pathological changes (Newman, 1954).

Trephination, defined as surgical procedures carried out on the skull, provided a framework of interpretation for the therapeutic procedures of these populations. Since the nineteenth century, trephination has been observed in several prehistoric and Incan skulls, such as those found in Cuzco by E. George Squieren in 1867 (Parry, 1923; Andrushko and Verano, 2008). Other skulls were studied by Broca, some years later; he associated trephination with therapeutic and ritual practices and documented the use of coca leaves as an anesthetic during the procedure (Parry, 1923:460). But perhaps the first systematic study about trephination was carried out by MacCurdy in 1923, with a sample of 341 Incan individuals from Cuzco. MacCurdy identified the relationship between this evidence and injuries caused by combat, although there was no clarity on the distribution by sex or the link with the social organization of these groups (Andrushko and Verano, 2008:5). On the other hand, trephination techniques were identified by Quevedo in 1939 and 1942, showing geographic variations in the execution of the procedure (Andrushko and Verano, 2008:5).

In the beginning of the twentieth century, an interest emerged in subjects related to the nutritional conditions of these populations and the relationship with their economic organization, especially in the transition from egalitarian to hierarchical societies. For instance, in Hrdlička's 1914 study of populations along the Peruvian coast, he associated high frequency of porotic hyperostosis in subadult individuals with the presence of anemia (Blom et al., 2005), a model that has been applied to many other osteological series.

In the 1970s, analysis began to include technologies, such as the use of radiology in the observation of diseases, and the identification of skeletal indicators such as Harris lines. In Peru, this established differences between the conditions of the coastal and the highland populations, in addition to comparisons over time, including contemporary populations (Allison, 1984). In fact, radiology was a useful tool for the analysis of mummies from Peru and the rest of South America, despite the fact that the results of these studies have not been widely reported. Dageförde and his colleagues (2014) pointed out that between 1977 and 2005, there were only 61 papers in the Pubmed platform addressing the issue of paleopathology in South American mummies. Of these, 24 were case studies, while the remaining 37 had an epidemiological perspective (Dageförde et al., 2014). However, in this period, they considered an increase of the application of technologies for

data extraction and related interpretation frameworks, including histological methods, computed tomography (CT), radiocarbon dating, ancient DNA (aDNA) analyses, and biochemical analyses (Dageförde et al., 2014: 218–219).

The use of radiology in the analysis of pre-Columbian and colonial period mummies of Peru has been useful in the identification of the scars of parturition, inflammatory processes that can be confused with another series of rheumatoid, traumatic, or infectious lesions (Ashworth et al., 1976). Also, the application of histological techniques in 1973 allowed for the identification of tuberculosis in a pre-Columbian mummy and later, in the 1990s, the DNA of the pathogen was detected (Salo et al., 1994; Sotomayor Tribín, 2007:145). Similarly, other materials began to be included in the paleopathological analysis; such was the case with coprolites, studied by specialists in paleoparasitology, a discipline that has been revealing interesting insights about material from the Peruvian Coast since the 1980s (Horne, 1985:305). In addition, the histomorphometrical analysis of bones was used in order to identify anomalies associated with metabolic disorders in the trabecular bone density (Weinstein et al., 1981).

In the 1990s these techniques provided further information about issues that had been studied since the beginning of the century, as was the case of trephination, for which CT and radiographic imaging provided additional data, minimizing the bias that macroscopic observation can have (Chege et al., 1996).

Certain injuries that are not usually well represented in osteological specimens, such as some neoplastic manifestations (Baraybar and Shimada, 1993), have been observed in Peruvian material and published as case studies. This provided a foundation for future epidemiological investigations of such diseases in pre-Columbian populations using a differential diagnosis.

## **STATUS OF PALEOPATHOLOGY IN VENEZUELA, COLOMBIA, ECUADOR, AND PERU**

Today, paleopathology research in the region is characterized by addressing a wide range of topics and methodologies including differential diagnosis, the application of biochemical techniques, DNA analysis, and imaging techniques. However, standardization of the recovery of information and the integration of data from different populations are needed to provide more complex and precise interpretations about the conditions of health in the past.

Tables 1 through 11 presented below (case studies not included) show trends in research about different indicators of health in the northwestern South America. The majority of works presented here were made in recent years in the region of the central Andes.

As seen in the tables, several indicators of health have been studied in the material from the northwestern South America. Nevertheless, this is a vast and diverse region, and some areas

have not yet been explored at all, while some indicators have not yet been studied or reported in areas where the material is available. It is clear in Table 1 that enthesal changes (also called musculoskeletal stress markers) are a relatively new subject of interest in the region, and some additional series would certainly facilitate the creation of a standardized method to study the level of physical activity in order to allow comparisons between series. Although degenerative joint disease has been studied for a long time, the reported results are not completely comparable, because standardized observation and data collection have only recently been applied. Trauma has been traditionally studied as well, but recent systematic observations have facilitated new research about relationships within and between populations. Infectious disease, porotic hyperostosis, and cribra orbitalia have been reported, but it would be worthwhile to establish criteria

in order to make the studies comparable. Stature has been reported for several series but not all. Dental indicators have been frequently reported but in some cases the methodology of data recording or the presentation of results is not clearly conveyed. Indicators such as Schmörl nodules, scurvy, auditory exostosis, and paleodemographic markers should be more frequently studied and reported.

#### VENEZUELA

Although works that include populational approaches to paleopathological studies are not frequent, Venezuelan paleopathology presents some case studies with rarely documented bioarchaeological anomalies. These case studies serve as a basis for comparison with other individuals and are studied by applying

TABLE 1. Studies documenting enthesal changes (also called musculoskeletal stress markers) in populations of Peru and Colombia.

Series or region	Reported data	Reference
Ancón, central coast of Peru, AD 600–1000	Total 7.8% (9/119), females 1.6% (1/63), males 14.9% (7/47)	Rojas-Sepúlveda and Dutour, 2009
Ancón 1, central coast of Peru, AD 600–1000	Several locations reported significant differences between right and left, and between osteological series. Only for reference: Insertion of the deltoid into the humerus: left 36.63% (37/101), right 41.18% (42/102) Insertion of the gluteus maximus into the femur: left 49.06% (52/106), right 45.37% (49/108)	Rojas-Sepúlveda and Dutour, 2014
Geographic Valley Río Cauca, Colombia, 340BC–AD 440	Achilles tendon marker: 68.4% females, 33.3% males Calcaneal spur: 43.8% females, 15% males (significant differences) Insertion of the deltoid into the humerus: 21.7% females, 55.9% males	Acosta, 2012
Muisca, central Colombia, Soacha, AD 11–13th centuries	Several locations reported significant differences between right and left, and between osteological series. Only for reference: Insertion of the deltoid into the humerus, left 17.57% (13/74), right 18.18% (14/77) Insertion of the gluteus maximus into the femur, left 50.75% (34/67), right 44.78% (30/67)	Rojas-Sepúlveda and Dutour, 2014
Muisca, central Colombia, Marín, AD 13–14th centuries	Several locations reported significant differences between right and left, and between osteological series. Only for reference: Insertion of the deltoid into the humerus, left 28.21% (11/39), right 35.9% (14/39) Insertion of the gluteus maximus into the femur, left 71.79% (28/39), right 65.0% (26/40)	Rojas-Sepúlveda and Dutour, 2014
Muisca, central Colombia, Tunja, AD 8–18th centuries	Several locations reported significant differences between right and left, and between osteological series. Only for reference: Insertion of the deltoid into the humerus, left 27.03% (20/74), right 29.73% (22/74) Insertion of the gluteus maximus into the femur, left 37.84% (28/74), right 37.5% (27/72)	Rojas-Sepúlveda and Dutour, 2014

TABLE 2. Studies documenting degenerative joint disease in populations of northwestern South America.

Series or region	Reported data	Reference
Highlands of Peru	“a rather common disease”	MacCurdy, 1923
Supe, central coast of Peru, Chavín culture [Early Horizon period]	30%	Newman, 1954
Mummies from Chile and Peru	“elevated frequencies” (young individuals)	Allison, 1984
Muisca series, central Colombia	41.9% (31/74)	Rodríguez, 1987
Ancón, central coast of Peru	“low presence”	Kauffmann, 1996
Several series from Peru, 700 BP	Chiribaya: 67.7% as an attributed score Estuquina: 86.1% as an attributed score San Geron: 61.3% as an attributed score Yaral: 56.8% as an attributed score	Buikstra (Steckel et al., 2002)
Several series from Ecuador, 7500–90 BP	Santa Elena, 7425 BP: 94.8% as an attributed score Highland, 2160 BP: 85.1% as an attributed score Realto 4663 BP: 80.5% as an attributed score San Francisco church, 190 BP: 89.8% as an attributed score South Coast, 1760 BP: 77.3% as an attributed score North Coast, 2050 BP: 71.4% as an attributed score San Francisco church, 90 BP: 78.9% as an attributed score Quito convent, 395 BP: 94.6% as an attributed score San Francisco church, 300 BP: 79.8% as an attributed score	Ubelaker and Newson, 2002; Steckel et al., 2002
Villa el Salvador, central coast of Peru, 100 BC–AD 100	Females: elbow 50% (N = 30), knee 47% (N = 30), cervical vertebrae 60% (N = 30), thoracic vertebrae 33% (N = 30), lumbar vertebrae 76% (N = 29) Males: elbow 72% (N = 29), knee 79% (N = 27), cervical vertebrae 68% (N = 31), thoracic vertebrae 48% (N = 31), lumbar vertebrae 77% (N = 31)	Pechenkina and Delgado, 2006
Soacha, Muisca, central Colombia, AD 11–13th centuries	Females: cervical 68.2% of the individuals (30/44), 39.3% of the vertebrae (106/270); thoracic 60.0% of the individuals (27/45), 19.6% of the vertebrae (86/438); lumbar 69.8% of the individuals (30/43), 51.4% of the vertebrae (114/222); whole vertebral column 89.1% of the individuals (41/46), 32.9% of the vertebrae (306/930) Males: cervical 56.3% of the individuals (18/32), 31.2% of the vertebrae (62/199); thoracic 64.5% of the individuals (20/31), 24.5% of the vertebrae (74/302); lumbar 59.4% of the individuals (19/32), 41.0% of the vertebrae (66/161); whole vertebral column 76.5% of the individuals (26/34), 30.5% of the vertebrae (202/662)	Rojas-Sepúlveda et al., 2008
Ancón, central coast of Peru, AD 600–1000	Total 76.5% (91/119), females 73.8% (48/65), males 85.4% (41/48)	Rojas-Sepúlveda and Dutour, 2009
Pre-Columbian and postcontact Mochica, Peru Muisca, central Colombia, Soacha, AD 11–13th centuries	Late pre-Hispanic: 50% (56/112); postcontact: 75.6% (34/45) Several locations yielded significant differences between right and left and between osteological series. Only for reference: elbow, left 17.74% (11/62), right 14.06% (9/64); knee, left 6.06% (4/66), right 10.14% (7/69)	Klaus et al., 2009 Rojas-Sepúlveda and Dutour, 2014
Muisca, central Colombia, Marín, AD 13–14th centuries	Several locations yielded significant differences between right and left and between osteological series. Only for reference: elbow, left 18.42% (7/38), right 25.71% (9/35); knee, left 8.33% (3/36), right 8.33% (3/36)	Rojas-Sepúlveda and Dutour, 2014
Muisca, central Colombia, Tunja, AD 8–18th centuries	Several locations yielded significant differences between right and left and between osteological series. Only for reference: elbow, left 13.64% (9/66), right 19.12% (13/68); knee, left 7.55% (4/53), right 16.95% (10/59)	Rojas-Sepúlveda and Dutour, 2014
Ancón 1, central coast of Peru, AD 600–1000	Several locations yielded significant differences between right and left and between osteological series. Only for reference: elbow, left 35.00% (35/100), right 46.53% (47/101); knee, left 51.96% (53/102), right 48.08% (50/104)	Rojas-Sepúlveda and Dutour, 2014

TABLE 3. Studies documenting trauma in populations of northwestern South America.

Series or region	Reported data	Reference
Cerro Colorado, Paracas, Peru, pre-Hispanic Cinco Cerros, San Damian, Central Highlands, Peru, San Diego Museum, pre-Hispanic	40% with trephination From 60 crania: 12 were trephined by sawing (42.8%), 6 by cutting (21.4%), 4 by scraping (14.3%), 3 by sawing and cutting (10.7%), 1 by scraping with cutting (3.6%), 1 by scraping with sawing (3.6%), and 1 by drilling (3.6%)	Stewart, 1943 Rogers, 1938
Supe, central coast of Peru, Chavín Period Peru and Chile	4/21 (one skeleton with five extensive healed fractures) Shamans: 0% Male commoners: 35% Female commoners: 16%	Newman, 1954 Allison, 1984
Several series from Ecuador, 600 BC – AD 1230	Santa Elena, 600 BC: 9% Guangala 100 BC: 33% Ayalán without urn AD 710: 18% Ayalán with urn AD 1230: 13%	Ubelaker, 1984
Ancón, central coast of Peru Several series from Peru, 700 BP	0% Estuquina, 700 BP: 92.6 as an attributed score Yaral, 700 BP: 100 as an attributed score San Geron, 700 BP: 100 as an attributed score Chiribaya, 700 BP: 98.8 as an attributed score	Kauffmann, 1996 Buikstra (Steckel et al., 2002)
Several series from Ecuador, 7500–90 BP	Santa Elena, 7425 BP: 90.8 as an attributed score Highland, 2160 BP: 94.4 as an attributed score Realto 4663 BP: 88.4 as an attributed score San Francisco church, 190 BP: 72.2 as an attributed score South Coast, 1760 BP: 87.6 as an attributed score North Coast, 2050 BP: 88.7 as an attributed score San Francisco church, 90 BP: 59.8 as an attributed score Quito convent, 395 BP: 58.8 as an attributed score San Francisco church, 300 BP: 75.0 as an attributed score	Ubelaker and Newson, 2002; Steckel et al., 2002
Villa el Salvador, central coast of Peru, 100 BC–AD 100	Males: cranial trauma 20% ( <i>N</i> = 30), postcranial trauma 22% ( <i>N</i> = 32) Females: cranial trauma 10% ( <i>N</i> = 29), postcranial trauma 29% ( <i>N</i> = 27)	Pechenkina and Delgado, 2006
Chachapoya region, northern highlands of Peru.	Trephination frequency: Revash funerary complex series where there are juvenile and adults, 8% (8/97)	Nystrom, 2007
Central Highlands, Peru. Wari Period (AD 650–800).	Cranial trauma frequency: 3 adult samples, Beringa 33% (13/39); Conchopata 26% (7/27); La Real 31% (32/104)	Tung, 2007
Cuzco region, Peru, AD 1000–1532	Qotakalli AD 1290–1532, 17.4% trephinations (34/195) Chokepukio AD 1000–1532, 8.4% trephinations (7/83) Colmay AD 1400–1532, 35.6% trephinations (21/59) Cotocotuyoc AD 1000–1400, 5.7% trephinations (2/35) Aqnapampa AD 1000–1532, 4.8% trephinations (1/21) Kanamarca AD 1400–1532, 16.1% trephinations (66/411)	Andrushko and Verano, 2008
Ancón, central coast of Peru, AD 600–1000	Total 12.9% (15/116), females 7.9% (5/63), males 21% (10/47)	Rojas-Sepúlveda and Dutour, 2009
Pitakilla, Paucarmás, Tuquillo, North, and Huallamarca, central Peru, AD 200–1532	Anatomically artificial cranial modification (ACM) Huallamarca: 8 unmodified, 0 with posterior flattening, 0 bilobed, 0 circumferential Paucarmás: 13 unmodified, 0 with posterior flattening, 0 bilobed, 11 circumferential Pitakilla 11 unmodified, 32 with posterior flattening, 0 bilobed, 0 circumferential Tuquillo: 14 unmodified, 1 with posterior flattening, 19 bilobed, 0 circumferential	Pomeroy et al., 2010
Puruchuco-Huaquerones, central coast, Peru Late Horizon (AD 1470–1532).	Evidence of weapon-related perimortem trauma: 18.6%, 48/258 individuals older than 15 years	Murphy et al., 2010
Region of Cuzco, Peru. Middle Horizon and Inca period (AD 600–1532).	Perimortem cranial trauma 22.0% (100/454 adults)	Andrushko and Torres, 2011



TABLE 3. (Continued)

Series or region	Reported data	Reference
Puruchuco-Hauquerones, Peru, AD 1470–1540	Juvenile: Late Horizon: 2/169 cases of fractures, 8/169 cases of endocranial bone deposition; early postcontact period: 1/73 cases of fractures, 1/73 cases of endocranial bone deposition	Gaither, 2012
Puruchuco-Hauquerones, Peru, AD 1470–1540	Juvenile: Late Horizon/Huaquerones: 1/169 cases of cranial trauma, 9/169 cases of postcranial trauma; early postcontact period: 8/73 cases of cranial trauma, 7/73 cases of postcranial trauma	Gaither and Murphy, 2012
Central Andes, Peru. Final Formative (late Early Horizon, 400 BC–AD 100) and Late Intermediate period (AD 1000–1400).	Cranial trauma Archaic period: 1.14% (1/88 individuals) Final Formative period: 17.5% (29/114 individuals) Early Intermediate period: 15.1% (42/278 individuals) Middle Horizon: 16.8% (80/476 individuals) Middle Horizon/Late Intermediate period: 5.08% (3/59 individuals) Late Intermediate period: 32.22% (199/599 individuals) Late Intermediate period/Late Horizon: 27.4% (152/555 individuals) Late Horizon: 18.46% (72/390 individuals)	Arkush and Tung, 2013
Highlands of Andahuaylas, Peru. Late Intermediate period (AD 1000–1250). Several periods from Ecuador	From 284 cranial, 32 individuals with trephination (11.3%)  Early precontact: 0.09 (bones/adults) Middle precontact: 0.06 (bones/adults) Late precontact: 0.12 (bones/adults) Early historic: 0.12 (bones/adults) Late historic: 0.29 (bones/adults)	Kurin, 2013  Ubelaker, 2014

imaging techniques in order to complement the data collection obtained by macroscopic analysis (Van Duijvenbode et al., 2015). However, the field of paleopathology in Venezuela still requires consolidation, in the assembly and cataloguing of osteological series, in the methodologies employed for data collection, in the publication of results, and in the strengthening of academic and professional training programs in paleopathology.

#### COLOMBIA

The concept of variability, borrowed from biological anthropology, has set a trend in the development of paleopathological research in Colombia. Considering the particularities of the bio-cultural contexts of the ancient populations in this region (Rodríguez, 1996), together with other avenues of inquiry, this research provides information that facilitates the reconstruction of prehistoric patterns of health and disease.

An ecosystemic approach has been applied to this concept, which seeks to establish the dynamics generated by the interaction between human groups, as well as environmental, biological, and socio-cultural adaptations, which manifest in the bioarchaeological record (Rodríguez, 2006:36). From the 1980s to the present, a human ecology perspective has characterized

paleopathological analysis in Colombia. It argues that individuals respond to changes in their environment and make adjustments (biological, social, and cultural) in order to adapt. Nevertheless, populations do not present the same processes of adaptation; they weigh their strategies, attending to the relationship between available food resources, health conditions, and the effectiveness of the mechanisms for demographic control in times of environmental fluctuation (Rodríguez, 2006:42).

This perspective has been complemented by other information relating to disease, which is revealed using ethnographic data from living indigenous people. This includes, the conception that indigenous populations have about a disease, their magical or religious beliefs, and the natural and folk remedies they use to explain and treat it (Rodríguez, 2006:43).

In addition, since the 2000s, several techniques such as imaging have been applied to the study of diseases in ancient populations. For example, in the case of mummies, radiological analysis has been utilized to broaden diagnosis in relation to diseases such as tuberculosis (Etxeberria et al., 2000). As shown in the tables, in recent years, paleoepidemiology has become increasingly relevant to paleopathology research performed in Colombia (Gómez, 2012; Langebaek et al., 2011; Rodríguez, 1987, 1996, 2006, 2011; Rojas-Sepúlveda et al., 2008; Rojas-Sepúlveda

TABLE 4. Studies documenting infectious disease in populations of northwestern South America.

Series or region	Reported data	Reference
La Paloma, central coast of Peru, 8000–4500 BP Peru	10–16% osteolysis, 22–25% periosteal reactions Shamans: 9% osteolysis Males: 20% osteolysis Females: 18% osteolysis	Benfer, 1984 Allison, 1984
Several series from Ecuador, 600 BC–AD 1230	Santa Elena, 600 BC: 7% (9 bones out of 127 individuals) Guangala 100 BC: 44% Ayalán without urn, AD 710: 4% Ayalán with urn, AD 1230: 14%	Ubelaker, 1984
Several series from Peru, 700 BP	Estuquina: 78.1 as an attributed score Yaral: 71.5 as an attributed score San Geron: 72.7 as an attributed score Chiribaya: 80.1 as an attributed score	Buikstra (Steckel et al., 2002)
Several series from Ecuador, 7500–90 BP	Santa Elena, 7425 BP: 98.7 as an attributed score Highland, 2160 BP: 93.5 as an attributed score Realto 4663 BP: 95.8 as an attributed score San Francisco church, 190 BP: 98.3 as an attributed score South Coast, 1760 BP: 94.1 as an attributed score North Coast, 2050 BP: 58.1 as an attributed score San Francisco church, 90 BP: 95.2 as an attributed score Quito convent, 395 BP: 84.8 as an attributed score San Francisco church, 300 BP: 72.8 as an attributed score	Ubelaker and Newson, 2002; Steckel et al., 2002
Villa el Salvador, central coast of Peru, 100 BC–AD 100	43% periosteal reactions, males ( $N = 30$ ) 13% periosteal reactions, females ( $N = 29$ )	Pechenkina and Delgado, 2006
Lambayeque Valley complex (north coast Peru), late pre-Hispanic and postcontact period.	Periosteal reactions: Odds ratio results, overall late pre-Hispanic–postcontact period comparison of systemic stress, strongly significant postcontact increase. Odds ratio results, late pre-Hispanic–early/middle colonial period comparison of systemic stress, 6.67 times greater in the early/middle colonial period.	Klaus and Tam, 2009
Ancón, central coast of Peru, AD 600–1000	Total 35.7% (41/115), females 34.9% (22/63), males 41.3% (19/46)	Rojas-Sepúlveda and Dutour, 2009
Lambayeque Valley complex, Peru, late pre-Hispanic and colonial	Five cases of tuberculosis lesions: one from the site Illimo (AD 900–1100) with 52 burials; two cases from La Caleta de San José (AD 1375–1450) with 26 burials; two cases from the colonial period Chapel of San Pedro Mórrope with 322 indigenous burials and 870 individuals (AD 1536–1750)	Klaus et al., 2010
Savanna of Bogotá, several sites, Colombia, preceramic 8th century BC–late Muisca, AD 13th century	Tuberculosis: Not present: early preceramic; late preceramic; early Herrera; late Herrera Present: early Muisca, late Muisca Treponematosi: Not present: early preceramic; 14.3%, late preceramic; 5.6%, early Herrera; present, late Muisca. Periostitis: 14.0% ( $N = 228$ )	Rodríguez, 2011
Savanna of Bogotá, Tibanica, Colombia, AD 10–16th centuries		Langebaek et al., 2011
Bogotá savanna, Tequendama, Checua, Aguazuque and Vista Hermosa, Colombia, middle and late Holocene	Periostitis in bones different to tibia: 15.9% (12/75)	Gómez, 2012
Puruchuco-Huaquerones, Peru, Late Horizon AD 1470–1532	Periostitis: 19% (30/157), females 13% (10/75), males 26% (19/73), indeterminate 11% (1/9)	Williams and Murphy, 2013
Osmore drainage, southern highlands, Peru, Late Intermediate period, AD 1000–1470	Periostitis: 7.0% (7762 elements analyzed)	Burgess, cited in Williams and Murphy, 2013
Armatambo, central coast, Peru, Late Intermediate period, AD 1000–1470	Periostitis: 33.0% ( $n = 34$ )	Chan, cited in Williams and Murphy, 2013
Lambayeque, north coast, Peru, late pre-Hispanic period AD 900–1532	Periostitis: 14.5% ( $n = 54$ )	Klaus, cited in Williams and Murphy, 2013

TABLE 4. (Continued)

Series or region	Reported data	Reference
Rinconada Alta, central coast, Peru, Late Intermediate period, AD 1000–1470	Periostitis: 24.6% ( $n = 122$ )	Salter-Pederson, cited in Williams and Murphy, 2013
Maranga, central coast, Peru, Late Intermediate period, AD 1000–1470	Periostitis: 6.7% ( $n = 15$ )	Boza Cuadros, cited in Williams and Murphy, 2013
Machu Picchu, central highlands, Peru, Late Intermediate period, AD 1000–1470	Periostitis: 5.0% ( $n = 177$ )	Verano, cited in Williams and Murphy, 2013
Lambayeque, north coast, Peru, colonial period, AD 1536–1750	Periostitis: 41.8% ( $n = 67$ )	Klaus, cited in Williams and Murphy, 2013
Several periods from Ecuador	Early precontact: 0.06 (bones/individuals), 0.09 (bones/adults) Middle precontact: 0.11 (bones/individuals), 0.14 (bones/adults) Late precontact: 0.06 (bones/individuals), 0.12 (bones/adults) Early historical: 0.13 (bones/individuals), 0.28 (bones/adults) Late historical: 0.22 (bones/individuals), 0.37 (bones/adults)	Ubelaker, 2014

and Dutour, 2009, 2014). It remains important for Colombian researchers to publish more widely and create a more notable presence in international circles.

#### ECUADOR

Some information about diseases in the pre-Hispanic past of Ecuador comes from secondary sources, such as representations of some injuries in motifs on pottery of these ancient peoples. Hermida-Bustos (2007) suggested the presence of leishmaniasis, “Peruvian wart,” and the birth of conjoined twins, from observations of decorations on some ceramics. Nevertheless, knowledge about ancient disease in Ecuador has been revealed mainly through studies of skeletal remains by researchers like Ubelaker (1984, 2014) and Ubelaker et al. (1995). Paleopathology has had a wide diffusion, but it is still necessary for Ecuadorian researchers to participate in international conferences and collaborations to more widely share their advancements.

#### PERU

The current emphasis in paleopathology research in Peru focuses on population dynamics. It addresses features about the pre-Hispanic groups, but also considers the status of populations at the time of the Spanish conquest and during the colonial period (Gaither, 2012; Gaither and Murphy, 2012; Klaus and Tam, 2009, 2010; Klaus et al., 2010; Klaus and Ericksen, 2013; Klaus, 2014; Pechenkina and Delgado, 2006). Different bone and dental indicators of systemic stress, along with paleoenvironmental and archaeological information, are used to understand the dynamic process of socio-cultural change in this population. In the same way, the application of radiology, CT scanning, and aDNA analyses has made it possible to integrate microscopic data with macroscopic observations of lesions.

The application of new techniques has also enhanced the analysis of mummified individuals, and researchers have used mitochondrial DNA and bacterial DNA to identify the pathogens that attacked these ancient populations (Luciani et al., 2006; Guhl et al., 2014).

Furthermore, studies concerning the nutritional stress of ancient populations tend to incorporate data from environmental contexts, inter- and intra-individual variability, and the bio-cultural characteristics of the populations being analyzed. In this way, they attempt to incorporate the greatest number of variables in order to establish more reliable interpretations, proposing nutritional dynamics for these groups by studying indicators such as osteological lesions, stature range (Williams and Murphy, 2013), and isotope data (Buzon et al., 2011; Knudson and Tung, 2011; Turner and Armelagos, 2012). Other aspects have also been studied, such as the impact of agriculture on lifestyles in the pre-Hispanic period (Lanfranco and Eggers, 2010; Turner, 2013; Ortner et al., 1999) and during the colonial period (Klaus, 2014).

As indicated, paleopathology in Peru has a long and very productive history. Nevertheless, it is not clear if this huge quantity of data has been included in Peruvian explanations of their past.

## CONCLUSIONS

The development of the discipline in the region has responded to a series of processes that produced different objectives for paleopathological research in the four countries under consideration: Venezuela, Colombia, Ecuador, and Peru. These differences are related to the analytical perspectives held by each of these countries throughout history. During the nineteenth and early twentieth centuries, the first research in bioarchaeology and paleopathology was conducted from a descriptive perspective, with a particular interest in identifying human morphological

TABLE 5. Studies documenting porotic hyperostosis in populations of northwestern South America.

Series or region	Reported data	Reference
Several series from Ecuador, 600 BC–AD 1230	Santa Elena, 600 BC: 0% porotic hyperostosis, 0% cribra orbitalia Guangala 100 BC: 23% porotic hyperostosis, 10% cribra orbitalia Ayalán without urn, AD 710: 8% porotic hyperostosis, 0% cribra orbitalia Ayalán with urn AD 1230: 7% porotic hyperostosis, 2% cribra orbitalia	Ubelaker, 1984
Several series from Peru, 700 BP	Estuquina: 92.7 as an attributed score Yaral: 87.1 as an attributed score San Geron: 79.6 as an attributed score Chiribaya: 87.5 as an attributed score	Buikstra (Steckel et al., 2002)
Several series from Ecuador, 7500.–90 BP	Santa Elena, 7425 BP: 100 as an attributed score Highland, 2160 BP: 97.1 as an attributed score Realto 4663 BP: 99.3 as an attributed score San Francisco church, 190 BP: 99.6 as an attributed score South Coast, 1760 BP: 93.1 as an attributed score North Coast, 2050 BP: 100 as an attributed score San Francisco church, 90 BP: 99.7 as an attributed score Quito convent, 395 BP: 95.7 as an attributed score San Francisco church, 300 BP: 94.6 as an attributed score	Ubelaker and Newson, 2002; Steckel et al., 2002
Coastal sites, Peru, series housed at Field Museum of Natural History (FMNH) in Chicago and Chen Chen, Moquegua Valley, Peru.	FMNH: 30.1% ( $n = 465$ ) with orbital lesions; 23.1% ( $n = 402$ ) of adults with cribra orbitalia; 81.8% ( $n = 66$ ) of children with evidence of anemia. Chen Chen: 57.4% ( $n = 115$ ) of children with cribra orbitalia; 71.6% ( $n = 155$ ) with porotic hyperostosis; 39.2% ( $n = 181$ ) of adults with cribra orbitalia	Blom et al., 2005
Villa El Salvador, central coast of Peru, 100 BC – AD 100	11% severe cribra orbitalia males; 19% severe cribra orbitalia females 23% severe porotic hyperostosis males; 6% severe porotic hyperostosis females	Pechenkina and Delgado, 2006
Lambayeque Valley Complex (north coast Peru), late pre-Hispanic and colonial period.	Odds ratio results, overall late pre-Hispanic–colonial period comparison of systemic stress: significant increase in the colonial period Odds ratio results, late pre-Hispanic–early/middle colonial period comparison of systemic stress: 1.17 times greater prevalence in the late pre-Hispanic period	Klaus and Tam, 2009
Ancón, central coast of Peru, AD 600–1000	Total: 6.8% (7/103), females 5.3% (3/57), males 9.5% (4/42) Cribra orbitalia: 2.8% (3/106), females 1.7% (1/59), males 4.7% (2/43)	Rojas-Sepúlveda and Dutour, 2009
Savanna of Bogotá, Tibanica, Colombia, AD 10–16th centuries	Cribra orbitalia: 13.6% ( $N = 228$ ) Hyperostosis: 15.0% ( $N = 228$ )	Langebaek et al., 2011
Machu Picchu, Peru, pre-Hispanic	7% porotic; % hiperostosis; 23% cribra orbitalia	Turner and Armelagos, 2012
Savanna of Bogotá, Tequendama, Checua, Aguazuque and Vista Hermosa, Colombia, middle and late Holocene	Cribra orbitalia: 11.7% (9/77) Porotic hyperostosis: 2.4% (2/81)	Gómez, 2012
Puruchuco-Huaquerones, Peru, Late Horizon AD 1470–1532	Total: 39% (61/157), females 37% (28/75), males 41% (30/73) Cribra orbitalia: 24% (38/157), females 19% (14/75), males 30% (22/73)	Williams and Murphy, 2013
Armatambo, central coast, Peru, Late Intermediate period AD 1000–1470	Total: 11% ( $N = 18$ ) Cribra orbitalia: 19% ( $N = 21$ )	Chan, cited in Williams and Murphy, 2013
Lambayeque, north coast, Peru, late pre-Hispanic period AD 900–1532	Total: 57% ( $N = 172$ )	Klaus, cited in Williams and Murphy, 2013
Rinconada Alta, central coast, Peru, Late Horizon AD 1470–1532	Total: 26.4% ( $N = 91$ ) Cribra orbitalia: 5.5% ( $N = 91$ )	Salter-Pederson, cited in Williams and Murphy, 2013

TABLE 5. (Continued)

Series or region	Reported data	Reference
Maranga, central coast, Peru, Late Horizon AD 1470–1532	Total: 63.6% ( <i>N</i> = 11) Cribra orbitalia: 9.1% ( <i>N</i> = 11)	Boza Cuadros, cited in Williams and Murphy, 2013
Huaca Huallamarca, central coast, Peru, Late Horizon AD 1470–1532	Total: 44% ( <i>N</i> = 9) Cribra orbitalia: 44% ( <i>N</i> = 9)	Pechenkina et al., cited in Williams and Murphy, 2013
Machu Picchu, central highlands, Peru, Late Horizon AD 1470–1532	Total: 3% ( <i>N</i> = 177) Cribra orbitalia: 3% ( <i>N</i> = 177)	Verano, cited in Williams and Murphy, 2013
Lambayeque, north coast, Peru, Late Horizon AD 1536–1750	Total: 53.7% ( <i>N</i> = 311)	Klaus, cited in Williams and Murphy, 2013

TABLE 6. Studies documenting Schmörl nodules, scurvy, and auditory exostosis in populations of Peru.

Study topic	Series or region	Reported data	Reference
Schmörl nodules	Ancón, central coast of Peru, AD 600–1000	Total: 19.8% (23/116), females 20.6% (13/63), males 19.1% (9/47)	Rojas-Sepúlveda and Dutour, 2009
Scurvy	Lambayeque Valley, Peru, AD 900–1750	Subadults: 0.79% (5/641)	Klaus, 2014
Auditory exostosis	Ancón, central coast of Peru, AD 600–1000	Total: 4.7% (5/106), females 0% (0/60), males 11.9% (5/42)	Rojas-Sepúlveda and Dutour, 2009

variability and the need for generating classification categories. This stance was developed by European researchers who had clearly ethnocentric positions. However, this research was the basis for the description of injuries and bone anomalies, as well as some cultural practices such as trephination, cranial deformation, and mummification.

Venezuela, Colombia, and Peru shared this phase, but each country also presents particular aspects. For instance, research in Venezuela was characterized by observations about cranial morphology and modifications made by the ancient populations to their bodies. These aspects were also discussed by the researchers in Peru, although the diversity of the groups present in the central Andes and along the Peruvian coast was beneficial for observations and comparisons. In this way, Peru provided the first data on infectious diseases, traumatic, and osteoarticular injuries, as well as typological proposals for the analysis of cranial modification and trephination.

The first half of the twentieth century was marked by the first systematic analysis of large osteological series, generating information for paleopathological analysis. However, the reports still maintained a descriptive perspective without a standardization of data collection techniques. In this period, researchers began to generate some questions about the health conditions of hunter-gatherers in Colombia, as well as those of complex societies, such as the prehistoric and Inca populations in Peru. Also,

they initiated the first courses in biological anthropology, which served as the training of the first local researchers.

Since the 1950s and after the 1980s, there was a more positivist perspective with the addition of some techniques in biomedical sciences, particularly radiology and biochemistry. These new ways to collect data provided information about paleodiet and generated interpretation models at the intra- and inter-population levels. In this phase, interdisciplinary work was important in designing paleopathology research. Venezuela, Colombia, and Peru began to strengthen their training programs in anthropology and archaeology; while in Ecuador, scientific research in bioarchaeology was initiated, generating important data which facilitated more advanced studies in the region. However, the impact of local research is considerably lower compared with the research conducted by American and European colleagues.

Currently, the challenges of paleopathology in the northwestern South America focus on the strengthening of strategies in order to unify the criteria of analysis and to generate a regional stance about the health conditions of ancient populations. For this reason, it is important to improve interdisciplinary approaches that allow researchers to take advantage of the various avenues of investigation that can inform paleopathology.

In this way, the same goals identified by Ortner (2011) for the discipline in general can be applied in this region. It is important to continue collaborations between medically qualified

TABLE 7. Studies documenting stature in populations of northwestern South America.

Series or region	Reported data	Reference
Tunja Muisca, Universidad Pedagógica y Tecnológica de Colombia (UPTC), Colombia, AD 11–13th centuries	Males: 159.7 ± 3.1 cm; females: 152.7 ± 3.6 cm	Alvarez and Rodríguez, 2001
Several series from Peru, 700 BP	Chiribaya: 3.2 as an attributed score San Geron: 4.0 as an attributed score Yaral: 1.2 as an attributed score	Buikstra (Steckel et al., 2002)
Several series from Ecuador, 7500.–90 BP	Santa Elena, 7425 BP: 8.7 as an attributed score Highland, 2160 BP: 7.4 as an attributed score Realto 4663 BP: 1.2 as an attributed score San Francisco church, 190 BP: 16.9 as an attributed score South Coast, 1760 BP: 2.7 as an attributed score North Coast, 2050 BP: 6.8 as an attributed score San Francisco church, 90 BP: 12.8 as an attributed score Quito convent, 395 BP: 4.8 as an attributed score San Francisco church, 300 BP: 3.7 as an attributed score	Ubelaker and Newson, 2002
Soacha and Marin, central Colombia, AD 11–13th centuries	Males: 154.43 cm; females: 142.16 cm	Martínez, 2005
Villa El Salvador, Peru, 100 BC –AD 100	Males: humerus length 301.3, femur length 410.5, tibia length 344.4 Females: humerus length 276.9, femur length 387.1, tibia length 323.7	Pechenkina and Delgado, 2006
Lambayeque Valley Complex (north coast Peru), late pre-Hispanic and postcontact period.	Late pre-Hispanic males: 158.48 ± 3.417 cm Late pre-Hispanic females: 151.28 ± 3.816 cm Postcontact males: 157.56 ± 3.417 cm Postcontact females: 147.95 ± 3.816 cm	Klaus and Tam, 2009
Puruchuco-Huaquerones, central coast, Peru, Late Horizon AD 1470–1532	165.9 cm males ( <i>n</i> = 59) 157.9 cm females ( <i>n</i> = 41)	Williams and Murphy, 2013
Osmore drainage, southern highlands, Peru, Late Horizon AD 1000–1470	161 cm males ( <i>n</i> = 45) 152 cm females ( <i>n</i> = 47)	Burgess, cited in Williams and Murphy, 2013
Armatambo, central coast, Peru, Late Horizon AD 1000–1470	161.5 cm males ( <i>n</i> = 6) 152.3 cm females ( <i>n</i> = 8)	Chan, cited in Williams and Murphy, 2013
Lambayeque, north coast, Peru, Late Horizon AD 900–1532	158.6 cm males ( <i>n</i> = 25) 151.2 cm females ( <i>n</i> = 29)	Klaus, cited in Williams and Murphy, 2013
Rinconada Alta, central coast, Peru, Late Horizon AD 1470–1532	157.8 cm males ( <i>n</i> = 47) 145.2 cm females ( <i>n</i> = 46)	Salter-Pederson, cited in Williams and Murphy, 2013
Maranga, central coast, Peru, Late Horizon AD 1470–1532	159 cm males ( <i>n</i> = 1) 151.4 cm females ( <i>n</i> = 3)	Boza Cuadros, cited in Williams and Murphy, 2013
Huaca Huallamarca, central coast, Peru, Late Horizon AD 1470–1532	160 cm males ( <i>n</i> = 20) 150 cm females ( <i>n</i> = 14)	Pechenkina et al., cited in Williams and Murphy, 2013
Machu Picchu, central highlands, Peru, Late Horizon AD 1470–1532	157 cm males ( <i>n</i> = 18) 148 cm females ( <i>n</i> = 18)	Verano, cited in Williams and Murphy, 2013
Lambayeque, north coast, Peru, Late Horizon AD 1536–1750	157.6 cm males ( <i>n</i> = 59) 147.9 cm females ( <i>n</i> = 29)	Klaus, cited in Williams and Murphy, 2013
Several periods from Ecuador	Early precontact: 149 cm females, 161 cm males Middle precontact: 151 cm females, 161 cm males Late precontact: 151 cm females, 161 cm males Early historical: 151 cm females, 155 cm males Late historical: 154 cm females, 161 cm males	Ubelaker, 2014

TABLE 8. Studies documenting life expectancy in Colombia and Ecuador.

Series or region	Reported data	Reference
Savanna of Bogotá and Cauca Valley, Colombia, preceramic–colonial	At birth: Estadium Deportivo Cali 24.5 y (N = 27), Coronado 22.3 y (N = 110), La Cristalina 19.8 y (N = 24), Guacarí 21.5 y (N = 44), Aguazuque 31.8 y (N = 62), Portabelo 29.5 y (N = 135), Candelaria 22.9 y (N = 48), Las Delicias 11.2 y (N = 15), Tunja 19.8 y (N = 102), Sogamoso 32.7 y (N = 119)	Rodríguez, 2006
Savanna of Bogotá, Colombia, preceramic 8 BC–18th century BC	At birth: early preceramic 25.8 y, late preceramic 31.8 y, early Herrera 25.5 y, late Muisca 24 y, Engativá males 25.4 y, Engativa females 23.1 y, Fontibón males 17.6 y, Fontibón females 16.4 y, Tunebia males 21.7 y, Guane males 17.0 y.	Rodríguez, 2011
Several periods from Ecuador	Early precontact: 25 y at birth, 28 at 5 years, 22 at 15 years. Middle precontact: 26 y at birth, 27 at 5 years, 23 at 15 years. Late precontact: 23 y at birth, 31 at 5 years, 25 at 15 years. Early historical: 15 y at birth, 23 at 5 years, 28 at 15 years. Late historical: 20 y at birth, 23 at 5 years, 23 at 15 years	Ubelaker, 2014

TABLE 9. Studies documenting proportions of immature to adult individuals, maximum life span, and Chagas disease in populations of Ecuador and Peru.

Study topic	Series or region	Reported data	Reference
Proportion of numbers of immature individuals to adults	Several periods from Ecuador	Early precontact: 0.57 Middle precontact: 0.32 Late precontact: 0.78 Early historical: 1.29 Late historical: 0.66	Ubelaker, 2014
Maximum life span (years)	Ecuador	Early precontact: 60 Middle precontact: 54 Late precontact: 68 Early historical: 55 Late historical: 61	Ubelaker, 2014
Chagas disease	Chiribaya, Peru, AD 1050–1550	Four mummies tested for <i>Trypanosoma cruzi</i> : two positive, two negative	Guhl et al., 2014

researchers and anthropologists, and to intensify publications in the diverse research specialities of paleopathology: skeletal and dental paleopathology, mummies, coprolites, ancient medical texts, and artistic representations of anomalies, as well as case reports.

The issue of gaining international recognition for local publications is very important for research in the region. It would be possible to consolidate a set of data for the construction of

models of interpretation. Additionally, with international recognition, it is possible to create a network of cooperation among researchers enabling the standardization of analytical techniques and the integration of perspectives from different disciplines. However, the current isolation of local publications does not enable these strategies to be carried out.

On the other hand, there is a weakness in paleopathology research in northwestern South America regarding the

TABLE 10. Dental studies conducted in northwestern South America.

Series or region	Reported data	Reference
Supe, central coast of Peru, Chavín cultural period	'a moderate amount of dental caries, affecting 1–4 teeth on the average,' 'tooth wear was also moderate': more than 50% of skulls with second degree wear; 4 cases of third degree wear	Newman, 1954
Several series from southern coast of Peru, AD 800–1350	Caries frequency: Algodonal (54.5%, number of teeth 67/123) Chen Chen (42.1%, number of teeth 428/1373) Chiribaya Alta (45.3%, number of teeth 166/366) Yaral (30.1% number of teeth 57/189)	Indriati and Buikstra, 2001
Several series from Peru, 700 BP	Chiribaya: 48.4 as an attributed score for hypoplasias, 86.4 as an attributed score for dental defects (completeness, abscess) Estuquina: 60.3 as an attributed score for hypoplasias, 100 as an attributed score for dental defects (completeness, abscess) San Geron: 89.3 as an attributed score for dental defects (completeness, abscess) Yaral: 100 as an attributed score for dental defects (completeness, abscess)	Buikstra (Steckel et al., 2002)
Several series from Ecuador, 7500–90 BP	Santa Elena, 7425 BP: 99.7 as an attributed score for hypoplasias, 91.1 as an attributed score for dental defects (completeness, abscess) Highland, 2160 BP: 99.7 as an attributed score for hypoplasias, 94.0 as an attributed score for dental defects (completeness, abscess) Realto 4663 BP: 96.4 as an attributed score for hypoplasias, 79.4 as an attributed score for dental defects (completeness, abscess) San Francisco church, 190 BP: 99.4 as an attributed score for hypoplasias, 62.1 as an attributed score for dental defects (completeness, abscess) South Coast, 1760 BP: 89.1 as an attributed score for hypoplasias, 81.8 as an attributed score for dental defects (completeness, abscess) North Coast, 2050 BP: 94.2 as an attributed score for hypoplasias, 89.7 as an attributed score for dental defects (completeness, abscess) San Francisco church, 90 BP: 91.0 as an attributed score for hypoplasias, 67.9 as an attributed score for dental defects (completeness, abscess) Quito convent, 395 BP: 89.1 as an attributed score for hypoplasias, 69.3 as an attributed score for dental defects (completeness, abscess) San Francisco church, 300 BP: 98.6 as an attributed score for hypoplasias, 71.8 as an attributed score for dental defects (completeness, abscess)	Ubelaker and Newson, 2002; Steckel et al., 2002
Villa El Salvador, Peru, 100 BC–AD 100	Males: Caries per tooth 12% (N = 583) individuals with caries 71% (N = 28), Teeth with Linear enamel hypoplasias (LEH) 42% (N = 200) individuals with LEH 66% (N = 29) Females: Caries per tooth 27% (N = 726) individuals with caries 90% (N = 30) Teeth with LEH 65% (N = 262) individuals with LEH 82% (N = 22)	Pechenkina and Delgado, 2006
Savanna of Bogotá and Cauca Valley, Colombia, preceramic–colonial	Carious lesions: Estadium Deportivo Cali 11.1% (N = 485), Coronado 20.0% (N = 745), Santa Bárbara 8.7% (N = 136), El Cerrito 17.0% (N = 200), Guacarí 16.7% (N = 201), Checua 0.3%, Aguazuque 5.0%, Los Santos 40.2% (N = 479), Portabelo 14.0%. Hypoplasia: Estadium Deportivo Cali 3.3% (N = 485), Coronado 12.3% (N = 745), Santa Bárbara 17.97% (N = 136), El Cerrito 9.6% (N = 200), Guacarí 2.5% (N = 201), Aguazuque 16.7%, Los Santos 6.2% (N = 479). Abscess: Aguazuque 26.4%, Portabelo 49.5%. Antemortem tooth loss: Estadium Deportivo Cali 17.6% (N = 485), Coronado 14.1% (N = 745), Santa Bárbara 10.1% (N = 136), El Cerrito 64.5% (N = 200), Guacarí 8.8% (N = 201), Los Santos 27.4%.	Rodríguez, 2006
Lambayeque Valley complex (north coast Peru), late pre-Hispanic and colonial period.	Enamel hypoplasia: Odds ratio results, overall late pre-Hispanic–colonial period comparison of systemic stress, significant postcontact decrease Odds ratio results, late pre-Hispanic–early/middle colonial period comparison of systemic stress, 1.29 times greater prevalence in the late pre-Hispanic period	Klaus and Tam, 2009



TABLE 10. (Continued)

Series or region	Reported data	Reference
Lambayeque Valley complex (north coast Peru), late pre-Hispanic and colonial period.	Late pre-Hispanic period: Caries frequency: anterior teeth 51/1397; posterior teeth 269/1890 Antemortem tooth loss: anterior teeth 63/1549; posterior teeth 229/2249 Periapical inflammation late: dentition sites 60/3798 Calculus: anterior teeth 149/970; posterior teeth 150/1340 Colonial period: Caries frequency: anterior teeth 70/1173; posterior teeth 183/1294 Antemortem tooth loss: anterior teeth 125/1652; posterior teeth 249/1926 Periapical inflammation: dentition sites 21/3579 Calculus: anterior teeth 217/1173; posterior teeth 401/1294	Klaus and Tam, 2010
Savanna of Bogotá, Colombia, preceramic 8 BC–late Muisca, AD 13th century	Cariou lesions: early preceramic 0.1%, late preceramic 5.5%, early Herrera 10.8%, late Herrera 21.8%, early Muisca 7.3–38.1%, late Muisca 12.0–40.2% Antemortem tooth loss: early preceramic 16.0%, late preceramic 16.9%, early Herrera 30.7%, late Herrera 13.7%, early Muisca 11.9%, late Muisca 17.3–27.4% Abscess: early Herrera 2.5%, late Herrera 6.2%, early Muisca 7.5%, late Muisca 4–49.5% Hypoplasia: early preceramic 0%, late preceramic 16.7%, early Herrera 7.7%, early Muisca 6.3%, late Muisca 5.0%	Rodríguez, 2011
Savanna of Bogotá, Tibanica, Colombia, AD 10–16th centuries	Cariou lesions: 46.9% (N = 228) Hypoplasia: 14.0% (N = 228) Periodontal disease: 37.0% (N = 228)	Langebaek et al., 2011
Savanna of Bogotá, Tequendama, Checua, Aguazuque, and Vista Hermosa, Colombia, middle and late Holocene	Hypoplasia: 15.6% (9/58)	Gómez, 2012
Machu Picchu, Peru, pre-Columbian	Anterior enamel hypoplasia: 71% Molar enamel hypoplasia: 36%	Turner and Armelagos, 2012
Puruchuco-Huaquerones, Peru, Late Horizon AD 1470–1532	Antemortem tooth loss: Total 73.3% (66/90), females 81.8% (27/33), males 69.1% (38/55) Cariou lesions: Total 84.4% (76/90), females 90.9% (30/33), males 81.8% (45/55) Dental infection (abscess): Total 57.8% (52/90), females 57.6% (19/33), males 58.2% (32/55)	Williams and Murphy, 2013
Lambayeque, north coast, Peru, late pre-Hispanic period AD 900–1532	Antemortem tooth loss: Total 7.7% (3798 loci), females 5.7%, males 24.1% Cariou lesions: Total 9.7% (3287 teeth), females 10.5%, males 13.6%	Klaus, cited in Williams and Murphy, 2013
Rinconada Alta, central coast, Peru, Late Horizon AD 1470–1532	Antemortem tooth loss: 16.9% (unknown) Cariou lesions: 17.9% (2088 teeth)	Salter-Pederson, cited in Williams and Murphy, 2013
Maranga, central coast, Peru, Late Horizon AD 1470–1532	Antemortem tooth loss: 6.6% (290 loci) Cariou lesions: 12.4% (212 teeth)	Boza Cuadros, cited in Williams and Murphy, 2013
Huaca Huallamarca, central coast, Peru, Late Horizon AD 1470–1532	Cariou lesions: 7.2% (332 teeth)	Pechenkina et al., cited in Williams and Murphy, 2013
Lambayeque, north coast, Peru, colonial period AD 1536–1750	Antemortem tooth loss: Total 10.5% (3578 loci), females 27.2%, males 16.2% Cariou lesions: Total 10.4% (2467 teeth), females 23.9%, males 12.1%	Klaus, cited in Williams and Murphy, 2013

(continued)

TABLE 10. (Continued)

Series or region	Reported data	Reference
Several periods from Ecuador	<p>Early precontact: 3% (permanent teeth with cavities), 1% (permanent teeth with abscess), 6% (permanent teeth lost antemortem), 1% (permanent teeth with hypoplasia)</p> <p>Middle precontact: 2.7% (permanent teeth with cavities), 1.9% (permanent teeth with abscess), 9.8% (permanent teeth lost antemortem), 2% (permanent teeth with hypoplasia)</p> <p>Late precontact: 8.7% (permanent teeth with cavities), 3.1% (permanent teeth with abscess), 11.8% (permanent teeth lost antemortem), 4.4% (permanent teeth with hypoplasia)</p> <p>Early historical: 5.6% (permanent teeth with cavities), 1.4% (permanent teeth with abscess), 20% (permanent teeth lost antemortem), 3% (permanent teeth with hypoplasia)</p> <p>Late historical: 16.6% (permanent teeth with cavities), 4.6% (permanent teeth with abscess), 25.4% (permanent teeth lost antemortem), 0.5% (permanent teeth with hypoplasia)</p>	Ubelaker, 2014

TABLE 11. Health index studies conducted in Peru and Ecuador.

Series	Reported health index data	Reference
Several series from Peru, 700 BP	<p>Chiribaya: 67.5%</p> <p>Estuquina: 85%</p> <p>San Geron: 67.8%</p> <p>Yaral: 69.4%</p>	Buikstra (Steckel et al., 2002)
Several series from Ecuador, 7500–90 BP	<p>Santa Elena, 7425 BP: 83.4%</p> <p>Highland, 2160 BP: 99.7 81.6%</p> <p>Realto, 4663 BP: 77.3%</p> <p>San Francisco church, 190 BP: 76.9%</p> <p>South Coast, 1760 BP: 75.1%</p> <p>North Coast, 2050 BP: 72.7%</p> <p>San Francisco church, 90 BP: 72.2%</p> <p>Quito convent, 395 BP: 71.0%</p> <p>San Francisco church, 300 BP: 70.9%</p>	Ubelaker and Newson, 2002; Steckel et al., 2002

interpretation of contemporary contexts. The potential of paleopathological models to explain many of the ailments that afflict contemporary populations has not been sufficiently explored. In other words: “we are still all amateurs in paleopathology looking toward a bright cooperative future” (Angel, 1981:513). In this sense, the diseases are the result of a series of historic, cultural, and biological processes that occur in the body. Aspects related to environmental pollution, industrialization, rapid urbanization, changes in eating habits, and patterns of work, among others, have a very high potential of analysis from the perspective of paleopathology. Some researchers have proposed that disciplines such as bioarchaeology and paleopathology can explain

the particularities of these processes from an adaptive and evolutionary approach (Armélagos and Van Gerven, 2003:62).

## ACKNOWLEDGMENTS

Claudia Rojas-Sepúlveda thanks the Universidad Nacional de Colombia and Javier Rivera thanks the Universidad del Norte for time conceded to write this contribution. Many thanks are due to the editors of this book, Sonia Colantonio and Douglas Ubelaker, who greatly improved our manuscript. We also are grateful to the anonymous reviewer for helpful comments, to anthropologist

Ancízar Sánchez for translating the abstract to Portuguese and to Smithsonian Institution Scholarly Press publications specialists for the careful work they did with the manuscript.

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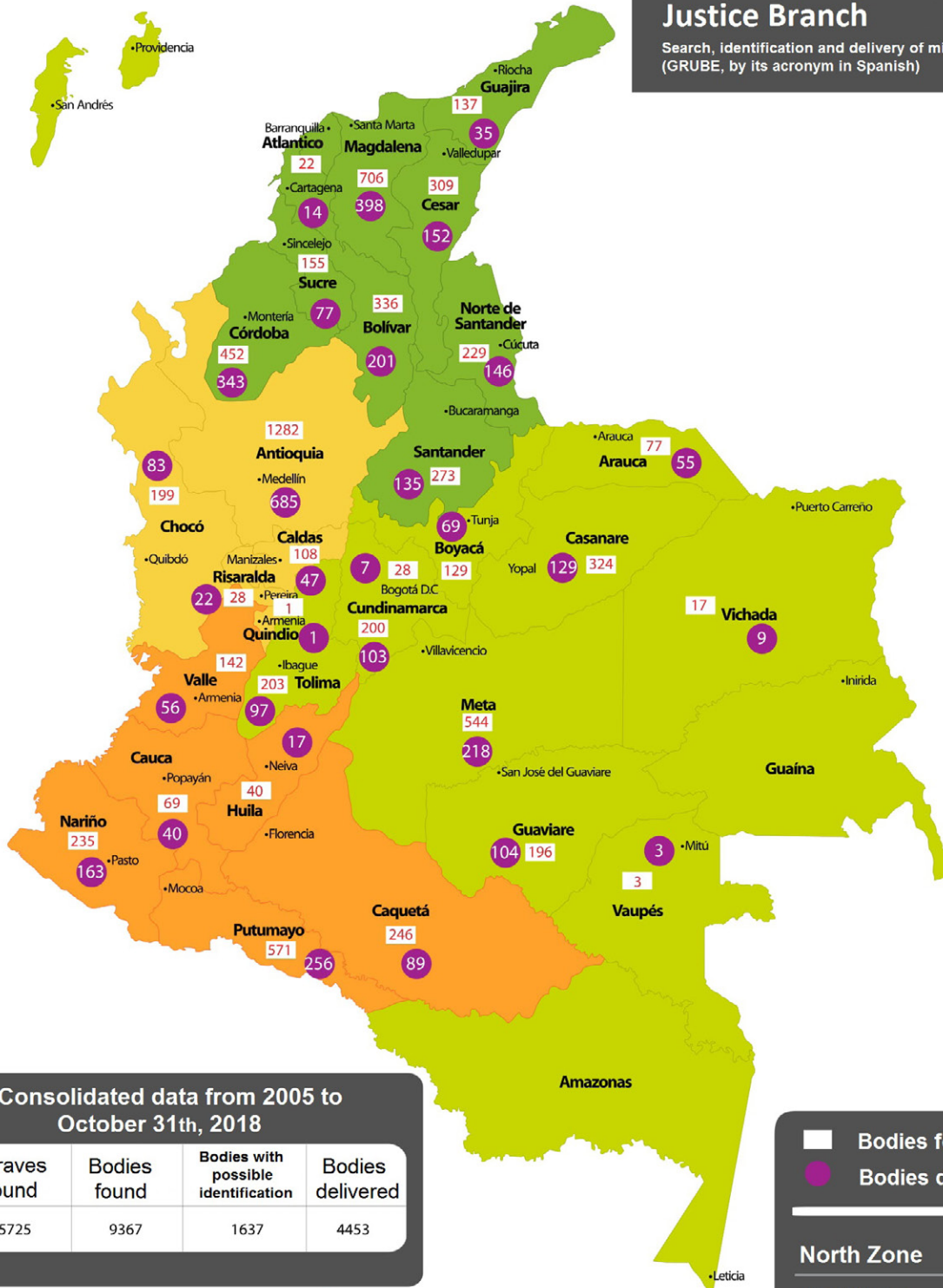
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# Transitional Justice Branch

Search, Identification and delivery of missing persons' Group (GRUBE, by its acronym in Spanish)



Consolidated data from 2005 to October 31th, 2018

Graves found	Bodies found	Bodies with possible identification	Bodies delivered
5725	9367	1637	4453

Bodies found  
 Bodies delivered

North Zone  
 East Zone  
 West Zone  
 South Zone



# Forensic Anthropology in Northwestern South America (Colombia, Venezuela, Ecuador, and Peru)

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**FIGURE 1.** (*Opposite page*) Geographical distribution of recovered bodies from clandestine graves 2005–2017 (killings attributed to paramilitary groups). From <http://www.fiscalia.gov.co/jyp/wp-content/uploads/2015/07/mapa-de-colombia.pdf> (accessed 2015).

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**ABSTRACT.** The genesis, development, and progress of forensic anthropology in Latin America have been closely linked to social problems such as forced disappearances, mass graves, and unidentified bodies, which are the result of internal armed conflicts, and more recently, organized crime. The constant discovery of unidentified bodies in South America is due to the nefarious intentions of the perpetrators to erase any kind of incriminating evidence, including the body. This chapter describes the sociopolitical scene which leads to the rise of forensic anthropology in northwestern South American countries such as Colombia, Peru, Venezuela, and Ecuador, and displays the challenges that this discipline has had to face in order to gain recognition as both an academic and a professional field.

**Key words:** forensic anthropology, missing persons, Venezuela, Ecuador, Peru, Colombia.

**RESUMEN.** La génesis, desarrollo y avances de la antropología forense en Latinoamérica han estado estrechamente ligados a problemáticas como la desaparición forzada de personas, fosas clandestinas y cadáveres no identificados, las cuales surgen principalmente en medio de contextos como conflictos armados internos, y más recientemente la delincuencia organizada. La constante de dichos cuerpos en el contexto suramericano ha sido la intención de los victimarios en desaparecer cualquier clase de evidencia, incluido el cuerpo, del cual se pudiesen obtener pruebas que los incriminen, esto es, en el marco de un diagnóstico forense. El presente capítulo muestra el panorama sociopolítico que dio paso al surgimiento de la antropología forense en países del noroeste latinoamericano, Colombia, Perú, Venezuela, Ecuador, y presenta los retos que esta disciplina ha debido afrontar para lograr su actual consolidación, tanto a nivel académico, como profesional.

**Palabras clave:** antropología forense, personas desaparecidas, Venezuela, Ecuador, Perú, Colombia.

**RESUMO.** A gênese, desenvolvimento e progresso da antropologia forense na América Latina foram relacionados a problemas, tais como desaparecimentos forçados, valas comuns e corpos não identificados, que surgem principalmente entre contextos como conflito armado interno, e mais recentemente crime organizado. A constante desses organismos no contexto sul-americano tem sido a intenção dos autores a desaparecer qualquer tipo de provas, incluindo o corpo, o que poderia ser obtido provas incriminatórias que este é no contexto de um diagnóstico forense. Este capítulo mostra a paisagem sócio-política que levou ao surgimento de antropologia forense em países latino-americanos a noroeste, Colômbia, Peru, Venezuela, Equador, e apresenta os desafios que esta

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

disciplina foi confrontado para alcançar sua consolidação atual, tanto acadêmica como profissional.

**Palavras chave:** antropologia forense, desaparecidos, Venezuela, Ecuador, Perú, Colombia.

## INTRODUCTION

Historically, victims of crime who have gone missing have been linked to political armed conflict, organized violence, and recently, to common delinquency. It is a global phenomenon that has affected millions of people. In most situations, victims are murdered and abandoned in mass graves or places of difficult access, in order to hinder discovery and identification of the body, and to ensure the anonymity of the offenders. Examples of mass disappearances have occurred in both hemispheres during the last century. They include the civil war in Spain, ethnic tensions in the former Yugoslavia and in Rwanda, and conflicts in Latin American countries such as Guatemala, El Salvador, Chile, Peru, Argentina, and Colombia (Sanabria, 2014). It is important to clarify that “ethnic cleansing” is equally insidious than forced disappearance, but that its objectives are aimed more at disappearing from a particular population than from an indiscriminate group of individuals. It is currently being carried out in Syria and Rakhine State in Myanmar.

In practice, forensic anthropologists have contributed to the search, exhumation, and identification of the victims. They also have proven to be efficient collaborators in the reconstruction of the national memory of these crimes, by aiding in the clarification of the cases, and encouraging state actors to undertake the process of reparation to the victims or their families. Some definitions of forensic anthropology classify it as social anthropology, because the field has gained so much popular support due to publicized accounts of justice being served and victims being honored by comprehensive reparations.

## GENESIS, EVOLUTION, AND DEVELOPMENT OF FORENSIC ANTHROPOLOGY

The scientific work of physical and biological anthropology is the foundation of forensic anthropology and revolves primarily around the study and interpretation of the natural variability of the human species. These studies have two avenues of application. The first involves explaining the biological diversity of contemporary human populations and understanding how adaptive processes generated phenotypic and genotypic differences that led to a broad mosaic of populations with distinctive physical traits. This variability can be seen by examining the osseous tissue, soft tissue, and genes, of both past and modern populations, as well as in living or deceased individuals.

The second application involves using the diversity of human traits to support the process of victim identification in

legal contexts. It is precisely the phenotypic and genotypic differences evident in each person that serve as the biological foundation of the identification and help differentiate one individual from another.

Hulse (1969:245–248) defined anthropology as “. . . the investigation of human nature from a biological, evolutionary and ecological perspective, considering the human being as biosocial. . .” This early definition relates to a contemporary context that includes studies on human variability—legacy, environment, and culture. Closely related is the argument of Sunderland (1973) that anthropology includes the study of the origin and evolution of humans and their morphological, genetic, and sociocultural characteristics.

These positions are complemented by Valls (1985) who does not use the terms *physical* or *biological* but considers anthropology to be the study of the origin, nature, and evolution of biological variability in human groups. Emphasis is on the interaction and impact of genetic, environmental, and social factors on human individuals, as well as on different racial groups and populations.

Human variability has been an issue of great interest in the last two decades, particularly for the process of forensic identification. International consensus (Orban and Polet, 2005; Kimmmerle and Jantz, 2008; Ubelaker, 2008) recognizes the need for each country to develop its own local demographic standards for the analysis of osseous and dental tissues during a forensic autopsy, and to avoid the use of standards developed in other countries with the traits of their populations, “. . . in a way that the methods are highly reliable and quantifiable, so it ensures compliance with the evidentiary rules of admissibility” (Kimmmerle and Jantz, 2008:521–523).

## FORENSIC ANTHROPOLOGY IN COLOMBIA

Although not about academic-scientific origins that are usually presented in discussions of the history of forensic anthropology, Rodríguez (2011) relates an interesting story which refers to colonial times in Colombia, in the late eighteenth century. This author mentions that “To our reports, forensic work dates back to the colonial era of New Granada, Colombia, when lawyers, with the intention to be accredited as forensic experts, had to request a license before the Real Hearing of Santafe of Bogota. Thus, Manuel del Campo and Rivas requested licenses in 1777 to complete forensic practice and guarantee business Joaquin Escobar requested in 1778 to be received as a lawyer of the Real Hearing of Santafe” (Rivera and Rojas, 2005:1–12). Lawyers had been practicing forensics since the eighteenth century in New Granada, but with the introduction of legal medicine in the nineteenth century, the need to identify victims and perpetrators in criminal cases was addressed. As a result, on May 30, 1860, doctors M. Vicente de la Roche and Manuel Uribe Angel analyzed a murder case that occurred in Antioquia, Colombia.



Evidence included a set of bones, a stained poncho, remains of shirts, underwear, pants, and a belt. Similar to the work of contemporary forensic anthropologists, they established a basic identification questionnaire that they answered according to information provided by the skeletal remains and the clothing (Rodríguez, 2011).

In 1985 the first case was carried out in which a forensic anthropologist was commissioned by the public prosecutor's office to collaborate with the identification of the bones found in the cave of Trementina, in the rural sector of a town called Becerril, in northern Colombia. A forensic doctor and a lawyer collaborated in the investigation. After the morphoscopic and metric analyses of the skeletons were completed, it was evident that they were pre-Hispanic remains (Rodríguez, 1994). Some of this enhanced technology had been provided for the investigation of alleged executions, assassinations, and abductions linked to the counterinsurgency actions carried out by federal armed forces or paramilitary groups against political leaders or civilians (Centro Nacional de Memoria Histórica [CNMH], 2013: 23–27; Cubides, 2005).

The Laboratory of Physical Anthropology was created at UN (Universidad Nacional de Colombia) in 1988 under the direction of José Vicente Rodríguez, who began offering assistance to the judicial system in identifying the many dismembered bodies (either decomposed or skeletonized) that began to appear in the country (Guzman and Sanabria, 2016).

The year of 1990 marks an important milestone for forensic anthropology in Colombia, the first forensic anthropology laboratory was officially opened in the National Institute of Legal Medicine and Forensic Sciences (INMLCF) in Bogotá, D.C. The fact that this laboratory was implemented as a state initiative distinguishes it from most Latin American countries, where forensic anthropology laboratories arose from civil initiatives.

During the first four years, one forensic anthropologist worked there permanently. In early 1995, another anthropologist was hired, and in 1999, a third was added. Between 2004 and 2015, various forensic anthropologists from the institute took positions with international organizations and other local entities. As of 2015, there were approximately 52 forensic anthropologists in Colombia, working in laboratories affiliated with offices of medical examination, the national police, and the prosecutor's office. This number of forensic anthropologists is likely to grow due to the current case load, and will grow exponentially as new cases arise. Negotiations currently are being conducted between the government and the guerrilla group known as "Revolutionary Armed Forces of Colombia" (FARC). This group has been active for 60 years. The signing of a peace treaty will require FARC to reveal the locations of victims in mass graves, which means the number of forensic cases will continue to rise.

In 1994 the Forensic Unit of Technical Investigation (CTI) of the Attorney General, founded a second laboratory called Laboratory of Specialized Identification (Rodríguez, 2004:34–35). This laboratory was not only composed of anthropologists, but also medical examiners, dentists, and morphologists. As part

of an institution of law enforcement, these anthropologists were trained in the analysis and documentation of the crime scene, the handling of physical evidence, and the recovery of bodies (FGN, 2005). Despite the institutionalization of forensic anthropology and archeology in different governmental organizations, the number of anthropologists experienced in osteological analysis was insufficient, given the high rate of homicide in the country. Therefore, it became common that initial on-site investigations of mass graves were carried out by agents of the law without proper training in forensic archeology. Many of the exhumations were being conducted without following the basic scientific protocols and documentation on site. As a result, a great amount of evidence, as well as the contextual information, was frequently lost (Guzman and Sanabria, 2016).

Between 1996 and 2005, the judicial system began to recognize the benefits of forensic archaeological techniques in the management of the scene and recovery of the human remains in clandestine graves. Therefore, more anthropologists and archaeologists were hired and new forensic laboratories were created. The CTI established five specialized laboratories; As a result, the number of anthropologists hired rose from 8 to 25 (FGN, 2005). Currently, there are more than 40 throughout the country.

Expertise in the field became apparent as the number of professionals continued to rise in correlation with the escalation of armed conflict and the growing number of cases that needed to be analyzed. Between 1989 and 1994, INMLCF examined 153 cases of human remains, while between 1995 and 2005, 1,928 case reports were completed. Also, between 1997 and 2000, CTI analyzed 720 cases. By 2005, the forensic anthropology laboratories in Colombia had already examined nearly 3,000 individuals, most of them unidentified with no leads or contextual clues to suggest their identities (Guzman and Sanabria, 2016). Between 2005 and 2014, forensic anthropology and archeology had a surge in activity due to the search for bodies in clandestine graves and the rise in forensic autopsies. This was mostly influenced by the signing of a peace treaty, signed in Colombia on November 24, 2016 with paramilitary groups, who are now required to reveal the locations of buried victims. As of June 30, 2015, 5,978 bodies discovered in 4,649 graves have been recovered (FGN, 2015) at various locations throughout the country. Most of them were skeletonized and not identifiable at the time of exhumation. So far, only 2,934 of these individuals have been identified and returned to their families. As of 31 October 2017, 7,036 bodies have been recovered from 5,515 graves distributed throughout the territory (Figure 1) (FGN, 2017). Most of the bodies were skeletonized and not identified at the time of exhumation. Of these, only 3,536 individuals have been identified and returned to their families. Bodies with possible identity number 1,656.

#### FORENSIC ANTHROPOLOGY CONDUCTED BY NONGOVERNMENTAL ORGANIZATIONS (NGOs) IN COLOMBIA

The year 2004 was important for forensic anthropology in Colombia. Civil organizations or NGOs emerged that provided

an additional option for families affected by the phenomena of abductions and missing persons.

One of these entities is the Interdisciplinary Team for Forensic Work and Psychosocial Assistance (EQUITAS), defined as “a team that offers scientific contributions, from a psychosocial perspective in the search and investigation of victims of serious violations to human rights. It supports families and their legal representatives in the task of demanding truth, justice and reparation” (EQUITAS, 2015).

Another NGO is the Colombian Forensic Anthropological Research Team (ECIAF), which began operating in 2008. The ECIAF is defined as a “scientific, humanitarian, cultural and social [entity, which] undertakes its activities in 2008 from the initiative of forensic anthropologists with individual experiences in a collective construction, [and] they aim to provide from anthropology how to solve many needs in the process of searching for truth, justice and reparation for the families of the victims of armed conflict” (ECIAF, 2015).

#### ACADEMIC TRAINING IN FORENSIC ANTHROPOLOGY AND OTHER FORENSIC SCIENCES IN COLOMBIA

Colombia has been recognized for its university graduate programs related to the field of forensic medicine, forensic dentistry, and forensic anthropology, the main disciplines involved in forensic autopsy.

In 1995, in the department of anthropology at the National University in Bogotá, Colombia, a specialization in forensic anthropology was initiated, which admitted doctors, dentists, biologists, and anthropologists, among other professionals. This program was terminated in 2008, after having graduated several classes. Also, since the late 1980s, the undergraduate program of forensic anthropology at this same university has offered lectures that are closely related to forensic anthropology. These courses currently form part of the academic curriculum of the degree in anthropology, either as mandatory or elective classes. The topics covered include diet, health, and demography, human osteology, anthropogenesis, biological anthropology, and forensic anthropology, among others.

Currently, most Colombian anthropology departments include a forensic anthropology class as an elective, however, the department of anthropology at the National University of Colombia is the only one where a laboratory exists for students to study both pre-Hispanic and modern skeletons.

In August 2015, undergraduate and graduate students from different disciplines and different Colombian universities conducted several investigations of population-specific samples. These projects seek to establish local bone and dental standards (Sanabria-Medina, 2011; Sanabria-Medina et al., 2011; Guerrero and Sanabria-Medina, 2013; Sanabria-Medina, 2013; Villalobos and Sanabria-Medina, 2013; Guerrero et al., 2015). These studies were made possible through the use of the INMLCF Colombian Human Bone Reference Collection, which reduces the need to use foreign bone and dental standards. This collection has

been instrumental for the academic training of national and foreign students of medicine, dentistry, and anthropology, as well as for professional forensic practitioners.

## FORENSIC ANTHROPOLOGY IN PERU

### THE ORIGINS OF FORENSIC ANTHROPOLOGY IN PERU

In Peru, the pioneering work of physical anthropologists such as J. Ballasts, J. Marroquin, A. Pezzia, S. Quevedo, R. Salazar, Julio Tello, Luis Valdivia, and Pedro Weiss (Valdivia, 1988) provided interesting results about pathologies, dental anomalies, cranial deformation, surgery, and the pre-Hispanic diet. M. T. Newman (1943) published a series of deformed and non-deformed skulls from different periods of coastal and sierra occupation, which, so far, are the most commonly used in South American craniological comparative studies (Rodriguez, 1996).

It is common knowledge that the origins of forensic anthropology in Peru are closely linked to the armed conflict that took place in this country during the 1980s and 1990s (Tello and Baraybar, 2005; Bacigalupo, 2005; Parra and Palma, 2005; Parra, 2006; COMISEDH, 2012).

One consequence of the internal armed conflict in Peru during these decades, was the disappearance of more than 16,000 Peruvian citizens (CICR, 2014). It is presumed that most of those victims must be in clandestine burial sites, some of which were inspected between 1997 and 2001 without the technical training necessary for proper forensic exhumation, which contributed to difficulties in obtaining results (Parra and Palma, 2005).

The magnitude of these actions of war and death generated the need to incorporate socio-cultural, biological, and archaeological applications in legal investigations. Forensic anthropology was emphasized, especially in relation to skeletonized remains from clandestine burial sites. An example of this is the 1993 case of the missing students from La Cantuta University, where the medical examiners were repeatedly consulted on how to identify skeletonized human remains from a clandestine grave in Cienequilla (Parra and Palma, 2005). The exhumations and analyses conducted in relation to this case involved the participation of a multidisciplinary team of archaeologists, physical anthropologists, and forensic experts. International experts from the Argentine Team of Forensic Anthropology (EAAF) also participated as observers, at the request of human rights organizations. This case, of particular relevance because of the political implications of their results, marks the dawn of forensic anthropology in Peru (Bacigalupo, 2005: 4).

According to Parra and Palma (2005), in response to this case, doctors H. Vidal and J. Vivar agreed to recommend the incorporation of anthropology in the curriculum of the Institute of Legal Medicine (IML). In late 1993 and during 1994, IML also incorporated forensic anthropology into their services, but without clarifying the weight of its significance. By 1997, a similar situation occurred at the Department of Criminology of

the National Police of Peru, which initiated a section of forensic anthropology in the Department of Forensic Medicine. In both cases, the specialists in charge of these studies had backgrounds in social anthropology, with little or no knowledge of the methods and techniques of forensic anthropology. In theory, the personnel in charge of these functions must undergo self-training on the subject and learn from practice. During the 1990s, investigations focused mainly on the daily demands of the respective institutional activities, highlighting the specialized intervention that forensic anthropology provides in accidents or disasters, as well as in the prosecution of criminal activity (Bacigalupo, 2005).

In 2003 the Specialized Forensic Team (EFE), was created by the public prosecutor and was implemented as part of IML. They are the official experts who direct the exhumation of the bodies of victims that were executed by the military and the terrorist group Sendero Luminoso between 1980 and 2000. The EFE brings together specialists in anthropology, archaeologists, medical doctors, dentists, and geneticists, as well as support staff like photographers and radiologists. Some of the EFE professionals have participated in national forensic investigations like the case of the Lucanamarca massacre (2002) and the detainees reported missing from the questionable military base Totos (2002) (IML, 2015).

#### FORENSIC ANTHROPOLOGY CONDUCTED BY PERUVIAN NGOS

In 1997, the Technical Group of Forensic Anthropology of the National Human Rights Coordinator was created, initially made up of archaeologists and anthropologists who began designing strategies for locating graves with the DDHH legal ombudsman's office, including instructions for "what to do and what not to do in case of finding mass graves with human remains." This effort followed "journalistic exhumations," involving exhumations on camera, which were conducted by some media to obtain ratings, and which subsequently invalidated the case, to the detriment of the family. In 2000, the group wrote the document entitled "Human Rights and Forensic Science: A proposal for effective forensic investigation of violations of Human Rights in Peru," which was prepared for the National Coordinator DDHH (C. R. Cardoza, Equipo Peruano de Antropología Forense (EPAF), "On the history of Forensic Anthropology in Peru," personal communication, 20 July 2015).

In 2001, several forensic anthropology workshops were held in coordination with the CNDDHH (Comisión Nacional de Derechos Humanos) and the Ombudsman office for judicial officers and lawyers of DDHH. These included teams of forensic experts from Argentina and Guatemala, as well as specialists from Colombia, Chile, Spain, France, Peru, and the United States. It was during the first workshop, with Clyde Snow, recognized American forensic pathologist, founder of the Argentine team of forensic anthropology, as guest of honor, when the district attorney in charge of the case known as "The House of the Ambassador of Japan," most commonly referred to as "Case Chavin

de Huantar" asked them to be the experts who would work the case. Since the case was sensitive and politicized, Dr. Snow was asked to provide support. That was how, in February 2001, the group was established and registered in public records as the Peruvian Team of Forensic Anthropology (EPAF) with Dr. Snow as an honorary member. It was with this case that the application of international standards of forensic anthropology started to be used on serious cases that violated human rights. 2001 was also the year when the agreement between the public ministry and EPAF was signed, and directive 011-2001-MP-FN was generated, requiring the training of prosecutors (Cardoza, pers. comm., 2015). This team has a goal, like other Latin American groups, to investigate crimes, identify the victims, and return them to their families (Congram and Fernandez, 2006).

The EPAF served as official experts in several cases at the request of the public ministry and the judiciary, and expert advisors or witnesses at the request of the relatives of victims or human rights organizations. Such cases include Chushi, Bernabé Baldeón, Cantuta, Cantoral and García, Accomarca, and Putis, among others (Cardoza, pers. comm., 2015).

The collaboration between EPAF and the Commission of Truth and Reparation (CVR) had good results, like the first scientific exhumation of a mass grave in Peru, in the community of Chuschi, Ayacucho, in January 2002, and the drafting of what would become the National Plan for Forensic Anthropological Research PNIAF (EPAF, 2015). The PNIAF demonstrated the need for forensic anthropological interventions and the creation of an independent forensic team to represent Peruvian civilians in research on the internal armed conflict. However, this joint organization created by EPAF and CVR was dissolved in 2002, and apparently the Peruvian aspiration to develop correct forensic audits collapsed. Thus, access to justice and memory retrieval was blocked (Parra, 2006).

Months later, given the need to continue with the investigations following the resignation of EPAF, the public ministry, the CVR, the ombudsman, and the National Human Rights Coordinator joined efforts and established agreements to coordinate efforts in the research of clandestine graves. Their main objectives were to contribute to clarifying the truth, to restore the dignity of the victims and their families, and to provide access to justice (Parra, 2006).

Also in 2002, an important team of foreign specialists led by Clyde Snow, Mercedes Doretti from the EAAF, and Fredy Peccereli from the Foundation of Forensic Anthropology of Guatemala (FAFG) arrived in Peru. The goal of this first mission was to demonstrate and recommend essential guidelines for future forensic interventions. A month later, a second visit of specialists was formed with the mission of reinforcing connections established during the first visit and ensuring that a thorough forensic methodology was being followed (Parra, 2006).

According to Bacigalupo (2005), another period can be approached that is closely related to forensic anthropology in Peru, which includes from 2003 to the present: It is part of the period known as the Post Commission, where, in light of the

recommendations raised by the CVR in its Final Report, the guidelines that the forensic anthropological investigation related to the serious violations of human rights should follow. In this period there is the conformation and consolidation of two forensic teams, the first one linked to the Legal Medicine Institute of the Public Prosecutor's Office and called the Specialized Forensic Team (EFE), which is in charge of carrying out almost all investigations in the topic; and a second team linked to civil society: the Andean Center for Forensic Anthropological Research (CENIA), which is made up of the members who carried out the process developed by the Forensic Investigation Unit of the CVR.

The Postcommission period is also noted for a series of tensions between the different participants which has not benefited the advancement of forensic anthropology. Thus the Association of Forensic Anthropology of Peru (ASAFP) was created in 2004 to address concerns and unite professionals under one agency, repeating nationally what the Latin American Association of Forensic Anthropology (ALAF) set out to do in Latin America when it was formed in 2003. Finally, one of the ongoing challenges of this period is to raise forensic anthropology in Peru to an academic, scientific, and professional level with the highest international standards. To this end, CENIA made important strides to address the academic and professional issues (Bacigalupo, 2005).

#### ACADEMIC FORENSIC ANTHROPOLOGY IN PERU

The work of identification and reparation for missing victims, practiced mostly by forensic anthropologists, has set a strong precedent for solving legal cases. However, in Peru, this field presents an educational dilemma, because it emerged as a kind of "non-anthropology" in the eyes of some social anthropologists. A similar phenomenon has manifested itself in different scenarios in Colombia. Peruvian universities, for example the National University of San Marcos and the Catholic University of Perú, maintain an academic curriculum mainly with a socio-cultural emphasis, with optional annual lectures on forensic anthropology. These have theoretical content because they do not require laboratory work. However, subjects like physical anthropology or biological anthropology are included in the curriculum of archaeology, an independent specialty of anthropology at the graduate and postgraduate levels.

In Peru, there were two major academic initiatives associated with forensic anthropology, which, for various reasons, have ceased their activities: The masters of forensic anthropology and bioarchaeology, at the Pontifical Catholic University of Peru, which began in 2007, and the diploma in forensic anthropology and human rights at the Faculty of Social Sciences of the National University of San Marcos this last start in 2006 and only had a promotion of graduates and did both programs end.

The EPAF, responding to invitations to teach, has given courses and lectures at the National University San Cristobal de Huamanga (Ayacucho), workshops at the national universities of San Marcos and Federico Villarreal in Lima, and academic presentations at the Pontifical Catholic University of Peru (Cardoza, pers. comm., 2015).

## FORENSIC ANTHROPOLOGY IN VENEZUELA

In terms of the foundation of forensic anthropology in Latin America, it could be suggested that Venezuela is the pioneering country, to the extent that ". . . it has the oldest anthropology lab in the continent . . ." (Rodríguez, 2011). However, unlike other countries, Venezuela has not been affected by the phenomenon of abductions and missing people, which sets it apart from countries like Argentina, Peru, Colombia, and Guatemala.

#### ORIGINS, ACADEMIC STATUS, AND PRACTICE

In Venezuela the first osteological work was carried out in the late nineteenth century by European researchers (Ernst, Vernier, Kate, Marcano, and Virchow) who were interested in craniometric variation, deformations, and the cranial capacity of the indigenous peoples of Venezuela (Díaz Ungría, 1993). In 1896, the first lecture on anthropology was presented. Beginning in the 1940s, several works were published about the physical aspect of pre-Hispanic indigenous communities, child development and growth, genetic polymorphisms, measurements, and the nutrition of modern populations (Rodríguez, 1996).

The early 1950s saw the establishment of the Technical Judicial Police of Venezuela (PTJ), which includes several forensic specialties. Throughout those years, Adelaida Diaz Hungaria, an anthropologist at the Central University of Venezuela (Universidad Central de Venezuela, or UCV), was invited by the PTJ to carry out anthropological analyses of skeletal remains. But it was not until the 1960s, specifically in 1968, that anthropologist Maritza Garaicoechea graduated from UCV and was hired by PTJ, which effectively made her the first official forensic anthropologist in Venezuela. In 1974, the Law of Judicial Police was passed, which underscored the relationship between forensic anthropology and other social and medical sciences (L. Muñoz A., "On the history of forensic anthropology in Venezuela," personal communication, 16 May 2015).

In 1953, the Department of Sociology and Anthropology at UCV was established with a full course for multiple semesters based on biological anthropology. The department became a school in 1957, and in 1987, anthropology became independent from sociology. During this time the thematical diversity of bioanthropological publications increased, driven in part by institutional support, and in part by the discovery of the Diego genetic marker in some indigenous populations, which encouraged genetic in other communities (Rodríguez, 1996).

The 1970s mark a milestone in the development of auxological research. In 1979, Project Venezuela of the Center for Biological Studies on Growth and Development in the Venezuelan Population (FUNDACREDESA, Fundación Centro de Estudios sobre Crecimiento y Desarrollo de la Población Venezolana) began. Sponsored by Simon Bolivar University and the National Institute of Nutrition, it aimed to characterize children in different regions of the country in terms of growth and development, height and weight, and nutrition. Despite the scope and diversity

of this study, Venezuelan researchers complained that it was not ideal, because of the “disorganization, isolation and suspicion, largely motivated by the competition, which results in a lack of collaboration at a time when it is essential, given the levels of specialization that characterize the disciplines and the multiplicity of the sections in which each is subdivided” (Díaz Ungría, 1993:146; Rodríguez, 1996).

#### FORENSIC ANTHROPOLOGY AT THE VENEZUELAN ACADEMY

The training of anthropologists in Venezuela is done in the School of Anthropology, which is part of the Faculty of Economics of UCV. Training is completed in ten semesters. There are courses in general osteology, physical anthropology, biodiversity, and archeology, among others. Graduates are usually employed by public institutions and organizations. The UCV library and the Department of Anthropology maintain collections of graduate theses, with anthropological subjects ranging from studies of pre-Hispanic ruins to analyses of contemporary remains (Muñoz, pers. comm., 2015).

### FORENSIC ANTHROPOLOGY IN ECUADOR

The information published on the origin and development of forensic anthropology in Ecuador is practically nonexistent, and most available data refer to studies of physical anthropology and pre-Hispanic archeology. Scientific research ranges from very early times (Saville, 1910) to many relatively recent studies (Munizaga, 1976; Ubelaker, 1979, 1983, 1988, 1992, 1994, 1995).

In Ecuador, research by J. R. Munizaga (1976) brought attention to cranial deformation and morphometric characterization. Work by Douglas H. Ubelaker, initiated in 1973 with support from the Smithsonian Institution in the United States and the Central Bank of Ecuador, led to excavation and analysis of bone samples dated from 8300 BP until the period of Spanish contact along the coast and in the highlands. Ubelaker published research on topics as varied as the incidence of enamel hypoplasia through time and space, status and diet in the pre-Hispanic Ecuadorian highlands, and funeral customs (Ubelaker, 1992, 1994; Rodríguez, 1996).

Some genetic studies related to indigenous populations (Cardoso et al., 2008; Baeta, 2009) have been published, as well as a few covering the genetics of the modern Ecuadorian population (González-Andrade et al., 2003; González-Andrade and Sánchez, 2004, 2006; González-Andrade, 2006).

In 2007, a cooperative effort between the French Embassy in Quito, and the Ecuadorian police, fostered two theoretical and practical workshops on forensic anthropology organized by Tania Delabarde, a French anthropologist and researcher affiliated with IFEA in Ecuador, which is a multidisciplinary research unit and a support platform for French and European research in collaboration with the Andean countries. Though participants had a basic knowledge of forensic anthropology, the role of

physical anthropology in forensic cases and the lack of specialists in the country provided motivation for conducting this workshop for legal, medical, and criminal experts (Delabarde, 2007).

In January 2014, the Ministry of the Interior inaugurated the Maria Eugenia Race Laboratory of Criminology and Forensic Science including a forensic anthropology section. According to the ministry, this new laboratory has top technology and special security at the entrance to each of its seven floors. It is divided into areas such as visual inspection; expert photography; ballistic photography; automated fingerprint identification system (AFIS); automated biometric identification voice system (AVIS); integrated ballistics identification system (IBIS), chemistry; toxicology; forensic anthropology; DNA; and computer forensics, among others. Here there are around 150 technical experts and civilian personnel hired to cover the areas of expertise listed above. The building was completed in 2008, with support from the national government. Planning included the technological training of skilled police officers who now perform advanced technical and scientific work. Goals include reducing response times and increasing the quality and objectivity of analysis in legal matters (Ministerio del Interior de Ecuador, 2014).

According to the ministry, the forensic anthropology laboratory assists identification based on anthropological techniques, corpses in various states of putrefaction, burned bones, and human remains. This process includes taking prints post mortem of the finger pads (mummified fingers), estimating the height, age, sex, weight, social status, ethnicity, type of bones, and determining the cause of death. Regarding forensic cases, this unit is also involved in the exhumation of bodies for DNA sampling and the reconstitution of the skin on fingers for fingerprint analysis (Ministerio del Interior de Ecuador, 2014).

According to reports from the website of the Ministry of the Interior (2014), the EAAF (Argentine Team of Forensic Anthropology) conducted academic conferences leading to the training of the judicial police in Quito on technical work related to topics such as missing persons, the violation of human rights, and procedures for the search, retrieval, and analysis of bodies, which is an important academic contribution for forensic experts.

### CONCLUSIONS

Forensic anthropology in northwestern South America has secured a leading role in investigative law enforcement, particularly in countries affected by internal armed conflicts permeated by the phenomena of abduction and subsequent murder, preceded in many cases by cruel and inhuman treatment and followed by concealment of bodies in mass graves.

This discipline has provided technical and scientific civilian support in the context of the issues outlined in this paper and also in the forensic identification of victims of massive disasters, of both natural and anthropogenic origin. Families of victims are ultimately the beneficiaries of forensic anthropological work, to the extent that they can advance their grieving process according to their religious beliefs.

Through our readings and conversations with different Latin American colleagues, numerous technical and administrative difficulties in the forensic anthropological work conducted in these countries have come to light; without a doubt these will likely also apply to other regions of Latin America. Analysis of these difficulties may reveal the solutions needed to overcome them and aid progress toward achieving quality standards that result in optimization of the work; and consequently, families of people reported missing will benefit.

Ongoing problems we have seen in northwestern South America, with some exceptions for Venezuela and Ecuador, are the following:

- **Absence of “training schools in forensic anthropology” for both graduate and postgraduate students in Latin America**

Where will the forensic anthropologists that will replace the current generations train? Although these problems are already quite complex, in reality they would not be difficult to overcome since Latin American countries have a sufficient number of experienced forensic anthropologists. Experts are available and willing to train new generations—all that is needed are innovative academic programs with opportunities for fieldwork. One option would be to implement a forensic anthropology training school at a masters and doctoral level in Latin America. Certainly, several universities would be interested in undertaking this project.

- **Lack of concise information about the actual number of people reported missing and antemortem information**

Tello and Baraybar (2005:1–12) proposed the task of “. . . main and urgent recovery of antemortem information by collecting antemortem chips. It should cover the total universe the estimation of missing people from the beginning of any investigation that is being carried out in every country in which similar events occur.” This problem of course applies not only for Peru, but for all countries in which the diversity of bureaucratic and technical issues prevent the standardization of information regarding people reported missing.

- **Absence of local bone and dental standards**

Even many years after having started this debate, and despite continuous recommendations made by many authors, we continue to use non-local reference standards, which is detrimental to good practice. The implementation of local documented human bone collections in Latin America should be promoted, which as already mentioned, would allow for transversal population investigations. The process of forensic identification would be much more efficient with local standards.

- **Uniformity in the expert reports—field, laboratory, and autopsy room**

Finally, we believe that in the countries we have observed, important advances have been made in the field

of forensic identification, which has a great impact on the context of the legal and humanitarian resolution of cases. It is necessary to expand the development of scientific research projects that would facilitate the creation of local standards for each country so that the use of foreign referents can be abandoned. This will provide quality results adjusted to meet international forensic anthropology requirements and will benefit the families of the victims.

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# Growth and Development, Health, and Nutrition in Northwestern South America

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**ABSTRACT.** This chapter profiles the research regarding growth, nutritional, and health status of the populations of Colombia, Ecuador, Peru, and Venezuela, including risk factors that modulate the status quo of individuals, according to anthropometric indicators and, to a lesser extent, demographic and economic ones. In some cases, some authors used health indicators related to nutritional aspects. The large amount of information has been summarized in synoptic tables, organized by country and subject, that in one way or another partially encompass all factors influencing the growth, maturation, and nutrition of children and adolescents. Topics that require further insight also have been considered.

**RESUMEN.** Este capítulo tiene como objetivo presentar los perfiles de crecimiento, estado nutricional y de salud en las poblaciones de Colombia, Ecuador, Perú y Venezuela; los factores de riesgo que modelan el *status quo* de los individuos a través de indicadores antropométricos, y en menor cuantía demográficos y económicos. En otros casos, algunos de los autores consultados usaron indicadores de salud relacionados con los aspectos nutricionales. La gran cantidad de datos recopilados fue resumida en cuadros sinópticos, organizadas por países y conceptualizadas por temas, para de una manera u otra analizar los factores que influyen el crecimiento, maduración y nutrición de los niños y adolescentes. También siguiendo las diferentes revisiones, se resaltaron los tópicos que requieren en un futuro inmediato investigaciones más profundas.

**RESUMO.** Este capítulo apresenta os perfis que descrevem o crescimento, nutricional e estado de saúde das populações de Colômbia, Equador, Peru e Venezuela; os fatores de risco que modulam o *status quo* dos indivíduos por meio de indicadores antropométricos e em menor medida, os demográficos e econômicos. Em outros casos, alguns autores utilizaram indicadores de saúde da população relacionadas ao aspecto nutricional. Uma grande quantidade de dados foi resumida em tabelas organizadas pelos países e apresentadas por assunto, que de uma maneira ou de outra, parcialmente engloba todos os fatores que influenciam o crescimento, desenvolvimento e nutrição das crianças e outros jovens. Além disso, seguindo as diferentes revisões, tópicos que requerem exigem posterior análise e abordagens adicionais foram considerados.

## INTRODUCTION

This chapter considers how humans respond to environmental conditions as individuals and as populations. In this sense, biological anthropology can be considered as a social science that must include aspects of ecological and social factors in all their ramifications. These factors include mating practices, size of breeding group, and other

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Manuscript received 28 April 2016; accepted 10 November 2017.

cultural forces that have the potential to influence human biology by modifying genotypes and morphology. Although the earliest studies were basically descriptive, their inclusion is important since they represent the blossoming of a young science that eventually expands to a trans-disciplinary field. Biological anthropology has seen dynamic growth in recent years, reinforcing various lines of research, and in many cases has provided solutions to national problems, with historical and social perspectives.

The current approach to biological anthropology takes into account the complexity of interconnections between genetic, epigenetic, and environmental factors, underscoring the plasticity of human adaptation, which can be identified both individually and across generations. Also important are the demographic, epidemiological, and nutritional transitions occurring in Latin America today, which influence the phenotype.

This chapter presents research which describes the growth and nutritional status of the populations of Colombia, Ecuador, Peru, and Venezuela. Anthropometric, demographic, and economic indicators are used to highlight the risk factors that modulate the *status quo* of individuals. In certain cases, some authors have used population health indicators to highlight the nutritional aspect.

This large amount of data has been summarized in synoptic tables, in an effort to systematize information, and make it more comprehensible due to the variety of topics. It was organized by countries and subject, that in one way or another partially encompass all factors influencing the growth, maturation, and nutrition of children and adolescents. The chapter concludes with a discussion of topics that require further insight. It was impossible to make a thorough investigation of available literature, but every effort was made to offer a comprehensive summary of population research throughout the region.

## THE REGION: A HISTORICAL APPROACH

Carnese (2011) highlighted several stages in the development of biological anthropology. Beginning in the nineteenth century, this development can be viewed as a transition from the empirical approach to the academic conception, focused on the biology of indigenous peoples and the racial characterization of native groups, based on genetic markers, craniometrists, and serological and molecular studies.

A second stage incorporates techniques and methods derived from genetic and serological analyses, with an emphasis on natural selection and a combination of micro-evolutionary factors that led to the serological characterization of populations. These are achieved with the incorporation of robust statistical methods in the processing and analysis of information.

The third stage is characterized by multidisciplinary organizations and inter-institutional collaborations. As a consequence, a new kind of research arose, closely linked to biomedicine, and supported by innovations in medical instrumentation and information technology.

Earlier studies in Colombia on health and nutrition were limited to pre-Hispanic populations, and were afterwards extended to rural and urban areas, as well as contemporary groups with African heritage residing along the Pacific coast. In the 1940s, multinational projects working with indigenous groups emerged in the southwestern and northwestern regions of the country. At that time the Colombian Institute of Anthropology merged with the National Ethnological Institute.

In the late 1960s, the national project “*El hombre y su medio ambiente pleistocénico-holocénico*” (Man and his pleistocenic-holocenic environment) began, which investigated the health and physical information of prehistoric hunter-gatherer populations in La Sabana de Bogotá (Rodríguez Cuenca, 1996). At this time, departments of anthropology were established in several universities: Los Andes, National Colombian, Antioquia, and Cuenca.

Biological anthropology studies were derived from bioarchaeology, with less emphasis on the fields of growth and development, sports medicine, environmental adaptation, nutrition, and ergonomics (Rodríguez Cuenca, 1996; 2008).

Starting in 2000, and specifically in the region of Cauca, studies focused on contemporary Pacific communities from a biocultural and interdisciplinary perspective addressing health problems, illnesses, and auxology (the study of all aspects of human physical growth). Research about growth and development, epidemiology, nutrition, biomedical concerns, ecological influences, and environmental anthropology became increasingly viable, through development by the anthro-Pacific group (Tabares et al., 2012:271), whose objective is the diffusion of bioarchaeological and bioanthropologic research.

Some recent studies aimed to establish a protocol for the development of auxological studies, as well as research regarding the prevalence of national individual and household malnutrition. Others sought to analyze the differences in nutritional status in comparison to international references (Table 1). In particular studies, the emphasis was on assessing nutritional status, physical activity, and the double burden in nutrition, as well as knowledge and behavior regarding sexual and reproductive health, in an effort to prevent teenage pregnancy (Table 2).

The first hints of biological anthropology in Ecuador emerged from the racist ideology of the colonial era. In this sense, the native indigenous groups living in the mountains of Ecuador became the focus of various studies, mainly to measure their somatoscopic characteristics, as well as the socioeconomic relationship of food intake to disease (Clark, 1999; Suárez, 1943; Santiana, 1941). García, (2011) reported three universities in Ecuador that teach anthropology: the Catholic University of Ecuador, the Salesian Polytechnic University, and the Ecuadorian branch of the Latin American Faculty of Social Sciences (FLACSO).

At the present time in Ecuador, the larger, national population surveys are underway, including those targeting children under five years old. The scope covers socioeconomic issues, anthropometric aspects, some health indicators (micronutrient and caloric deficiencies), and infectious diseases—factors that point

**TABLE 1.** Features of studies about national anthropometric and macronutrient deficit prevalence of Colombian children and adolescents.

Objective	Study and characteristics of the sample	Methods*	Results and conclusions
To establish a protocol of auxological studies in children from large cities.	Cross-sectional individual and household (10,487) analysis from the 2010 Colombian Demographic and Health Survey.	Probabilistic polyetapic sampling of individuals.	Prevalence of malnutrition according to age and the growth reference used. In malnourished children, severe emaciation increased from 36.0% (NCHS) to 63,3% (WHO)
To determine the prevalence of malnutrition for individuals and households.	Effects of altitude on rate of growth in different environments.	Anthropometric, demographic, and socioeconomic indicators. LMS curve method.	Higher prevalence of wasting and stunting with WHO 2006–2007.
To record agreement and discrepancy in growth status using different international references.		Comparison of international references (WHO, NCHS, and CDC) for all age groups. Comparison of WHO 2006–2007 and NCHS references. Kappa correlation for children younger than 5 years old.	Correlation of overweight and obese children with a prevalence of anemia and stunting children. National Surveys (2005–2010) show evidence of the double burden of malnutrition: overweight and micronutrient deficiency (iron, vitamin A, zinc) in children and adolescents, similar to findings in other latin american countries.

Studies described above: Álvarez-Uribe et al., 2008; Velásquez et al., 2011; Benjumea Rincón et al., 2012; Briceño et al., 2012; Acosta and Meisel, 2013; Sarmiento et al., 2014.

\*World Health Organization: WHO; National Center for Health Statistics: NCHS; Center for Disease Control and Prevention: CDC

**TABLE 2.** Features of studies about nutritional status, physical activity, and reproductive health of Colombian children and adolescents.

Objective	Study and characteristics of the sample	Methods*	Results and conclusions
To assess nutritional status, physical activity level, and the double nutritional burden.	Cross-sectional socioeconomic studies of urban children attending public and private school.	Nutritional anthropometric WHO references.	Wasting prevalence greater in rural areas, public schools, and single mother households.
To identify knowledge of reproductive health and level of sexual activity.	Cross-sectional study of mothers and households, with children ranging in age from 6–18 months to adolescents.	Household survey using socioeconomic and demographic questionnaires. The Colombian Household Food Security Survey. FITNESSGRAM* protocol. Youth Risk Behavior Survey.	Food insecurity in 48.6% of Tunja households. Overweight prevalence greater in private schools and associated with low physical performance. Scant basic knowledge of nutrition in 50% of mothers. Higher knowledge of sexual health insufficient to prevent teenage pregnancy or early sexual activity.

Studies described above: Alvarado et al., 2005; Tovar et al., 2008; Díaz-García et al., 2012; Pastor Galiano et al., 2012; Rengifo-Reina et al., 2012; Rosique et al., 2012.

\*FITNESSGRAM is a “non-competitive health-related fitness assessment based on the scientifically established Healthy Fitness Zone®” from Cooper Institute <http://www.cooperinstitute.org/fitnessgram>

TABLE 3. Nutritional understanding and the double burden of malnutrition in Ecuador.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To describe the prevalence and distribution of malnutrition (stunting, anemia and zinc deficiency), excessive weight gain, and obesity in Ecuador.	Cross-sectional national, regional, urban, and rural studies at household and individual levels.	Socio-demographic and anthropometric variables. Follow-up questionnaire to determine recall ability 24 hours later.	Persistence of stunting.  Double burden of malnutrition and excess body weight at the household and individual levels, as well as the coexistence of an overweight or obese mother with an anemic or zinc deficient child.
To highlight the double burden of malnutrition.	Database from the 2012 Ecuadorian National Health and Nutrition Survey: 57,727 individuals and 19,803 households.	History of anamnesis of mother and child.	Caloric and micronutrient deficiencies  Prevalence for excessive weight gain or obesity varies according to socioeconomic status and altitude.
To demonstrate the effect of a balanced diet on growth.			

Studies described above: Galicia Paredes et al., 2001; Larrea and Freire, 2002; Freire et al., 1988, 2014; Yépez et al., 2008.

out the double burden of nutrition. The relationships between different regions (coast and mountain) have been compared across the surveys, with particular emphasis on excessive weight gain and obesity in adolescents, as well as the nutritional status of mothers and infants in rural areas, with emphasis on food (Table 3).

As for specific reports, the research highlights the prevalence of chronic malnutrition according to various international standards, the use of anthropometric indicators in assessing the nutritional status, their correlation with physical activity and caloric intake, as well as the positive impact of nutritional intervention. Likewise, the socio-demographic effects on the knowledge and application of reproductive health, and the challenges to be considered by current and future generations are equally addressed (Table 4).

Regarding Peru, in some universities, both at the undergraduate and graduate level, ethnographic and theoretical aspects in urban, suburban, and rural Andean, Amazonian, and coastal areas are emphasized. Forensic anthropology is directly identified with biological anthropology. The different population censuses undertaken with schoolchildren and their families on demography, health, and nutritional status began in 1986 and continued until 2012 (Table 5).

Since the middle twentieth century, physical growth studies have been conducted in various communities, especially those with indigenous populations, monitoring the stress and morphological modifications that altitude produces. Some other studies were developed with smaller samples to investigate growth, motor development, physical activity, and physical fitness, taking

into account the differences derived from ethnicity, altitude, geographical regions, and socioeconomic status (Tables 6, 7).

Pioneering studies in Venezuela started with Sánchez Carvajal, in 1939, followed by Tovar Escobar (1946), Vélez Boza (1948) and Barrera Moncada, (1954). In 1962, the table “Growth and Development of the Venezuelan Child” by Barrera Moncada and Méndez Castellano was published (Bengoa, 1998).

Tables 8–13 show that the reference-oriented studies of Venezuelan population growth began in the 1970s according to the Tanner school, following his guidelines: the National Study of Human Growth and Development (ENCDH) (1981–1987) and “The Longitudinal Study of Caracas Metropolitan Area” (1976–1982). The first was the direct result of the Presidential Committee that started Fundación Centro de Estudios sobre Crecimiento y Desarrollo de la Población Venezolana (FUN-DACREDESA) [Center for the study of growth and development of Venezuelan population] (2002) which, under the leadership of Méndez Castellano, was responsible for these comprehensive studies (López-Blanco and Landaeta-Jiménez, 2011).

In the mid-1950s, Díaz Ungría carried out an important investigation in the Museum of Natural Sciences and the School of Sociology and Anthropology. She is considered to be the person who drove the systematic study of Venezuelan physical anthropology, which in the beginning was focused on the anthropometric measurement of the human body and osteometric analysis, based on typology. Although her research was not encompassed within auxology, it is necessary to highlight the important contribution she made to the field of population genetics, especially for the indigenous groups of Venezuela. Her research offers

**TABLE 4.** Nutritional status of children and adolescents in Ecuador, and the impact of intervention programs.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To assess nutritional status.	Cross-sectional studies of infants, children, and adolescents.	Direct survey questionnaire about socio-demography and parity of food resources.	High prevalence of chronic malnutrition based on WHO. Low prevalence of excessive weight gain.
To determine how altitude affects nutritional status.	Multiethnic: nutritional status of native Amazonian children; rural and urban subjects.	Anthropometric survey about nutritional status (based on WHO standards).	Inverse correlation between BMI and physical activity level and food intake.
To discern the relationships between anthropometric indicators, physical activity, and food intake.		CDC questionnaire about physical activity.	Living in isolated communities in the highlands favors poor nutrition.  Positive impact of nutritional intervention, its Effects of socio-demographic environment on reproductive health; knowledge, application and challenges for current and future generations.

Studies described above: Egas Estrella and Cerón Sousa, 2000; Castro et al., 2003; Buitrón et al., 2004; León Valencia et al., 2009; Gordillo, 2013; Katuli et al., 2013.

\* World Health Organisation: WHO; Center for Disease Control and Prevention: CDC; BMI: Body Mass Index

significant contributions to our understanding of the distribution of blood groups and cultural adaptations in the biological structure of indigenous groups (Struck et al., 2004).

Initially, physical anthropology was taught as part of the general anthropology course load in Venezuela, but in the 1950s, the Department of Sociology and Anthropology was created a part of the School of Economic and Social Science at the Central University of Venezuela. The department started as Sociology and Anthropology and later on during the 1960s developed as a separate department. Physical anthropology is only taught at the undergraduate level. Although other universities in the country have considered anthropology as an important part of their academic curricula, biological anthropology does not stand by itself as a part of the curricula. It is worthwhile to mention that the Venezuelan Institute of Scientific Research has an important section of population genetics at the master's and doctoral level.

More recently, many specific studies in Venezuela have been developed by inter-institutional and multidisciplinary groups whose research focuses on the social, economic, and cultural aspects of nutritional anthropology and auxological epidemiology. It is also worthwhile to mention advances in kinanthropometry as a tool for the classification and description of the physique, which researchers use to analyze morphological function and physiological adaptation in relation to the environment. In this

sense, biological anthropology takes on a dynamic dimension by facilitating the study of morphology in relation to athletic ability and the exertion levels demanded by particular lifestyles.

Other studies regarding levels of athletic ability in urban and rural populations focused on: assessment of nutritional status, micronutrient deficiencies, current modification of morphology, effectiveness in predicting nutritional risk, sexual and bone maturation on performance, causes and consequences of food and nutritional transition, impact of nutrient fortification of flour, and sexual and reproductive knowledge and behavior (Tables 14–21)

## RELEVANT TOPICS FOR INVESTIGATION

Our literature review revealed several important topics:

- Longitudinal studies are needed and would be beneficial. For instance, neither the development of a person's physique overtime, nor the early identification of risk factors for cardiometabolic diseases, is well understood. In this sense, it is important to highlight that many of the growth, neurological, psychological, dental, biochemical, and endocrinological variables of the Caracas Longitudinal Study were partially analyzed and are available for comprehensive investigation.

**TABLE 5.** Features of national surveys to record demographic, family health, nutritional status, and stunting statistics in Peru (ENDES 1986, 1992, 1996, and 2012).

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To obtain information on national, departmental, and regional levels about fertility, mortality, family planning methods, AIDS, and domestic violence.	Cross-sectional urban and rural, individual and household, national surveys (men, women of childbearing age, and children younger than 5 years old).	Nutritional status analysis according to NCHS, CDC, and WHO standards. Afterwards, WHO 2006 growth standards.	Prevalence of mortality for infants and children younger than 5 years old in rural areas, with variations according to geographic location.
To measure nutritional status and height of school-aged children.		Direct surveys with national and regional questionnaires, followed Department of Health Services, Illinois: individuals and households, including access to basic services.	Frequent infection, diseases, and high prevalence of anemia in children younger than five years old.  An increase in the use of modern family planning methods, a higher educational level in boys and prolonged breast feeding.
		Health information included demographic aspects, health of mother and child, nutrition, AIDS, domestic violence, and reproductive health.	High prevalence of adolescent pregnancy. Low vaccination coverage. HIV information has increased.  Prenatal control care increases with deliveries.  High percentage of domestic violence. Identification of vulnerable areas and populations.  Diminishing prevalence of malnutrition, especially in children.

Studies described above: ENDES (1986, 1991–1992, 1996, 2012); Ministerio de Educación (2000).

- It is necessary to develop research that measures the effects of the use of World Health Organization (WHO) growth standards in different populations and to study the predictive value and appropriate limit values, in particular for body mass index.
- Specific studies in multi-ethnic communities focusing on dietary habits, parasitic infections, micronutrient deficiencies, and nutritional status—in particular stunting and anemia—are mandatory as a tool for preventing chronic malnutrition.
- In Venezuela, the lack of a standardized household survey to analyze the double burden of malnutrition (excess weight gain or obesity in relation to stunting) as a basis for public health policies is inexcusable.
- Auxological studies of the relationship between maturity timing and physical activity must be conducted longitudinally; such studies should always take geographic variables into account and are particularly recommended for those regions where altitude is an important factor.
- The effect of social mobility (socioeconomic mobility), in developing countries: rural-urban, between different geographical regions or ethnic groups; could affect the biological and health status of individuals, which is reflected partially in the nutritional, epidemiologic and demographic transition found in the countries of the region. This is an issue that should be considered particularly in children.

**TABLE 6.** Features of studies that gauge the effects of altitude on growth, development, cardio-respiratory aptitude, and body composition in various Peruvian communities.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To record differences in growth, development, body composition, and physical fitness according to geographical regions and ethnicity.	Cross-sectional, semi-longitudinal studies of different groups ranging from 1,100 to 7,000 subjects.	Anthropometric variables using IBP guidelines. Heath-Carter somatotype.	Late sexual dimorphism and adolescent growth spurt.
To assess multiple stresses of high altitude environments.	Study participants represent diverse ethnic and socio-economic statuses.	Cole cut-off- points. Graffar method for socio-economic status. WHO growth references.	Heavier weight and greater subcutaneous fat deposition. Stunting at high altitude.
To determine relationships between excessive weight gain, obesity, and cardio-respiratory aptitude.			All these characteristics reflect genetic adaptation to the environment. Hypoxia stress is not evident in moderate altitudes.

Studies described above: Frisancho and Baker, 1970; Crespo et al., 1995; Mortola et al., 2000; Toselli et al., 2001; Hartinger et al., 2006; Shimabuku et al., 2009; Cossio--Bolaños et al., 2011, 2012; Bustamante and Maia, 2013; Bustamante Valdivia et al., 2014.

IBP: International Biological Program; Heath-Carter: Heath Carter Method of somatotyping, Graffar: Socioeconomic classification method; Cole cut-off: Body Mass Index cut-off points according to Timothy Cole

**TABLE 7.** Somatic growth, physical aptitude, motor development, and physical activity of Peruvian children and adolescents.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To test physical aptitude parameters using reference values.	Cross-sectional studies from birth to adolescence, urban, suburban, and rural origins.	Anthropometric variables. EUROFIT.	Sexual dimorphism in physical activity according to age.
To determine the prevalence of malnutrition and excessive weight gain according to origin, food intake, and socio-economic status.	Samples ranging from 230 to 7,800 individuals.	Godin and Shepard questionnaires. Prevalence using WHO and Must standards. Unsatisfied basic needs method.	Results: Percentile charts by age and sex for physical fitness. Excessive weight gain and obesity coexist with stunting and vary according to residential location. Significant differences in growth seen in urban and rural locations. Poverty related to food consumption. Variables of body size and composition related to socioeconomic status. Infant growth improves with breast feeding and urban environments.

Studies described above: Pajuelo et al., 2000; Rojas et al., 2004; Bustamante, 2005; Calderón et al., 2005; Mispireta et al., 2007; Iannotti et al., 2009; Bustamante et al., 2012; Lozano-Rojas et al., 2014.

EUROFIT: test to evaluate physical condition. Godin and Shepard questionnaires: Godin Leisure time questionnaires.

TABLE 8. Venezuelan growth references, part 1. Features of the cross-sectional study of Caracas.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To determine provisional physical growth reference values.	Cross-sectional study of 5,580 upper strata (Graffar-Méndez Castellano) individuals. Two-stage sampling of 32 schools and health centers.	Weight, height, sitting height, circumferences (chest, head, arm), diameters (biacromial/biiliac), and skinfold measurements (triceps, subscapular) following IBP guidelines.	Development of growth curves using SPSS; Construction of curve fitting with ARMA modelling.

Source: Méndez Castellano et al.(1986a).

Graffar-Méndez Castellano : socioeconomic classification method ; IBP : International Biological Program ; ARMA modeling ;Time series method of modeling; SPSS; Statistical Package for Social Science

TABLE 9. Venezuelan growth references, part 2. National Growth and human development of the Venezuelan Republic: Project Venezuela

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To establish reference values for anthropometry, pubertal and skeletal maturation, tooth and craniofacial development, neurological and psychological development, clinical values, nutritional, biochemical, hematological, and endocrinological variables; intestinal parasite analysis.	Cross-sectional national study: more than 65,000 in a multiple stage sampling. Age range: 0–40 years old.  The population was stratified according to the Graffar-Méndez Castellano method: I:246.370 — 1,06% II:1.478.219 — 6,36% IV: 9.257.462 — 39,83% V: 9.703.716 — 41,75%	IBP guidelines and CIE/ICH models in the analysis of weight, height, sitting height, head, arm, and leg circumferences, upper and lower limb lengths, biiliacand biacromial diameters, triceps and subscapular skinfolds, and selected indices (BMI, AFA, AMA).  Percentiles adjusted with a smoothing spline function.	Development of Reference values in growth and selected indices for the monitoring of nutritional status.  Differences according to social strata were statistically significant; fewer in urban and rural communities.  As compared to Anglo-Saxons (British and Americans), Venezuelans are shorter, lighter, less muscular, and have less peripheral fat but more central fat, from puberty onwards. Local standards of reference are recommended in order to prevent a miscalculation.
To determine differences between urban and rural populations and inter- social strata.			
To develop the Graffar-Méndez Castellano stratification method for socio-cultural family studies.			

Studies described above: López Contreras-Blanco et al.(1986, 1992);Méndez Castellano et al. (1986b); Landaeta-Jiménez et al. (1994a, 1994b, 1995); López-Blanco et al. (1995c).

IBP: International Biological Program ; CIE/ICH models: Models from Institute of Child Health and London Centre International de l'Enfance Paris; BMI: Body Mass Index; AFA: Arm Fat Area, AMA: Arm Muscle Area



**TABLE 10.** Venezuelan growth references, part 3. National Growth and Human Development of the Venezuelan Republic: Project Venezuela

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To establish references in pubertal and skeletal maturation.	Cross-sectional, national study: more than 65,000 subjects in a multiple stage sampling. Age range: 0–20 years old.	TW2 and Greulich-Pyle methods.  Centiles estimated for TW20 bones/ RUS and Carpal bones.	Development of references for skeletal and pubertal maturation. Significant differences in maturity according to social strata; differences in urban and rural communities were less evident.
To determine differences in maturation in urban and rural populations and inter-social strata.	More than 10,000 X-rays taken and rated according to TW2 and Greulich-Pyle methods.	Pubertal maturation according to Tanner stages. Age at menarche according to the <i>status quo</i> method; analyzed by Logic method.	Venezuelans mature earlier than the British at the onset of puberty and age at menarche with a prolonged period from the start of puberty (G2/B2) to the end of puberty. (G5/B5). Skeletal maturity showed retardation in carpal bones and advancement in long bones (radius, ulna and metatarsals and phalanges). Thus, the need for an atlas of a local skeletal reference.
To select X-rays from the Atlas of Skeletal Maturation as a reference guide for the Venezuelan population.	Pubertal maturation analyzed in more than 23,000 boys and girls.		
To record secular trends of age at menarche.			

Studies described above: López Contreras et al., 1981, 1986; Izaguirre de Espinoza et al., 2003.

G refers to genital stage from 1 to 5 according to Tanner, and B refers to breast development from 1 to 5, G1/ B2: genital 1 and breast 2

TW2 and Greulich-Pyle methods: Tanner-Whitehouse method and Greulich-Pyle method for bone development; TW20 bones/RUS: Tanner-Whitehouse long bones method: Radius, Ulna and Short bones (of metatarsals and phalanges) method

**TABLE 11.** Venezuelan growth references, part 4. National Growth and Human Development of the Venezuelan Republic: Project Venezuela

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To demonstrate that growth is a mirror of the conditions of a developing society.	Cross-sectional national study: more than 65,000 subjects in a multiple stage sampling. Age range: 0–40 years old.	Nutritional status evaluation using WHO references.	Significant social stratification differences; wealthier participants had a higher prevalence of excessive weight gain and poorer participants tended to be underweight with a higher prevalence of stunting.
To record differences in nutritional status in the urban and rural populations and inter-social strata.	Secular trends in height and weight were reanalyzed in a region of the country one decade later.		Smaller differences between urban and rural communities and non-significant differences in some age groups in weight, height, bone maturity and age at menarche.
To determine secular trends of height and weight.			

Studies described above: López Contreras-Blanco et al. (1989, 1991); Landaeta-Jiménez et al. (1989); Méndez Castellano et al. (1990, 1995); López-Blanco et al. (1995d).

TABLE 12. Venezuelan growth references, part 5. Features of a longitudinal study conducted in Caracas Metropolitan Area.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To establish dynamic references for anthropometry, pubertal and skeletal maturation, dental, neurological, and psychological development, and clinical values: nutritional, biochemical, endocrine.	Mixed longitudinal study (1976–1982).  Two-stage sampling: 457 children in upper-strata schools (Graffar-Méndez Castellano).	IBP guidelines and ICC/ICH models. Assessment of velocity and tracking. Clinical longitudinal charts for height and weight.	Development of dynamic references in height, weight, pubertal, and skeletal maturity.  Differences in rate of growth and maturation, development, and clinical variables.
To record differences in rate of growth and maturation, as well as the interaction and sequence of pubertal events.			

Studies described above: López de Blanco et al.(1986, 2013a); López-Blanco et al.(1995a);Saab Verardy et al.(2013).

CIE/ICH models: Models from Institute of Child Health and London Centre International de l'Enfance Paris; IBP : International Biological Program; Graffar-Méndez-Castellano: socioeconomic classification method with five categories.

TABLE 13. Venezuelan growth references, part 6. Features of a mixed longitudinal study conducted in metropolitan Caracas.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To monitor variations in the longitudinal pubertal patterns of boys and girls, including characterization of early, average, and late maturation. To determine patterns of growth in anthropometric, clinical, and biochemical variables that track over time.	Mixed longitudinal study (1976–1982).  Two-stage sampling: 457 students in upper-strata schools (Graffar-Méndez Castellano).	Pubertal stages by direct inspection. Age at menarche with the prospective method. Measure testicular volume using Prader's orchidometer.  A survival analysis for intervals between events.  Longitudinal analysis and index-tracking program using Kappa statistics.	Definition of Intervals, sequence of events, age and rate at growth spurt. Statistical differences in the rate of maturation.  Statistical correlations between early maturation, BMI, and blood pressure.  The tracking index predicted risk of chronic disease.

Studies described above: Izaguirre Espinoza et al. (1989a); Izaguirre-Espinoza et al. (1989b); López-Blanco et al. (1994, 1995b, 1999, 2000, 2001); Moya Sifontes et al. (1999); Blanco-Cedres et al. (2000a, 2000b); Macías-Tomei et al. (2000a, 2000b); Izaguirre de Espinoza and López de Blanco (2009).

Survival analysis: statistical analysis; Kappa statistics: statistical concordance method of analysis; Prader's orchidometer: instrument for measuring testicular volume

## CONCLUSION

The literature review presented in this chapter has focused on research regarding the different biological and social factors that contribute to variations in growth and development, based on current scientific knowledge and evidence-based data. It is important to emphasize that the choice of studies reviewed in this

chapter was based on the information that was available. Many of the studies were conducted in different eras. The earliest studies were performed in Venezuela in 1939 and Colombia in 1940, followed later by Ecuador and Peru.

The information analyzed in this chapter was carefully reviewed and demonstrates differences across the northwestern region of South America. These include patterns of growth in

**TABLE 14.** Features of a study assessing nutritional status in Venezuelan children and adolescents.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To characterize nutritional status, prevalence, dietary habits and physical activity, with socio-economic indicators and food security at home.	Cross-sectional studies of apparently healthy children and adolescents, in urban and suburban environments.	Anthropometric indicators of body composition and proportionality, intake habits, food security at home, and physical activity according to age group.  Application of WHO standards.	The prevalence of excessive weight gain and obesity in the national sample was 28% in children 7–12years old and 21% in those 13–17years old; the deficit was 17% in both (double burden).  In some cases, no relationship was found between food insecurity at home and caloric intake. Stunting prevailed in peri-urban areas of Caracas and Vargas state.

Studies described above: Arechabaleta et al. (1999, 2000); Herrera et al. (2001); Landaeta-Jiménez and Macías-Tomei (2003); Sánchez Jaeger et al. (2005); Hernández Hernández et al. (2007, 2011a); Rivas et al. (2007, 2013); Acuña and Solano (2009); Pietrini et al. (2009); Instituto Nacional de Nutrición (2013); Zambrano et al. (2013).

**TABLE 15.** Features of a study measuring biochemical indicators of nutritional status and macronutrient deficiencies (vitamin A, iron, folic acid, vitamin B12, and riboflavin) in Venezuela.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To assess nutritional status and micronutrient prevalence, incorrelation with anthropometric variables, body composition, social strata, and intestinal parasitic infection.	Cross-sectional samples of children and adolescents in some urban areas of Venezuela.	Anthropometric indicators and blood analysis with radioimmunoassay. Kato-Katz method.	The relationship between adequate nutritional status, biochemical indicators, and adequacy of diet was not always evident.  Association of parasitic infection with alteration of micronutrients.

Studies described above: García Casal et al. (2005); Barón et al. (2007); Paéz et al. (2008); Papale et al. (2008); Solano et al. (2008); Carias et al. (2009); Ávila et al. (2012).

Radioimmuno assay Kato-Katz method: method for assessing parasitic infection

different environments, anthropometrical outcomes based on national and international growth references, nutritional status, prevalence of malnutrition, micronutrient deficiencies and the impact of iron fortification, causes and consequences of food and nutrition transitions, and the developmental origins of health and disease: under-nutrition, overweight/obesity (the double burden of nutrition), the latter of which has current relevance for pathological studies. Also, valuable information was evaluated related to food insecurity assessments at household and community levels, including the invasive and non-invasive indicators of biological maturation and body composition.

Furthermore, auxological studies regarding the relationship between structure and function in athletes and non-athletes and variations in physical activity versus physical fitness, were taken into account. Research regarding reproductive health and genetic epidemiology included in this analysis has become important recently.

Overall, the information is consistent in the sense of the difficulty to isolate a single factor that explains the variability of particular phenomena, and in the consensus reached on the importance of the social and cultural environments which impact the growth of children and adolescents.

**TABLE 16.** Features of a study measuring anthropometric indicators of body size and composition in Venezuelan children and adolescents and their effectiveness in predicting nutritional risk.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To analyze several indicators of body composition. To assess early risk and nutritional disorders through the predictive ability of some indices and indicators.	Cross-sectional studies of urban and rural samples in children younger than 5 years old to adolescence from public and private schools.	Evaluation of the effectiveness of anthropometric indicators: energy and protein, arm circumference, waist-to-height, waist, BMI, and conicity.	Energy and protein index is highly predictive in pediatric ages.
		Percentile calculation and adjustment by Cole (LMS) method.	In some studies, the WHO arm circumference index predicts nutritional risk.  BMI is an effective indicator of adiposity.
		ROC curves, predictive value, and agreement of indicators.	Indicators of adiposity distribution (waist to height and conicity) do not always show satisfactory sensitivity and specificity.

Studies described above: Dini Golding and Henríquez Pérez(2009); Henríquez-Pérez et al.(2009); Pérez et al.(2009); Morales et al.(2010);Henríquez-Pérez and Rached-Paoli(2011); Hernández Hernández et al.(2011b); Vargas et al.(2011); Macías-Tomei et al.(2012).

Conicity: conicity index for measurement of fat distribution; WHO: World Health Organization; BMI: Body Mass Index

**TABLE 17.** Features of a study measuring body composition and fat distribution in the Venezuelan population.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To analyze the relationship between fat distribution indicators and physical activity.	Cross-sectional studies in children and adolescents in urban and suburban populations.	Anthropometric indicators of adiposity using BMI and distribution (conicity, WHR), sum of folds, fat area, WTR index.	BMI relates more to biological age than chronological age.
To study the relationship between indicators of maturity in pubertal development, as well as the relationship between proportionality indicators and malnutrition.		Pubertal development self-assessment.	Adiposity distribution differs according to indicators (Centripetal Index, Modified Body Development Index BDI <sub>m</sub> , Waist to Height index, Subscapular Triceps Index)
		Bone age by densitometry (BMD) and proportionality by Hull rating.	In some studies, femur diameter reflects more the nutritional deficit.
		Godin and Shepard method for leisure evaluation and Kreece-Plus method for assessing physical activity.	In some samples, the different levels of physical activity proved significant except for limb skinfolds.
		Baecker questionnaire for assessing physical activity habits.	Sexual dimorphism in physical activity.

TABLE 17. (Continued)

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
		METs Score.	Physical inactivity is associated with a central distribution of adiposity.
		Modified Body Development Index (BDIm).	

Studies described above: Prado and Meza (2001); Pérez et al. (2002b, 2010, 2012a, 2012b); Campos Cavada and Macías-Tomei (2003); Prado and Arias(2008); Guerrero and Sánchez Jaeger(2009); Morillo Piña et al.(2010).

BMI: Body Mass Index; Conicity: Conicity Index; WHR: Waist Height Ratio; WTR: Waist Triceps Ratio; Goding and Shepard Method: for leisure time evaluation; Kreece-Plus: method for assessing physical activity; Baecker questionnaire: for assessing physical activity habits; METs Score: Measurement of Exercise Tolerance is the ratio of the work metabolic rate to the resting metabolic rate; BDIm: Modified Body Development Index for the measurement of corporal development.

TABLE 18. Features of studies measuring the relationship between bone structure and function and the effects of sexual and bone maturation in performance in the Venezuelan population.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To optimize athletic performance based on sexual and bone maturation in athletic talent identification.	Literature review.  Cross-sectional studies of several samples of athletes with different athletic ages and competitive levels, children and adolescents.	Evaluation of sexual maturation by Tanner, testicular volume.  Bone maturation (TW2 method).  Assessment of proportionality according to Phantom Stratagema.	Influence of biological development can be seen in physical fitness.  Relationship between skeletal maturation and morphological age (derived from BDIm)
To study the morphological and functional variations of athletes related to sport performance.	A non-athletic sample of the population was also studied.	ISAK Guidelines.	Some body proportions characterize high performance swimmers.
To select the anthropometric variables and pubertal development stages that identify high-performance athletes.		EUROFIT Protocol.  APTOKIDS Software.  Modified body development index (IBDm).  Somatotype (Heath-Carter).	Height was associated with physical fitness, especially in boys.  Sexual dimorphism evident in aerobic power.  Sexual maturation is important in athletic talent identification.

Studies described above: García (1998); García and Salazar (2001); Pérez et al. (2002a, 2006, 2007); Ortega de Mancera and Ledezma (2005); García Avendaño (2006); Salazar Loggiodice et al. (2006); Flores-Estévez et al. (2008); García Avendaño et al. (2010); Alexander and Méndez-Pérez (2014).

BDIm: Modified Body Development Index for measurement the corporal development; TW2: Tanner-Whitehouse method; Phantom Stratagema: Method for Body proportionality measurement; ISAK Guidelines: International Society for the Advance of Kinantropometry method; EUROFIT Protocol: test to evaluate physical condition; APTOKIDS Software: software created for anthropometric and physical fitness assessments, developed by Pedro Alexander and Carlos Castillo, under the sponsorship of APTO of Venezuela C.A.; Somatotype (Heath-Carter): Heath Carter Method of somatotyping; Morphological age: related to BDIm, and refers to the assessment of growth taking in to account different body segments (diameters and circumferences) besides height and weight

TABLE 19. Features of a study monitoring the food and nutrition transition (TAN) in Venezuela.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To study the characteristics of the Food and Nutritional Transition in Venezuela, including causes and consequences.	<p>Analysis of demographic and epidemiological indicators of nutritional status, food availability, and lifestyle.</p> <p>Analysis of the double nutritional burden: metabolic syndrome, excessive weight gain, and obesity coexisting with stunting.</p>	<p>Literature review of several population indicators.</p> <p>Specific studies of anthropometric, biochemical, and clinical indicators of cardio-metabolic risk and disease in children and adolescents.</p>	<p>Demographic and epidemiological transition is long-standing; the nutrition transition began in the early 1960s and rapidly evolved, giving rise to the double burden of nutrition.</p> <p>The importance of nutrition during the first 1,000 days of life and the metabolic programming with its different theories and epigenetic mechanisms. (Developmental Origins of Health and Disease: DOHaD)</p> <p>Absence of criteria consensus for assessing risk.</p>

Studies described above: Molero Conejo et al. (2003); Velásquez et al. (2003); Vera et al. (2003); López de Blanco and Carmona (2005); Ryder (2005); Laurentin et al. (2007); Nuñez (2008); Mattioli and Parra (2009); Maulino et al. (2009); Macías-Tomei (2009, 2014); Morales and Montilva (2012, 2014); Herrera Cuenca et al. (2013); López de Blanco et al. (2013b); López-Blanco et al. (2014a, 2014b); Herrera Cuenca (2014); Laurentin (2014); Macías-Tomei et al. (2014); Pérez (2014); Villalobos et al. (2014).

DOHaD: Developmental Origins of Health and Disease

TABLE 20. Features of studies monitoring the nutritional impact of flour fortified with iron and vitamins in Venezuela.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To record iron bioavailability from diet by socioeconomic status.	Proyecto (Project) Venezuela: 4,661 family households and 3,228 children 0–16 years old.	Literature review of several cross-sectional studies.	The key issue for iron bioavailability was the inhibitors in the lower strata and the enhancers in the upper strata.
To determine the impact on the population of iron and vitamin enrichment of precooked flours.	Preliminary survey in 1994 of 307 children.		<p>Anemia and iron deficiency was most prevalent in poor children younger than 3 years old (50% anemia and 45% iron deficient), pregnant women, and adolescent girls.</p> <p>An early response to the effect of the fortification was the decrease in the prevalence of anemia and iron deficiency from 37% and 19% respectively in 1992 to 15% and 10% in 1994.</p>

Studies described above: Taylor et al. (1993, 1995); Beard (1996); Layrisse et al. (1996); FUNDACREDESA and UNICEF (2002).

**TABLE 21.** Features of studies about reproductive health and congenital abnormalities in Venezuela, including genetic epidemiology, public health, and physical anthropology.

Objectives	Study and characteristics of the sample	Methods	Results and conclusions
To study the causes of congenital abnormalities in the Venezuelan population.	Cross-sectional urban studies. Different samples of women in prenatal control care.	Studies had a quantitative and qualitative focus. Questionnaires surveyed maternal age, family history, chromosomal abnormalities, and prenatal diagnosis.	Abnormal outcomes represent the 10th cause of neonatal mortality, and the 2nd for children younger than 5 years old.
To demonstrate the importance of prenatal care and macronutrient intake, and to record the presence of congenital abnormalities.		Analysis of public health policies for the prevention of abnormal outcomes.	

Studies described above: Struck et al. (2007, 2008, 2009, 2010, 2011); Vidal-Aguilera et al. (2007, 2009); Caricote Ágreda (2009); Struck and Vidal-Aguilera (2012); Vidal-Aguilera and Struck (2012).

## ACKNOWLEDGMENTS

We are in debt to our research assistants, Vanessa Castro, Xiomarys Marcano, and Gloria Pereira, for their thorough reviews of this chapter; also, to Dr. Coromoto Macías-Tomei for her support. The revision made by the reviewers was invaluable and enhanced the quality of the text.

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# Population Genetics in Argentina, Bolivia, Chile, Paraguay, and Uruguay

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**ABSTRACT.** This chapter reviews the studies of population genetics in Bolivia and the countries of the Southern Cone of South America. These five countries have different demographic histories, and as a consequence, their genetic characteristics vary. Studies in each country have different emphases and therefore, they will be considered separately after a general review of historical studies in the region. Current studies (those which incorporate the latest molecular techniques) are considered separately. In Argentina, the main aim is to analyze the regional particularities; in Uruguay, it is the search for an admixed ancestry; in Chile, the native populations and the ancient peopling of the continent; in Paraguay, native populations and diseases; and in Bolivia, the genetic diversity of the native population. In contrast to research in Argentina, Chile, and Uruguay, most of the studies in Bolivia and Paraguay were conducted by foreign researchers.

**RESUMEN.** En este capítulo se revisan los estudios sobre genética de poblaciones realizados en los diferentes países del Cono Sur y Bolivia. Los cinco países tienen historias demográficas diferentes, y consecuentemente, varían en sus características genéticas. Los estudios en cada país poseen diferentes énfasis, por lo que luego de una revisión general de los estudios históricos, se tratan los avances actuales (esto es, a partir de la incorporación de técnicas moleculares) en cada país por separado: en Argentina el objetivo principal es analizar las particularidades regionales, en Uruguay la búsqueda de una ancestría compleja; en Chile las poblaciones nativas y el poblamiento antiguo del continente; en Paraguay las poblaciones nativas y enfermedades; en Bolivia la diversidad genética de su población nativa. A diferencia de Argentina, Chile y Uruguay, los estudios sobre las poblaciones de Bolivia y Paraguay fueron mayormente realizados por investigadores extranjeros.

**RESUMO.** Este capítulo revisa os estudos sobre genética de populações realizados nos diferentes países do Cone Sul e Bolívia. Os cinco países têm histórias demográficas diferentes, e consequentemente, variam em suas características genéticas. Os estudos em cada país têm diferentes ênfases, e portanto, depois de uma revisão geral de estudos históricos, estudos atuais (isto é, a partir da incorporação de técnicas moleculares) são considerados separadamente: na Argentina o objetivo principal é analisar as particularidades regionais; no Uruguai a busca por uma ancestralidade miscigenada; no Chile as populações nativas e o povoamento antigo do continente; no Paraguai populações nativas e as doenças, enquanto que na Bolívia a diversidade genética de sua população nativa. Diferentemente de Argentina, Chile e Uruguai, os estudos sobre as populações de Bolívia e Paraguai foram realizados em sua maioria por pesquisadores estrangeiros.

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

## INTRODUCTION

This chapter discusses the history and current state of population genetic studies in southern South America. The region corresponds to what is commonly known as

the “Cono Sur” (Southern Cone) with the exception of Bolivia which, due to its similarity to northwestern Argentina and northern Chile, can be included here for the purposes of analysis. This region covers more than 5 million km<sup>2</sup> and has a population of over 80 million inhabitants who are unequally distributed. Rio de la Plata and Central Chile have the highest population density, while there are vast areas with very low demographic density such as Patagonia and Chaco. Argentina, Chile, and Uruguay are more urbanized and Bolivia and Paraguay have a significant rural population. Moreover, these populations have several historical similarities, but also differences. As one example, though the region was first settled by paleo-Americans around 14,000 years ago, the characteristics of this process vary widely in each territory.

The entire region also was affected by the Spanish conquest, but differences increased during the colonial period, when Asunción (Paraguay) became the most important city in the region in the sixteenth and seventeenth centuries. After the colonial period, new waves of immigrants came into the region—predominantly the Spanish in Bolivia, Paraguay, and Chile—but Rio de la Plata experienced a greater influx of newcomers from other countries besides Spain. Another difference is related to the slave trade: the region received slaves from Africa mostly to work as domestic servants or in agricultural production (with the exception of Bolivia where slaves were forced to work in mines), but their distribution was heterogeneous. Nowadays, according to local censuses, people who claim to have African ancestry comprise different percentages of the population of these countries: less than 1% in Chile and Argentina, around 2% in Paraguay and Bolivia, and 8% in Uruguay.

Population genetics studies also have different histories, in part due to the perception particular countries have about their populations. While Argentina and Uruguay have traditionally chosen to align their national identity with their European ancestry, Paraguay and Bolivia claim closer ties to their indigenous roots, while Chile falls somewhere in the middle. Consequently, during a great part of the twentieth century, genetic studies in Uruguay were focused on comparisons with European populations, while in Chile, Bolivia, and Paraguay they were focused on native populations, and in Argentina both lines of ancestry were considered.

This chapter focuses on the genetic characterization of the populations of the five countries, initially using classical markers (that is, blood groups or proteins) and later, incorporating DNA mutations. It is necessary to point out that, although population genetics studies are usually related to living populations, there are also studies related to skeletal remains (metrics, non-metrics, and DNA). Our review of the data includes some references to these subjects. Also, the analysis of information will be done for each country separately, but it is necessary to mention some general studies concerning indigenous South Americans (Steward, 1940–1947; Salzano and Callegari-Jacques, 1988), Latin American populations (Salzano, 1971; Salzano and Bortolini, 2001), and population admixture (Sans, 2000; Salzano and Sans, 2014).

Finally, the “History of Physical Anthropology: An Encyclopedia,” edited by Spencer (1997), has several entries related to some of the countries considered here. But none of the populations of these five countries were included in projects such as HapMap or the 1000 Genomes Project.

#### POPULATION GENETIC STUDIES: A BRIEF HISTORY IN THE REGION

In this section we will briefly review the history of genetic studies in each country, from the initial studies to approximately the 1990s when testing was expanded to include molecular techniques.

In Argentina, according to Carnese et al. (1997), physical anthropology began to emerge as an independent scientific discipline during the second half of the nineteenth century. The authors classified the history of the discipline into three periods, starting in 1860. This first period is characterized by the adoption of Darwinism and the studies by F. Ameghino. The second period, however, is antievolutionary, manifested by the work of J. Imbelloni and others. Concurrently, the use of ABO blood typing was recognized in anthropological investigations, as the first serological testing used in the 1920s. Since 1960 biological anthropology has shown a growing interest in issues related to microevolutionary processes and the dynamics of adaptation.

Chile also has a relatively long tradition in genetic studies related to Chilean populations. Studies in this country started with the description of different ethnic groups, incorporating anthropometric, morphological and serological data. Starting in the 1940s, R. Etcheverry, R. Nagel, E. Covarrubias, E. Henckel, A. Lipschutz and R. Cruz-Coke studied the genetic polymorphisms of the Mapuche, Alacaluf, Yaghan, Aymara and Pehuenche (Cruz-Coke, 1999). During the 1960s–1980s, studies were mostly focused on craniometrics (Rothhammer and Aspillaga, 1997). Studies concerning cosmopolitan populations are relatively recent and include analyses of genetic systems as well as admixture estimations. An early example of the latter is the application of ABO alleles to estimate either European and Amerindian components (Rothhammer and Cruz-Coke, 1977), or differences in sexual dimorphism related to Amerindian and European admixture (Valenzuela, 1975). There is a long tradition of research in genetic or complex diseases, one of the first of these was based on the correlation of the ethnic structure and the prevalence of single gene defects. Results showed that single gene defects in Chile are probably shaped by factors related to ethnic population structure (Cruz-Coke and Moreno, 1994). In reference to native populations it is necessary to highlight “The multinational Andean genetic and health program,” a collaborative study between researchers from the United States and Chile co-directed by W. J. Schull and F. Rothhammer, in 1972.

In Uruguay, the first genetics studies—on ABO and Rh blood systems—were started in the 1950s by H. Caragna and S. Laffite as well as other researchers. It is worthwhile to mention the studies on dermatoglyphics by R. Kolsky, C. Scazzochio and

M. Oyhenart that were conducted in the 1970s. In the 1980s, the quantity of analyzed genetic systems increased through the incorporation of histocompatibility antigens (HLA) by I. Alvarez and associated researchers, as well as the use of different blood groups by A. Miller and G. Surraco. Also, in this decade, population admixture studies in Uruguay shifted focus from the European component to the indigenous component, based on the recognition of the Mongolian spot by M. Sans, F. Mañé-Garzón and R. Kolki, which was first analyzed by T. Rovira.

In Paraguay and Bolivia, studies related to microevolution are scarce and most of them were performed by researchers living in other countries, such as the one by Matson et al. (1968) who dedicated two parts (third and sixth respectively) of their “Distribution of blood groups among Indians in South America” to Bolivian (Aymara, Itonama, and others from several regions) and Paraguayan ethnic groups (Lengua, Toba, Chulupi, and others). Ten years later, the study by Salzano et al. (1978) included the Ayoreo from Paraguay and Bolivia, while in the same year, Ferrell et al. (1978) attempted to identify the extent of non-indigenous contribution to the gene pool of two populations in the Bolivian highlands, using the assessment of biochemical and immunological marker frequencies.

#### POPULATION GENETICS: CURRENT ADVANCES

As in the past, the current focus of population genetics studies varies from country to country, and also its aims: characterization of populations or substructures within them, relationships between genetic mutations and diseases, understanding of national, regional, or particular histories, or recovering of genetic backgrounds.

##### *Argentina: Heterogeneity in Composition of Population across Different Regions*

There are two main groups being studied in Argentina: the cosmopolitan populations and the indigenous communities. The current population of Argentina is the result of a process of genetic admixture, first between indigenous groups, Spanish colonizers, and Africans brought as slaves starting in the early and late 1500s respectively, then with a larger European immigrant population that arrived mainly between 1880 and 1920, and more recently with the addition of immigrants from neighboring countries. “In spite of this rich history of immigration and admixture, most of the Argentine population self-identifies as being of European-descent, with only 1% of the total population self-identifying as descendants of an indigenous group” (Avena et al., 2012). In contrast to this perception, it has been reported that a considerable proportion of the Argentine population has at least one native ancestor, mainly by maternal lineage. Several cosmopolitan populations of Argentina have been studied to estimate the European, Amerindian, and African participation in their gene pools, showing great variability in the country and a regional pattern, with a greater European contribution in the

center, and the indigenous component higher in the samples from the south and north, particularly in the northwest where most gene flow was also recorded from sub-Saharan African populations (Table 1). There are certain differences between studies in the same city or region. As noted by Salzano and Sans (2014), this may be due to problems of sample representation, type and number of markers used, and methods of quantitative ancestry estimation. Taking this into consideration, three very important facts can be pointed out: the first is the presence of a greater indigenous component than what is commonly accepted, the second is the existence of an African component, and the third is that research focused on a single line of ancestry shows that most people have more than one line of ancestry (Seldin et al., 2007; Corach et al., 2010; Avena et al., 2012).

Some studies demonstrate the existence of local differentiation. Acreche et al. (2004) studied human diversity in four ecological zones of the Salta Province (Puna, Valle Calchaquí, Valle de Lerma, and Chaco). They concluded that environment and topography might determine the isolation and adaptation of human populations, inducing genetic differentiation. Wang et al. (2008) reported variability within the Northwest Region, with more indigenous contribution in the north than in the south. Gómez Pérez et al. (2011) studied populations in the Jujuy province where the indigenous contribution was much greater in the highest areas, with a growing importance of European contribution when the altitude decreased. Avena et al. (2012) observed in Buenos Aires a greater European contribution in the inner city while Amerindian contribution increased in the greater conurbation (surrounding urban areas). (Table 1).

The studies conducted in the cosmopolitan populations mentioned above have employed biparental markers to estimate the population gene admixture degree, while mitochondrial DNA (mtDNA) and Y-chromosome haplogroups have allowed us to analyze the direction of gene flow. As Parolin et al. (2012: 54) write, a “major presence of Amerindian maternal uniparental lineages in relation to paternal was observed, concordantly with a scheme where the crossbreed mainly occurred between Native women with men of different origins, which has been widely observed in our country.”

There are numerous studies that characterized the genetic structure in many native populations not mentioned here (see Carnese 2011 for a review). The main lines of research of aboriginal peoples have been the study of the genetic diversity of these communities, the genetic relationships between different groups, the genetic admixtures with non-native populations, the process of prehistoric peopling, and recently, archaeological issues based on aDNA. The most used marker has been mtDNA, because its advantages include a widely proven correlation between polymorphisms and geographical origin. As already mentioned, the admixture processes had a sex-asymmetric tendency allowing the conservation of maternal lineages in high proportions, with the possibility to observe the preservation of a substantial proportion of native lineages in contemporary populations (Pauro et al., 2013). This means that by studying

TABLE 1. Parental contribution to Argentinian urban populations.

Location	Origin %			Reference
	European	African	Indigenous	
Jujuy (Northwest)	47	53	0	Alfaro et al., 2005
Salta (Northwest)	55	41	3	Alfaro et al., 2005
Salta (Northwest)	25	72	3	Wang et al., 2008
Salta (Northwest)	33	64	3	Avena et al., 2012
Tucumán (Northwest)	67	24	9	Alfaro et al., 2005
Tucumán (Northwest)	65	31	4	Wang et al., 2008
Santiago del Estero (Northwest)	46	30	24	Alfaro et al., 2005
Catamarca (Northwest)	53	37	10	Alfaro et al., 2005
Catamarca (Northwest)	53	44	3	Wang et al., 2008
Northeast	79	4	17	Corach et al., 2010
Northeast	54	5	41	Avena et al., 2012
Buenos Aires, general (Center-East)	81	16	3	Avena et al., 2001
Buenos Aires, inner area (Center-East)	79	17	4	Avena et al., 2012
Buenos Aires, 1st circle (Center-East)	80	16	3	Avena et al., 2012
Buenos Aires, 2st circle (Center-East)	68	29	3	Avena et al., 2012
Center	79	2	19	Seldin et al., 2007
Center	81	15	4	Corach et al., 2010
South	68	28	4	Corach et al., 2010
South	54	43	3	Avena et al., 2012
Puerto Madryn (South)	68	29	3	Parolin et al., 2013

the current population we can access the Native American mitochondrial lineages and likely their spatial distribution (Motti et al., 2013). Finally, several Argentine archaeological samples have been analyzed in laboratories abroad and it has been possible to compare the variability of aDNA (Dejean et al., 2014). For example, some of the B haplotypes detected in Pampa Grande (Salta province) have never been described in modern samples (Carnese et al., 2010). The first results obtained in laboratories from Argentina were recently published (Nores et al., 2011, Dejean et al., 2014).

*Chile: Native Populations and the Peopling of the Region and the Continent*

As mentioned when revising the history of genetic studies in the region, the emphasis on Chilean studies is mostly related to relatively isolated native populations and the process of the prehistoric peopling of the Americas. Among the first, the ones based on mtDNA analyses are the most numerous. Moraga et al. (2000) focused on populations from the south (the Mapuche, Pehuenche, and Yaghan), Rocco et al. (2002) on Aymaras and Atacameños (in the north), Henriquez et al. (2004) on the Changos from Poposo Cove (also in the north), and García et al. (2006) focused on populations of the Chiloé Archipelago in

southern Chile. This last study determined three clusters: the first formed by the Aymará and Atacameño, the second by the Huilliche and northern Chiloé Archipelago, and the third including the Mapuche, Pehuenche, Fueguians and the southern archipelago, confirming a North-South gradient in the frequency of haplogroup B (García et al., 2006) (Table 2). Other studies on native populations are based on nuclear DNA (nDNA), such as those testing variants of the O allele in the ABO system in the Aymara, Huilliche, and individuals with mixed ancestry from Santiago de Chile, which detected that all O alleles were O1, with O1v having the highest frequency (Llop et al., 2006). HLA was characterized in the Mapuche, and the tests detected that out of the nine most frequent alleles, five were newly discovered and one was of European origin, which conformed with an estimation of 11% European admixture in the Mapuche (Rey et al., 2013).

Several studies related to the prehistoric peopling of South America, mostly based on mtDNA from different populations. Some are focused on both Chile and Argentina (Bailliet et al., 1994; Rothhammer and Bianchi, 1995), while others are more comprehensive (Horai et al., 1993; Merriwether et al., 1995). Bodner et al. (2012) and de Saint Pierre et al. (2012a, 2012b) showed mtDNA clades located mainly in the Southern Cone of South America, such as D1j, D1g, B2i2 and C1b13, each clade



**TABLE 2.** Frequency of the main four mitochondrial DNA haplogroups in Chile modern and ancient populations).

Location or population	MtDNA haplogroup (%) <sup>a</sup>				Reference
	A	B	C	D	
Aymara (North)	7	68	12	13	Merriwether et al., 1995
Aymara (North)	7	57	18	16	Rocco et al., 2002
Atacameño (North)	12	72	11	6	Merriwether et al., 1995
Atacameño (North)	9	61	26	4	Rocco et al., 2002
Ancient, Late Archaic (North)	50	36	7	7	Moraga et al., 2005
Ancient, Middle Horizon (North)	32	42	26	0	Moraga et al., 2005
Ancient, Late Intermediate (North)	20	53	20	7	Moraga et al., 2005
Ancient, Archaic Chinchorro (North)	33	39	6	22	Rothhammer et al., 2010
Santiago1 (Center) <sup>b</sup>	7	21	33	23	Rocco et al., 2002
Santiago2 (Center) <sup>b</sup>	7	26	31	20	Rocco et al., 2002
Mapuche (South)	0	7	44	49	Moraga et al., 2000
Huilliche (South)	4	29	19	49	Merriwether et al., 1995
Pehuenche (South)	3	10	41	46	Moraga et al., 2000
Yaghan (South)	0	0	48	52	Moraga et al., 2000
Caremapu (South)	4	30	38	26	Garcia et al., 2006
Quetalmahue (South)	0	31	36	26	Garcia et al., 2006
Detif (South)	11	22	37	30	Garcia et al., 2006
Laitec (South)	0	0	36	57	Garcia et al., 2006
Ancient Fueguian (South) <sup>c</sup>	0	0	42	56	Lalueza et al., 1997
Ancient Aonikenk (South) <sup>c</sup>	0	0	39	60	Lalueza et al., 1997

<sup>a</sup> Columns may not add to 100% because of “others” not included.

<sup>b</sup> Santiago1: medium to low socioeconomic level, Santiago2: high socioeconomic level.

<sup>c</sup> From Chile and Argentina.

with a precise distribution: B2i2 and C1b13 in central and southern Chile, while D1g had the southernmost distribution, D4h3a5 in the Fuegian and Patagonian region, and D1j in northern Chile (de Saint-Pierre et al., 2012a). Recently, Chilean populations have been included in studies about the peopling of the Americas using different markers (Wang et al., 2007; Yang et al., 2010; Reich et al., 2012).

Concurrently to studies performed on living populations, others were achieved using aDNA. Moraga et al. (2005) studied chronological changes in the Lluta, Azapa, and Camarones valleys, in northern Chile, showing that all main mitochondrial haplogroups were present and concluding that haplogroup B tends to increase (from 36 to 63%) and haplogroup A to decrease (50 to 20%) from the late Archaic (Chinchorro) to the Inca period. This rate of fluctuation is even more noticeable when contemporary Aymara are considered. Lately, Rothhammer et al. (2010) showed the relationship between the Chinchorro culture (7,900–4,000 BP) and the fishermen living in Caleta Potoso along the northern coast, who are contemporary descendants of the Changos (an ethnic group which was presumed to have died out at the end of the nineteenth century).

Two other subjects are important in Chilean genetic studies: population admixture, and the genetics of complex diseases. Among the first, Acuña et al. (2002), using nDNA, found differences between high and medium-low socioeconomic status. Fuentes et al. (2014), analyzed individuals from all 15 Chilean regions using ancestry informative markers (AIMs), estimating components as 44% native, 52% European, and 4% African for the entire country (Fuentes et al., 2014, Table 2). Chilean populations were also included in a global study about admixture in Latin America based on AIMs and phenotypic characteristics (Ruiz-Linares et al., 2014), showing low regional variation and low levels of African ancestry compared to other Latin American countries, finding European ancestry higher around urban areas and a predomination of native ancestry in the south.

Finally, there is a large body of research devoted to the genetics of complex diseases, a quantity that exceeds the limits of this chapter. Such studies include those conducted by Romero et al. (2014) about mtDNA Native haplogroups and Leber's hereditary optic neuropathy, by Calaf et al. (2010) about breast cancer risk in the Aymara and the urban inhabitants of Arica, and by

Droguett et al. (2008) about HLA antigens and renal transplants in the Mapuche.

#### Uruguay: The Search for a Complex Ancestry

After an initial study performed by Sans et al. (1986) that showed an apparently large non-European component, several studies were dedicated to the determination of population admixture and the percentages of parental contributions, mainly focused on the possible native component in the genetic background of the Uruguayan population. Uruguayans based their national identity on the extermination of native populations in the first half of the nineteenth century, and only in the 1980s, after more than a century without references to the presence of natives or their descendants, have historians such as E. Acosta y Lara or R. Gonzalez-Risotto and S. Rodriguez-Varese started to review historic sources. The first study quantifying admixture components in two Uruguayan populations was based

on several classic polymorphic markers (Sans et al., 1997) (Table 3).

After the impact of demonstrating an unexpected native component (20% in the northeast), several studies were done in different regions, considering maternal components (mtDNA), paternal components (Y-chromosome), or autosomic components (classical markers and nDNA) (Table 3). For the whole country, components were estimated as 6% African, and 10% Native (Hidalgo et al., 2005), and based on AIMs, up to 48% native and up to 43% African individually (Bonilla et al., 2015). As in other countries in Latin America, the maternal native component is clearly greater than either the paternal or autosomal component. Recently, ancestry has also been related to cancer (Bonilla et al., 2015, Capetta et al., 2015) and hemoglobinopathies (Da Luz et al., 2013).

Some studies were dedicated to particular populations, such as the Basque descendants in Trinidad (central-south region) and Montevideo (south), or the present inhabitants of Bella Union

TABLE 3. Parental contribution to Uruguayan populations.

Location	Origin %			Reference
	European	African	Indigenous	
Autosomal				
Uruguay	84	6	10	Hidalgo et al., 2005
Uruguay	77	10	13	Bonilla et al., 2015
Montevideo (South)	92	7	1	Sans et al., 1997
Montevideo (South)	85	15	2	Hidalgo et al., 2014
Tacuarembó (Northeast)	65	15	20	Sans et al., 1997
Cerro Largo (Northeast)	82	10	8	Sans et al., 2006
Basque descendants (Montevideo)	88	10	2	Hidalgo et al., 2014
Basque descendants (Trinidad)	78	12	10	Hidalgo et al., 2014
African descendants (Melo)	19	62	29	Sans et al., 2002
African descendants (South)	23	47	20	Da Luz et al., 2010
Maternal: mtDNA				
Uruguay	58	8	34	Pagano et al., 2005 <sup>a</sup>
Uruguay	56	8	37	Bonilla et al., 2015
Montevideo (South)	n/d	n/d	21	Gascue et al., 2005
Tacuarembó (Northeast)	21	17	62	Bonilla et al., 2004
Cerro Largo (Northeast)	49	21	30	Sans et al., 2006
Bella Unión (Northwest)	30	6	64	Sans et al., 2015
Basque descendants from Trinidad (Center-South)	78	2	20	Sans et al., 2011
African descendants from Melo (Northeast)	39	52	9	Sans et al., 2002
Paternal: Y-chromosome				
Uruguay	>98	<1	<1	Pagano et al., 2005 <sup>b</sup>
Tacuarembó (Northeast)	>92	>1	2 to 8	Bertoni et al., 2005
African descendants from Melo (Northeast)	30	54	6	Sans et al., 2002

<sup>a</sup> Modified from Pagano et al. 2005a.

and its neighboring region, in the northwest, founded in 1829 with indigenous groups brought from the Jesuit missions (Sans et al., 2011, 2015). Self-identifying African descendants were studied in Montevideo and in the northeast, showing different paternal components: in both regions, African genes contributed nearly half of the ancestry (39–52% respectively), but the indigenous components vary from 20% in the south to 29% in the northeast (Sans et al., 2002; Da Luz et al., 2010).

A last point to mention is the use of aDNA from skeletal remains, mainly mtDNA. Recently, haplogroup C1d3—defined by van Oven and Kayser (2009) based on a contemporary Uruguayan—was also detected in individuals buried in a mound from eastern Uruguay (the most ancient dated to 1610±46 BP) and probably in the Charrúa Chief Vaimaca Perú (ca. 1780–1833), showing the continuity of this lineage from prehistory to the present (Figueiro et al., 2011; Sans et al., 2012).

*Paraguay: Native Populations and the Point of View from the Outsiders*

Contrary to the other countries in the region, with the exception of Bolivia, most Paraguayan population studies were conducted by researchers from other countries, and the majority of them focused on native populations. A series of these studies is related to human viruses, mostly in native populations. While Paraguayan population studies not related to diseases are rare, there are some, mainly in reference to natives living in the Chaco. Goicoechea et al. (2001) analyzed several genetic systems among the Ayoreo and Lengua, noting differences with other South American native populations, while Catanesi et al. (2007) included STR markers. Dornelles et al. (2004) studied Alu inserts and mtDNA in Ayoreo, and Kohlrausch et al. (2005), analyzed STRs in Ayoreo, Ache, and the Brazilian Surui. HLA was analyzed among Angaité (Aida et al., 2002) and Guarani from southeastern Paraguay, and then compared with Paraguayan “mestizos” (Benitez et al., 2011). This last study was uniquely focused on admixture and concluded that mestizos were more closely related to the Spanish than to the Guarani.

The most studied Paraguayan native population is the Ache (also known as Guayaki), who live in the eastern part of the country. Demarchi et al. (1999, 2005) studied apolipoprotein B, Wilbur et al. (2007) analyzed the vitamin D receptor gene polymorphisms and their relationship with the susceptibility to tuberculosis, and R. G. Bribiescas published several studies with his colleagues, mainly focused on evolutionary biology, endocrinology, reproduction, and metabolism (Amir et al., 2015). The peculiarities of the Ache are not only genetic, as shown in “It’s a wonderful life” (Gurven et al., 2000). The title refers to food sharing in this foraging-agricultural society, or their longevity in juxtaposition to the theory of non-adaptative aging (Libertini, 2013). But the main reason their genetic systems have been so frequently analyzed is related to their unclear origin and their relationships with other native groups. Battilana et al. (2002)

concluded that the Ache cluster separately from the Caingang and the Xavante, with the Guarani in an intermediate position, emphasizing the striking genetic distinctiveness of the Ache. Tsuneto et al. (2003) mentioned that the Ache are most closely related to the M’byá-Guaraní, while Schmitt et al. (2004) emphasized the differences and reduced mtDNA variability as compared to other indigenous South American groups, debating if these peculiarities already existed in their founding populations or were acquired after a long period of isolation in the forest. Finally, Callegari-Jacques et al. (2008) reviewed the genetic information on this population focusing on two aspects: (a) the distinctiveness in relation to the general pattern of Amerindian genetic data; and (b) the reduced genetic variability within the population. According to the authors, the Ache seem to descend from the Tupi-Guarani but with some degree of Jê admixture, especially when the maternal component is considered.

*Bolivia: Native Communities from the Highlands and Lowlands*

Native communities in Bolivia have been widely studied, particularly in the highlands and especially in Quechua communities (Luiselli et al., 2000). Recently, several studies of Aymara and Quechua communities have been conducted: Gaya-Vidal et al. (2010) also included Peruvian Quechua, showing that Bolivian samples (Aymara and Quechua) have high genetic similarity and were clearly differentiated from the Peruvian Quechua. This fact suggests that the Quechua language expansion in Bolivia took place without any important demographic component of Quechua speakers migrating from Peru into Bolivia. In the same sense Batai and Williams (2014) mentioned that in the Bolivian highlands, geography correlates better with mtDNA variation than with language, and the Aymara and Quechua are virtually indistinguishable from each other. Another related topic is the origin of the Uros. Using Y-chromosome and mtDNA data, Sandoval et al. (2013) indicated that these populations appear more closely related to the Aymara and Quechua from Lake Titicaca and surrounding regions than to the Amazonian Arawaks. The Andean–Amazonian boundary is a region of interest because the genetic diversity observed there is higher than that observed in the highlands. Moreover, results show that Amerindian populations living in the Piedmont are genetically more related to those in the Andes than in the Amazonian populations (Corella et al., 2007).

At a national level, Taboada-Echalar et al. (2013) have studied the three main regions of the country: Andean, Sub-Andean, and the Llanos (including Amazonia). The vast majority of the Bolivian mtDNA components (98.4%) were found to belong to the main indigenous haplogroups. However, the analysis of AIMs revealed a higher European introgression in Bolivians (25%), especially in the sub-Andean and Llanos regions.

Finally, Bolivians with African descent have been poorly studied. The populations in the region of Nor Yungas have a

strong African ancestry, displaying infrequent interbreeding with either indigenous groups or Europeans, mainly by paternal lineage (Iudica et al., 2014).

## FINAL CONSIDERATIONS

In sum, the different histories of each country have shaped the aims of past and present genetic studies. Despite the differences, the incorporation of molecular techniques has facilitated and increased the possibilities of analysis, and they are applied to a broad quantity of subjects within the five countries. In the future, it is expected that the use of molecular techniques will increase. However, financial aid, research, state politics (for example, whether population samples may be sent for analysis in other countries), and ethics (especially when studying indigenous or minority groups), will determine the type of results obtained. One example of this can be found in the strategies used to obtain entire genomes: while population samples from Perú and Colombia have been included in public databases such as 1000 Genomes, the five countries in the Southern Cone region are not part of that project. Moreover, some of these countries are making their own efforts (such as Chile, Uruguay, and Argentina, but that data had not yet been published by the time this article was written).

Besides entire genomes, the analysis of entire mitogenomes is gaining importance in this region, as it allows understanding population movements in different scales (local, regional, and also continental). As discussed earlier, the use of clades with precise distribution facilitates the understanding of migrations. At present, a greater percentage of these mitogenomes belong to native populations (or paleo-American mtDNA haplogroups), with few exceptions. Probably this tendency will continue, but other populations (such as those with cosmopolitan or African ancestry) also will be included in the studies.

One last remark related to the characterization of populations is the interest that new immigration patterns present, as the region continues to receive individuals and families from abroad. As in the past, these migrants could modify, in one or more generations, the characteristics of current populations.

Finally, the characterization of the populations in these five countries, in view of its tripartite (or more complex) origin, contributes to medical research in genetic and complex diseases. As post-genomic medicine includes not only genomes but other omic levels in which population data are scarce, the incorporation or augmentation of this information into population studies will present new challenges.

## ACKNOWLEDGMENTS

The authors thank Dr. Rafael Bisso-Machado for translating the Portuguese abstract.

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# Bioarchaeology in the Southern Cone of South America: The Pampas, Patagonia, and Uruguay

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**ABSTRACT.** The aim of this chapter is to present the historical development and current status of research in bioarchaeology in a sector of the Southern Cone of South America. The areas under consideration are the Pampas and Patagonia regions (Argentina) and Uruguay. This chapter analyzes the historical background of biological anthropology in these regions since the late nineteenth century to the present day, and reviews the local archaeological sites with human remains. From the perspective of these aspects (history of the discipline and characteristics of the bioarchaeological record), we discuss some trends linked with the use of specific places for burial purposes. In particular, we focus on changes in the frequency and distribution of the burial sites in space and time, and changes in the modes of burial and the persistent use of certain locations.

**RESUMEN.** El objetivo de este capítulo es dar a conocer el desarrollo histórico y el estado actual de la bioarqueología en un sector del Cono Sur de Sudamérica. Se consideran las regiones Pampeana y Patagónica (Argentina) y la República Oriental del Uruguay. Para cumplir con este objetivo se analizarán por una parte los principales antecedentes sobre la bioantropología desde fines del siglo XIX hasta la actualidad y por otra se presentarán los sitios arqueológicos con restos humanos procedentes de las tres regiones. A partir de estos aspectos (antecedentes y características del registro bioarqueológico) como siguiente paso metodológico se discutirán algunas tendencias vinculadas con: los cambios en la frecuencia y distribución de los sitios con inhumaciones en cada región, las variaciones en las modalidades de entierro y la persistencia en el uso de los lugares con fines inhumatorios.

**RESUMO.** O objetivo deste capítulo é apresentar o desenvolvimento histórico e a situação atual da bioarqueologia num setor do Cone Sul da América do Sul. Portanto, se contemplam as regiões Pampeana e Patagônica (Argentina) e a República Oriental do Uruguai. Para cumprir com esse objetivo se analisaram por um lado os principais antecedentes sobre a bioantropologia desde o final do século XIX até a atualidade e, por outro, se apresentarão os sítios arqueológicos com restos humanos procedentes das três regiões. A partir destes aspectos (antecedentes e características do registro bioarqueológico), como seguinte passo metodológico se discutirão algumas tendências ligadas com: as diferenças na frequência e distribuição dos sítios com inumações em cada região, as variações nas modalidades de enterro e a persistência no uso dos lugares com funções funerárias.

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

## INTRODUCTION

In the Southern Cone of South America, biological anthropology and archaeology had an early beginning at the end of the nineteenth century. The development of these fields during the twentieth century was uneven, however, and they contributed to the assessment of past populations only in a secondary way. It was not until the end of the twentieth century that bioarchaeology, as a new field of research, started to play an important role in the understanding of prehistoric groups.

Bioarchaeology, a relatively new field, was proposed in the 1970s with the aim of studying human remains in relation to their archaeological context (Larsen, 1987; Wright and Yoder, 2003). The biocultural approach served as a conceptual framework within which the first studies were generated (Bush and Zbevel, 1991; Dressler, 1995; Boyd, 1996). The main goal of this perspective was to comprehend the relationships between human populations, culture, and environment. Through this lens, bioarchaeology was delimited as an inter- and intradisciplinary field of research (Buikstra, 1981; Larsen, 1987). Bioarchaeology addresses the formation processes that act on human remains, as well as the demography, biological relations, health and disease patterns, physical activity, nutrition, growth, and development of the populations that left the remains. By applying the framework of bioarchaeology, researchers can gain a deeper understanding of the adaptation and evolution of past human populations. From this perspective, human remains cease to be an appendix of a parallel archeological history and become an integrated component of archaeological reports.

Within the Southern Cone of South America, in the last two decades of research in the Pampas and Patagonia regions of Argentina and in Uruguay, both local and regional archaeological problems have been addressed in conjunction with theoretical and methodological issues. As a result, studies have diversified, a variety of topics make up the research agenda, and the number of specialists working in subjects related to bioarchaeology has increased considerably (Luna et al., 2014).

The goal of this chapter is to present the development and current state of bioarchaeology in three regions of the Southern Cone of South America: Pampa and Patagonia, in Argentina, and Uruguay. First, the main foundations of biological anthropology in the region from the late nineteenth century to this day will be considered. Then, a summary of the spatial and temporal distribution of archaeological sites with human remains will be presented. The area considered in this work is large, with an important environmental variability. It spans approximately from 30° to 55°S and from 75° to 55°W (Figure 1). Finally, we will present a synthesis of the tendencies in terms of frequency and distribution of sites with human remains in each region, the variations in mortuary practices, and the persistence of the use of particular locations for burial purposes.

The Pampas region is located in east-central Argentina and includes the provinces of Buenos Aires, southwestern La Pampa, southern Entre Ríos, and Santa Fe. It is a large plains region with

grassland vegetation, interrupted only by two mountain ranges: Tandilia and Ventania. For the sake of organizing the discussion, we chose to divide the region into two main subregions following Berón and Politis (1997): Humid Pampa (*Pampa Húmeda*) and Dry Pampa (*Pampa Seca*). The Humid Pampa is divided into eight areas: Paraná Delta, North, Salado Depression, West, Tandilia, Ventania, Interserrana (an area comprising the plains between Tandilia and Ventania), and South. The South and Delta areas are ecotonal zones that combine features of the Pampas region with Patagonia and northeastern Argentina, respectively. Although certain authors consider four areas for the Dry Pampa, we have chosen to treat it as a single, undivided unit.

Uruguay will be treated as a separate region, as its bioarchaeological record and the historic development of the discipline in the country show unique characteristics. However, it is usually included as a part of the Pampas region, together with the neighboring Brazilian state of Rio Grande do Sul, both from a biogeographical (Cabrera and Willink, 1973; but see Haretche et al., 2012) and an archaeological standpoint (Politis, 2008). Within Uruguay, the location of human remains allows us to distinguish three areas: East (Atlantic coast and the Leguna Merin basin), West (along the coast of the Uruguay River), and South (along the coast of the La Plata River). Most of the evidence is located in the East and West areas.

The Argentinean Patagonia occupies a wide region that spans the provinces of Neuquén, Río Negro, Chubut, Santa Cruz, and Tierra del Fuego. It harbors a diversity of environments where the greatest variability is found from west to east in an altitudinal gradient, from heights of 3,800 meters above sea level in the Andes, down to the Atlantic coast. This is also the direction of flow of the main Patagonian rivers (e.g., Colorado, Negro, Chubut, Deseado, Coyle, and Gallegos), which are also the main sources of fresh water. The rivers interrupt the interconnected basaltic plateaus of Somuncurá and Deseado; these volcanic structures span from the Colorado River in the north to the area south of Santa Cruz, where they are replaced by glacial formations (Codignoto and Malumian, 1981). Based on these variables (e.g., altitude, fresh water availability, and geology) three main environments can be defined for Patagonia: forest, steppe, and coast. We present the information based on four quadrants: northwest, northeast, southeast, and southwest, and treat Tierra del Fuego as a separate area. The Chubut River acts as the boundary between north and south, while the basaltic plateaus divide east and west.

## FOUNDATIONS OF BIOARCHAEOLOGICAL STUDIES IN THE REGION

The development of biological anthropology in Argentina can be divided into several periods, each of which was dominated by distinct theoretical frameworks that guided the questions to be asked and the methods and techniques to be applied (Carnese et al., 1991–1992; Carnese and Pucciarelli, 2007). In Uruguay,

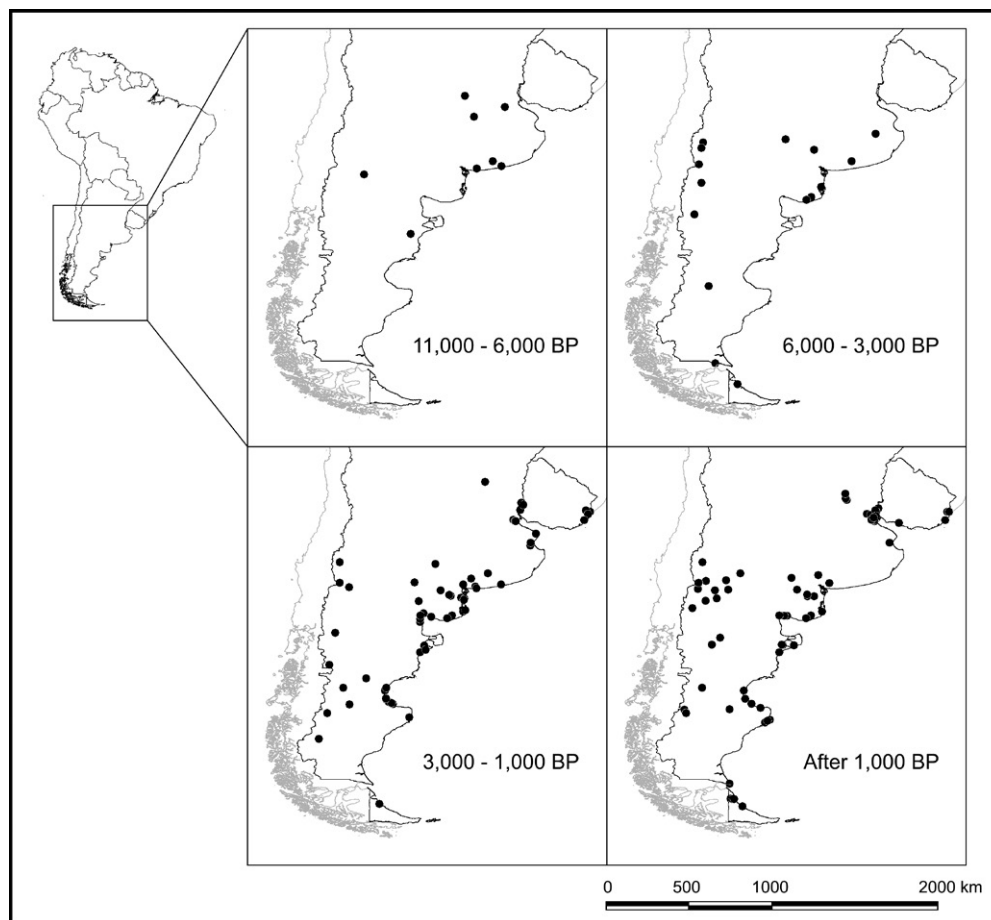


FIGURE 1. Spatial and temporal distribution of the bioarchaeological record in Pampa, Patagonia, and Uruguay.

anthropology as an academic discipline was not established until 1976, however the few studies carried out since the end of the nineteenth century fit, albeit with less volume and development, in the same succession of paradigms found in Argentina.

During the second half of the nineteenth century, studies in biological anthropology were carried out in an evolutionary framework. The methodology in anthropology—a field that had recently separated from the natural sciences—was focused on the description and classification of human remains with the aim of determining the antiquity of the first human beings in the territory (Ameghino, 1880, 1889; Lehmann Nitsche, 1907).

Florentino Ameghino was one of the most important researchers, whose work stimulated the growth of anthropological sciences in the region. In *La Antigüedad del Hombre en el Plata* (1880) he argued in favor of the great antiquity of humans in the Pampas region; later he would propose the autochthonous origin of man in America. Although his hypothesis was severely criticized, particularly by A. Hrdlička et al. (1912), it had the merit of spurring interest in archaeological studies (Carnese

and Pucciarelli, 2007; Politis and Bonomo, 2011). Various institutions promoted research on the antiquity and authenticity of the findings made in Argentina. Pursuing this goal, Zeballos and Moreno, among others, participated in the compilation of anthropological collections (Podgorny 2007). The development of institutions and the increase in activity of both Argentinean and foreign researchers led to the consolidation of biological anthropology as a scientific discipline in Argentina (Carnese et al., 1991–1992). In Uruguay the only work related to anthropological research in this period was carried out by José H. Figueira, describing the burials found in earthen mounds in the east. In a final note in this monograph, he advances the intention of publishing a “Craniological [and] anthropological examination” of the remains (Figueira, 1892: 219) which was ultimately never written.

In the 1920s, when evolutionary ideas were discredited in anthropology (Carnese et al., 1991–1992; Carnese and Pucciarelli, 2007), a “typological” paradigm took hold, its main goal being to ascribe human remains to various “races” proposed

through physical traits. Morphological analysis and the measurement of the skeletons were a fundamental part of the research protocol. In Pampa and Patagonia cultural change was explained in a cultural–historical framework (Imbelloni, 1938; Bórmida, 1964). From this perspective, races were discrete entities that did not undergo change; their variation through time was explained by mechanisms of migration and diffusion (Neves, 1984). One of the major representatives of this school of thought was Italian anthropologist José Imbelloni, who generated a racial taxonomy and made important contributions to the study and classification of artificial cranial deformation in America (Imbelloni, 1924–1925).

The typological perspective with an emphasis on metric studies is also noted in Uruguayan research conducted during the same decade. Of particular importance is the work of J. I. Muñoa (1954), who was influenced by Imbelloni's classification. Muñoa carried out an osteometric and craniometric analysis of prehistoric remains from eastern Uruguay and established a sequence for the peopling of Uruguay, published posthumously (Sans, 1997a, 1997b).

Starting in the 1960s and gaining momentum in the 1970s and 1980s, biological anthropology gradually adopted a neo-Darwinian evolutionary framework which focused on genetic affinities between individuals and populations and abandoned the concept of race with regard to the human species. The basis for this new paradigm was S. Washburn's "New Physical Anthropology;" its focus shifted from an essentialist view of "type" (which saw variation as unimportant) to variation itself, and the unit of analysis turned to the population (Washburn, 1951; Carnese and Pucciarelli, 2007). This new framework for biological anthropology considered variation in morphology as the result of genetic and environmental factors, and that mechanisms such as genetic drift, natural selection and mutation played an important role in population change through time. The use of multivariate statistical analysis was implemented together with the mentioned shifts in methodology. Finally, by the end of the twentieth century, two important changes took place within the paradigm in the discipline. The human body started to be viewed as an open system, which adjusted in response to different stimuli (Neves, 1984). The second change was the emphasis of socio-cultural factors on the biology of populations (Boyd, 1996; Carnese and Pucciarelli, 2007). These changes, together with the development of processual archaeology, were fundamental to the emergence of bioarchaeology as a separate field of study. It is worth mentioning that, beginning in 1970, H. Pucciarelli formally introduced experimental studies in Argentinean biological anthropology.

During the 1980s and 1990s, R. Guichón made a series of significant contributions to bioarchaeology in the Patagonian region, carrying out biological characterizations of the paleo-American populations of the area through the use of such novel techniques as stable isotope and experimental analyses. From the late 1990s up to the present day, studies in biological anthropology and bioarchaeology in Patagonia have shown an exponential rise. G. Barrientos' doctoral dissertation (1997), which focused

on the Pampas region, is an example of the application of a bioarchaeological perspective.

In Uruguay, the adoption of population analysis to achieve a biocultural approach came with the establishment of anthropology as an academic discipline, with M. Sans taking a leading role in the creation of the Biological Anthropology department of the University of the Republic (Universidad de la República). The staff carried out a series of studies of past populations, and in 1986, the systematic survey of skeletal remains found in public and private collections throughout the country. This survey deserves particular mention due to the comprehensive goals it set out to achieve: "to estimate . . . sex and age, [and] analyze genetic, epigenetic and environmentally induced traits that will allow for the characterization of the populations and [their] comparison. We also seek to link the data obtained with the geographic location, features of the archaeological sites, associated industry, approximate chronology, means of subsistence, and environment" (Sans, 1988: 2–3). Skeletal analyses in a bioarchaeological framework (although no actual mention of bioarchaeology as such was ever made) gained impulse with the recovery of well-preserved remains and their archaeological contexts in eastern Uruguay in the 1980s and 1990s, which led to a proliferation of studies related to their analysis (Sans and Solla, 1992; Sans et al., 1997; Portas, 1999; Sans, 1999; Bracco et al., 2000; Sans and Femenías, 2000; Calabria, 2001; Bertoni et al., 2004, among others). It should however be noted that the integration of human remains into archaeological analysis beyond purely funerary aspects is still a pending issue in Uruguayan archaeology.

## THE ARCHAEOLOGICAL RECORD THROUGHOUT THE HOLOCENE

The following section is intended to present the empirical context of the available bioarchaeological evidence in each of the three regions considered in this chapter, which also conveys a picture of the amount of research made in each case (Figure 1). Only sites with radiocarbon dates on human bone or associated contexts are considered. It should also be pointed out that human remains in Uruguay are dated to the late Holocene; therefore, the description of the early and middle Holocene records is restricted to findings in Argentina.

The majority of sites mentioned are the result of research efforts carried out in the last 20 years; nonetheless, in more recent years, the study of skeletal collections from earlier stages of the discipline has been undertaken. Examples of these collections are the remains recovered from the sites Túmulo de Malacara, Paso Mayor Y1S2, Arroyo de Frías, and Arroyo Fredes; the collections gathered by Moreno (lower Negro River valley, now curated at the Museum of La Plata [MLP]), Cremonessi and Pozzi (lower Chubut River valley, curated at MLP), the Rada Tilly collection (curated at the Rada Tilly Regional Museum, Chubut), the Antonio Garcés collection (Museum of Comodoro Rivadavia), and

**TABLE 1.** Frequency of sites with burials in the Pampa region according to subregion and geographical area. Abbreviations: B.P.: before present; H.P.: Humid Pampa; D.P.: Dry Pampa; DEL: Delta; N: North; W: West; SD: Salado Depression; I: Interserrana; V: Ventania; T: Tandilia; S: South.

Chronology (Years B.P.)	H.P. Subregion								D.P. Subregion	Total
	DEL	N	W	SD	I	V	T	S		
11,000–6,000	0	2	1	0	7	0	0	1	0	11
6,000–3,000	0	0	1	1	1	0	0	2	1	6
3,000–1,000	7	1	1	2	6	0	0	7	3	27
<1,000	18	0	0	2	1	0	0	4	4	29
<b>Total</b>	<b>25</b>	<b>3</b>	<b>3</b>	<b>5</b>	<b>15</b>	<b>0</b>	<b>0</b>	<b>14</b>	<b>8</b>	<b>73</b>

the collections gathered by Francisco Oliveras and Carlos Maeso Tognochi (National Museum of Anthropology, Montevideo) and Carlos Seijo (National History Museum, Montevideo). Data are being gathered from these materials within the framework of bioarchaeology.

Between 11,000 and 8,000 B.P., the sites with human remains in Argentina are few. Knowledge about these first populations is based mainly on other remains left by them in their everyday activities, such as tools and food remains.

For this period, four sites with human skeletons are known in the North, West and Interserrana areas of the Pampas region, all containing primary burials. The earliest remains are found in Arroyo de Frías and Laguna El Doce in the North. In the former, a skeleton dated to between  $10,300 \pm 60$  and  $9,520 \pm 75$  B.P. was recovered (Politis and Bonomo, 2011; Politis et al., 2011). In Laguna El Doce 19 individuals were excavated, and a date of  $8,274 \pm 68$  B.P. was obtained from one of the skeletons (Ávila and Ceruti, 2013). In the West, at least nine individuals were recovered from Laguna de los Pampas, dated to between  $8,971 \pm 77$  and  $8,835 \pm 83$  B.P. (Politis et al., 2012). Finally, El Guanaco 2 is the only site with human remains found in the Interserrana area; the two individuals recovered were dated to between  $8,433 \pm 84$  and  $8,123 \pm 82$  B.P. (Flegenheimer et al., 2010) (Table 1).

Although evidence of human occupation is found in Patagonia dating to the Pleistocene–Holocene transition, the earliest sites with burials are dated to the early Holocene. To date, only one site has been identified in Cueva Epullán Grande, in the Limay river basin (province of Neuquén, northwestern Patagonia). The remains of four individuals were recovered and dated to between  $9,970 \pm 100$  and  $7,550 \pm 100$  B.P. (Crivelli Montero et al., 1996) (Table 2). Evidence of slightly earlier occupations on the Chilean side of the Andes (Dillehay and Pino, 1997) should be mentioned.

Between 8,000 and 6,000 B.P., there is an increase in the bioarchaeological record, which allows us to gather deeper knowledge about the populations of this period (Tables 1 and 2). In the Pampas region, evidence is found in the Interserrana and South areas, especially in sites located near the coast. For this

**TABLE 2.** Frequency of sites with burials in Patagonia according to region. Abbreviations: B.P.: before present; NW: Northwest; NE: Northeast; SW: Southwest; SE: Southeast; TF: Tierra del Fuego.

Chronology (Years B.P.)	NW	NE	SW	SE	TF	Total
11,000–6,000	1	0	0	0	0	1
6,000–3,000	6	2	1	1	1	11
3,000–1,000	6	15	7	9	1	38
<1,000	10	13	6	8	4	41
<b>Total</b>	<b>23</b>	<b>30</b>	<b>14</b>	<b>18</b>	<b>6</b>	<b>91</b>

period, primary burials persist and the first evidence of secondary burials appears (Scabuzzo and Politis, 2011). In the Arroyo Seco 2 site in the Interserrana plains, the two earliest interment events comprise primary and secondary, with both individual and collective burials of at least 24 skeletons of various ages. Arroyo Seco 2 is the site with the largest number of burials in the region for this period, with a chronology spanning from  $7,805 \pm 85$  to  $6,300 \pm 70$  B.P. (Politis et al., 2014). In the Interserrana coast, the remains from five sites—Chocorí, La Tigra (Politis et al., 2011), Meseta del Chocorí, Necochea, and Arroyo del Moro (Bonomo et al., 2013)—have been studied. Some of them come from museum collections, and at the time of their discovery, were key elements in the debate over the Tertiary antiquity of man in the Americas initiated by F. Ameghino (Politis and Bonomo, 2011; Politis et al., 2011).

These findings contributed new information about the bioarchaeological record between  $7,623 \pm 78$  (Meseta del Chocorí) and  $6,885 \pm 73$  B.P. (Arroyo El Moro; Bonomo et al., 2013). All are primary burials, found in numbers from one to five individuals per site. Finally, in Monte Hermoso 1 in the South, two individuals were recovered, dated to between  $7,866 \pm 75$  and  $6,606 \pm 79$  B.P. Both are represented by a small number

of fragments, which precluded the determination of the type of interment (Politis et al., 2009).

Between 6,000 and 3,000 B.P., there is a slight decrease in the number of sites with human remains in the Pampas region—only six sites are registered (Table 1)—but their distribution widens; the earliest burial places in the Salado River depression and the Dry Pampa date to this period. All sites have a low density of burials, all of them primary. In Arroyo Seco 2, three individuals were buried with a chronology of between  $4,793 \pm 69$  and  $4,487 \pm 47$  B.P. (Politis et al., 2014). In the Salado Depression, the Laguna La Colorada site yielded three burials dated to  $3,140 \pm 60$  B.P. (Murgo and Aldazabal, 2007). In the West, six individuals were recovered from Laguna Chadilauquen, two of them dated to between  $3,714 \pm 56$  and  $3,629 \pm 56$  B.P. (Mendonça et al., 2013). In the South, three individuals were recovered in the site of Cantera de Rodados Villalonga and dated to between  $4,889 \pm 58$  and  $4,100 \pm 80$  B.P. (Martínez et al., 2012). In Laguna de Puán 1, also in the South, an individual dated to  $3,330 \pm 100$  B.P. was found (Oliva et al., 1991). Finally, in the Dry Pampas, the remains of five individuals were excavated in the site Loma Chacalcó, which were dated to  $3,040 \pm 100$  B.P. (Berón et al., 2009).

In Patagonia, there is an increase in the number of burial sites dated to 6,000–3,000 B.P., distributed in all four areas (Table 2). The earliest site for the period is Chacra 375, located in the Chubut River valley in the Northeast, with a date of  $6,070 \pm 50$  B.P. (Gómez Otero and Dahinten, 1997–1998). On the other hand, in northern Tierra del Fuego, the remains found at the site of La Arcillosa 2 were dated to  $5,205 \pm 58$  B.P. (Salemme et al., 2007). In northwestern Patagonia, human remains found in Cueva Chenque Haichol were dated to a sequence starting at  $5,650 \pm 70$  B.P. (Fernández and Panarello, 1990; Kozameh and Barbosa, 1992). In the southwest, Gradín and Aguerre (1994) published the date of a plant spicule on a skeleton recovered in El Rodeo, in the middle Pinturas River, with an age of  $4,860 \pm 150$  B.P.

In the province of Neuquén, in northwestern Patagonia, two important burial sites were identified, dated to between 4,000 and 3,000 B.P. The sites, named Aquihuecó and Hermanos Lazcano, yielded an unusual number of individuals for hunter-gatherer groups. Aquihuecó (located in Chos Malal, Neuquén) was dated to between 4,200 and 3,500 B.P., and the minimum number of individuals has been estimated at 80 (Gordón 2016, personal communication). The site is located in a sand-dune on the Curi Leuvú River Valley (Neuquén Province, Northwestern Patagonia). It contains several primary (single and multiple) burials of individuals of both sexes and various age groups. Burial goods were identified, consisting of shell necklaces and milling implements. The burials were marked with vertical, rectangular rocks, and most individuals had circular cranial deformation (Della Negra and Novellino, 2005; Perez et al., 2009). Hermanos Lazcano (also in Chos Malal) was dated to  $3,780 \pm 50$  B.P. It is located near Aquihuecó, in a similar dune, but with a different taphonomy (that is, process of bone decay). Twelve individuals (eight adults and four subadults) were identified, with

a substantially poorer preservation than the Aquihuecó burials (Vázquez and D'Abramo, 2013; Della Negra et al., 2014). The earliest sites in southeastern Patagonia are dated to just before 3,000 B.P. (Orejas de Burro 1;  $3,565 \pm 45$  B.P., L'Heureux and Barberena, 2008), as are the earliest burial sites in the lower Negro River valley along the north coast (ancient Laguna del Juncal,  $3,272 \pm 53$  B.P., Gordón, 2011) and in west-central Patagonia (Población Anticura site,  $3,180 \pm 30$  B.P., Fernández and Rizzo 2009; Rizzo 2013) (Table 2).

Between 3,000 and 1,000 B.P., the bioarchaeological record grows significantly both in Pampa and in Patagonia (Tables 1 and 2). Human remains in archaeological sites in Uruguay are also dated to this period (Table 3).

In the Pampas region, 27 sites with burials are known for this time period. Burials are found in all areas with the exception of the Ventania and Tandilia ranges. On the other hand, the earliest interments in the Paraná Delta date to this period, and there is an important increase in the number of sites with burials in the South area (Table 2).

In the North, remains of an individual in the San Clemente III site were dated to  $1,550 \pm 90$  B.P. (Paleo et al., 2002). In the Salado Depression, the bioarchaeological record comes from La Guillerma Ñandú, where cranial fragments of at least one individual were recovered and dated to  $1,640 \pm 40$  B.P. (González, 2002), and from the Laguna La Salada site, which consists of seven primary burials dated to  $1,470 \pm 50$  B.P. (Murgo and Aldazabal, 2007). In the West, in the Chillhué site, a female individual with artificial cranial deformation was recovered and dated to  $1,930 \pm 30$  B.P., (Berón et al., 2009).

In the Interserrana area six sites with human remains have been found: Túmulo de Malacara ( $2,710 \pm 40$  B.P., Politis et al., 2011), Laguna Tres Reyes (between  $2,470 \pm 60$  and  $2,245 \pm 55$  B.P., Madrid and Barrientos, 2000), El Guanaco 1 (between  $2,280 \pm 30$  and  $2,470 \pm 60$  B.P., Mazzia et al., 2004), La Toma ( $2,075 \pm 70$  B.P., Madrid and Politis, 1991), Laguna La Salada Grande ( $2,470 \pm 60$  B.P., Bonomo et al., 2013), and La Pandorga ( $1,990 \pm 90$  B.P., Bonomo et al., 2013). In these sites, the

TABLE 3. Frequency of sites with burials in Uruguay according to area.

Chronology (Years B.P.)	East	West	South	Total
2,000–1,200 <sup>a</sup>	4	3	0	7
<1,200	4	0	1	5
Total	8	3	1	12 <sup>b</sup>

<sup>a</sup> Although chronologies for sites older than 2,000 B.P. are assigned to some recovered burials, these chronologies are context based, so it is prudent to place these burials into the oldest group dated according to bone.

<sup>b</sup> This total differs from the 25 sites with human remains detailed in Figueiro (2014) because most sites still lack radiocarbon dates.

density of burials ranges from one to 13 individuals per site; most burials are primary, although secondary burials are found in El Guanaco 1 and Túmulo de Malacara. The increase in the number of burial sites is also noted in the South area where seven sites are registered: Villa Sapito (2,306 ± 41 B.P., Scabuzzo et al., 2016), Laguna del Toro (2,369 ± 52 B.P., Scabuzzo et al., 2016), Laguna del Sauce (1,959 ± 42 B.P., Scabuzzo et al., 2016), La Primavera (between 2,882 ± 49 and 2,728 ± 48 B.P., Martínez, 2010), Zoko Andi 1 (1,438 ± 50 and 1,350 ± 41 B.P., Martínez et al., 2014), El Puma 2 (1,548 ± 51 B.P., Martínez et al., 2012), and San Antonio (1,053 ± 53 B.P., Martínez and Martínez, 2011). The number of burials in each of these sites range from one to ten individuals. Although most burials are primary, in Zoko Andi 1 secondary burials and bone arrangements were recorded (Martínez et al., 2014). In the Dry Pampa, the known sites with human remains are La Lomita (2,960 ± 50 B.P., Luna, 2008), Tapera Moreira 3 (2,630 ± 60 B.P., Berón, 2013), and Médano La Enriqueta (1,005 ± 25 B.P., Carrera Aizpitarte et al., 2013). Each of these sites holds between two and nine individuals, and in two sites, the presence of primary burials could be determined. Finally, in the Paraná Delta seven sites with human remains have been excavated: Anahí (1,020 ± 70 B.P., Loponte, 2008), Las Vizcacheras (between 1,090 ± 40 and 1,070 ± 60 B.P., Loponte, 2008), La Bellaca 1 (1,110 ± 70 B.P., Loponte, 2008), Garín (1,060 ± 60 B.P., Loponte, 2008), Arroyo Sarandí (1,290 ± 40 B.P., Loponte, 2008), Túmulo de Campana (between 1,754 ± 49 B.P., and 1,600 ± 20 B.P., Politis and Bonomo, 2015; Loponte and Acosta, 2015) and Paraná Ibicuy I (between 1,810 ± 70 and 1,480 ± 70 B.P., Del Papa et al., 2015). Most of the burials are primary in this area as well, with the exception of Arroyo Sarandí, where secondary burials are also found. An important innovation in this area is the construction and use of artificial mounds, which show evidence of domestic as well as funerary activities.

Twenty-nine sites with burials have been dated in the Pampas region to between 1,000 and 400 B.P., in the following areas: Salado Depression, Interserrana, South, Paraná Delta, and Dry Pampa. In the Salado Depression, in two sites at La Guillerma, the remains of five individuals were recovered and dated to between 430 ± 40 and 370 ± 40 B.P. (González, 2002). The evidence found in the Interserrana area consists of a primary burial dated to 579 ± 42 B.P. from the Laguna Seca 1 site (Kaufmann and González, 2013). In the South, there is a decrease in the number of sites for this period, and only four are known: Laguna Los Chilenos 1 (470 ± 40 B.P., Barrientos et al., 2002), Paso Mayor Y1S2 (700 ± 42 B.P., Bayón et al., 2010), La Petrona (between 770 ± 49 and 248 ± 39 B.P., Flensburg et al., 2011), and Paso Alsina 1 (between 570 ± 44 and 446 ± 44 B.P., Martínez et al., 2007). The density of burials varies from seven individuals in Paso Mayor Y1S2 to 56 in Paso Alsina 1. A remarkable combination of primary and secondary burials is observed in most of the sites, with the exception of Paso Alsina 1 where all are secondary burials. In the Dry Pampa, four sites with human remains are known. Médano Petroquímica yielded dates between

393 ± 41 and 378 ± 41 B.P., and Puesto Hernández was dated to between 896 ± 58 and 823 ± 41 B.P. (Mendonça et al., 2010). In these sites, both primary and secondary burials were recovered, with a minimum number of 23 individuals in the former (Mendonça et al., 2010). In the third site, Don Aldo 1, the primary burial of one individual was excavated and dated to 780 ± 45 B.P. (Prates et al., 2006). The fourth site, Chenque I, is a burial location with over 68 individuals showing a variety of disposal modes (primary, secondary, and various arrangements). A series of dates situate the burials between 1,029 ± 41 and 370 ± 40 B.P. (Luna, 2008).

Finally, the Paraná Delta is the area with the greatest number of sites yielding human remains for this period, with a total of 18 sites known to date: La Bellaca 2 (Loponte 2008), Arroyo Fredes (Loponte et al., 2011), Arroyo Sarandí, El Cerrillo, Arroyo Malo, Túmulo I Brazo Largo, and La Glorietta (Bonomo et al., 2011), Isla Talavera S1, S2, and S5 (Caggiano and Flores, 2001), Río Luján (Toledo, 2011), Cerro Grande de la Isla Los Marinos (Kozameh and Brunás, 2011), Cerro El Castaño 2 (Cornero, 2009), Laguna de los Gansos 2 (Bonomo et al., 2011), Túmulo I Brazo Gutiérrez, Túmulo II del Paraná Guazú (Bernal, 2008), Cerro Lutz (Mazza, 2010), and Los Tres Cerros 1 (Scabuzzo et al., 2015). A total of 30 date ranges are available for these sites which place the burials between 976 ± 42 B.P. (Cerro Lutz; Mazza, 2010) and 310 ± 40 B.P. (Isla Talavera S1; Caggiano and Flores, 2001). A high variability of disposal modes is observed, including primary burials, secondary burials (both in the ground and in urns), isolated remains, and bone arrangements. As in the previous period, mounds are the primary burial location. The densities of burials per site ranges from one burial to more than 40.

As in the Pampas region, during the period ranging from 3,000 to 1,000 B.P., there is an increase in the frequency of burial sites and the density of burials per site (Table 2). For this period, 38 sites have been found. The earliest sites in northeastern Patagonia are located in the Gulf of San Matías (Islote Lobos: 2,670 ± 37 B.P., Favier Dubois et al., 2009), ancient Laguna del Juncal and the lower Negro River valley ("Moreno collection, 1874", La Plata Museum, between 3,009 ± 49 B.P. and 3,002 ± 52 B.P., Bernal, 2008; Gordón, 2011). In southeastern Patagonia, dates were obtained from the sites RT5-BB in the southern coast of Chubut (2,944 ± 51 B.P., Gordón et al., 2013), Cañadón El Algarrobo (2,300 ± 50 B.P., Zilio et al., 2014), Bahía Lángara 5 (2,170 ± 50 B.P., Zilio et al., 2014), and El Zanjón 1, along the northern coast of Santa Cruz (2,130 ± 90 B.P., Zubimendi et al., 2011). In the Southwest, the archaeological site of Sierra Colorada in west-central Santa Cruz has been dated to 2,607 ± 41 B.P. at the earliest (Goñi, 2000–2002). In some of these sites (e.g., El Zanjón 1 and Sierra Colorada), burials of multiple individuals were detected. This trend in multiple burials continues after 2,000 B.P., with 68.4% of the 38 sites for the 3,000–1,000 B.P. period (n = 26) being dated to 2,000–1,000 B.P.

Finally, 41 sites are known in Patagonia dating to the last 1,000 years (Table 2), with an increasing presence of double and

multiple burials in all areas. On the other hand, from 1,300 B.P. to the post-colonial period, secondary burials are found in the northeast.

The bioarchaeological record in Uruguay ranges from 2,000 B.P. to post-colonial times; the earliest dated burial was recovered from El Cerro, in the West ( $1,910 \pm 50$  B.P., Castillo, 2004). Most of the sites in this area are located in the confluence of the Negro and Uruguay rivers, and were studied in a non-systematic way during the twentieth century. Sans (1988) counts a total of 59 individuals with fairly well-preserved crania and dentition removed from 12 sites in western Uruguay, most of them kept in private collections. As a result of the lack of systematic studies in the area, the archaeological context of the remains is unknown, and only three radiocarbon dates from bone are available. The dates come from primary burials recovered in El Cerro (between  $1,910 \pm 50$  and  $1,857 \pm 49$  B.P., Castillo, 2004; Gascue et al., 2014) and Yaguareté ( $1,791 \pm 50$  B.P., Gascue et al., 2014), both found at the mouth of the Negro River.

Erchini (1997) and Gascue (2009) attempted to systematize the mortuary data available from the coast of the Uruguay River. The work of Erchini (1997) compiles published and unpublished data from the Salto Grande area, observing strong evidence for post-mortem rearrangement of the bones in bundles, but it is not possible to assign a chronology to this pattern. The analysis of mortuary data from western Uruguay by Gascue (2009) concludes that 54.1% of the burials in the area are secondary, compared to 44.7% as primary burials and 0.9% as isolated elements. Furthermore, a third of the burials comprise more than one individual.

In eastern Uruguay, most of the burials have been recovered from the *cerritos de indios*, artificial mound structures distributed throughout northeastern Uruguay and southern Brazil, with a chronological range spanning from 5,400 B.P. to the seventeenth century A.D. (Bracco, 2006). However, human remains yield dates only in the latest quartile of the available radiocarbon dates, suggesting that the use of the mounds as burial grounds was a custom adopted in later times, starting 1,600 B.P. To date, date ranges are available from five sites: CH2D01-A (between  $1,610 \pm 46$  and  $220 \pm 50$  B.P., Bracco, 2006; Sans et al., 2012; Mut, 2015), PSL (between  $1,470 \pm 90$  and  $1,360 \pm 100$  B.P., Pintos and Bracco, 1999), CH2D01-B ( $980 \pm 100$  B.P., Bracco, 2006), Cerro de La Viuda ( $960 \pm 65$  B.P., Bracco, 2006), and CG14E01 ( $850 \pm 70$  and  $830 \pm 70$  B.P., Bracco, 2006) (Table 3).

Mortuary practices in these sites show a substantial range of variation. Based on the position of some burials in the mounds, López Mazz (1992, 2001) suggests that these would have been placed at the beginning of the construction of the structure. On the other hand, Cabrera (1999: 69) mentions cases that show “a complete absence of arrangement of the body, which frequently seems to have been thrown into the grave,” implying a lack of effort in the care of the body of the deceased.

Of the remains with discernible treatment, individual primary burials ( $n = 30$ ) represent 41.6% of the total number (Brum, 2008). Of the other 42, four are secondary burials in

bundles (two in Los Indios and two in CH2D01-A) (Femenías et al., 1990; Gianotti and López Mazz, 2009), three are urn burials found in CG14E01 (one containing a single individual, another with two individuals; Cabrera et al., 2000; Cabrera, 2004), and the remaining 35 are classified as partial burials, interpreted as the purposeful interment of isolated elements or sets of elements. Crania, or cranial fragments with various associated postcranial elements, compose the majority of these arrays ( $n = 29$ ), and the few individuals whose sex could be determined within this type of burial ( $n = 6$ ) were male (Figueiro, 2004). The interpretations of these partial assemblies differ from one site to another. In PSL, they are interpreted as interments (Pintos and Bracco, 1999), while those found in Cráneo Marcado (Capdepon, 2004) and Los Indios (Gianotti and López Mazz, 2009) have been tentatively interpreted as the result of anthropophagy based on their association with faunal remains (Figueiro, 2014).

Finally, although several works from the first half of the twentieth century (e.g., Penino and Sollazzo, 1927; Seijo, 1930; Maeso Tognochi, 1977) mention numerous findings of human remains along the coast of the La Plata River in southern Uruguay, few of these have been preserved and studied. Mentions of funerary patterns are scarce and limited to spectacular finds, such as child burials with shell necklaces in Punta del Este (Seijo, 1930) and Arazatí (Maruca Sosa, 1957). Recently, however, the study of these remains has been undertaken in the context of broader initiatives which could ultimately situate these remains in the proper archaeological context (e.g., Beovide and Malán, 2009; Erchini et al., 2011; Beovide et al., 2014). The first radiocarbon dating of human remains from Arazatí was obtained as a part of one of these projects ( $476 \pm 30$  B.P.; Beovide et al., 2014).

## DISCUSSION AND CONCLUDING REMARKS

The summary of the history of bioanthropological research presented at the beginning of this chapter was intended to provide a context for the development of the discipline in the three regions. As mentioned, biological anthropology began in the late nineteenth century, continuing into the twentieth and twenty-first centuries. However, the pace of this development varied across the different regions of the Southern Cone.

The analysis of the bioarchaeological record in the three regions considered in this chapter allows us to note some trends in the frequency and distribution of burials, the variation in interment modes, and the persistence of certain locations for burial and ritual. The analysis of these trends takes into account the heterogeneity of the data between different regions and areas. For example, while there is an early bioarchaeological record in Pampa and Patagonia, the dating of the Uruguayan record is more recent.

The first trend to highlight is related to the number of interment sites through time. Beginning around 3,000 B.P., the bioarchaeological record grew significantly both in Pampa and



Patagonia. Not only did the number of sites increase, but their distribution widened and the number of individuals interred in each site grew. In the Pampas region, throughout the Holocene, burial sites are found in all areas except Tandilia (where the bioarchaeological record is absent) and Ventania (where the chronology of the bioarchaeological record is unclear due to the lack of datings). Between 11,000 and 3,000 B.P., 17 sites with human remains are found in the Pampas, a number that increases to 56 after 3,000 B.P. (Table 1). This trend is also observed in Patagonia, where 12 sites with burials are found dated to between 11,000 and 3,000 B.P., while 79 sites are found afterwards (Table 2). Finally, in Uruguay evidence for the bioarchaeological record is not found earlier than 2,000 B.P. Although there is a slight and insignificant majority of sites dated prior to 1,200 B.P., the dating of the remains ( $n = 16$ ) does not show any visible trend, with a uniform distribution from 1,910 to 220 B.P. (Table 3).

The scarcity of prehistoric human remains in the different regions has been explained in various ways. On one hand, mortuary practices were invoked (e.g., surface disposal); on the other, taphonomic bias and shortcomings in sampling design have been mentioned as factors (Dillehay, 1997). In Uruguay, where the archaeological record shows the earliest human presence during the Pleistocene-Holocene transition (López Mazz, 2013), taphonomy could play a role in the absence of early human remains. However, the observed pattern of human remains restricted to coastal areas is most probably a result of a historic sampling bias, which has also been noted in surveys of fauna and vegetation (Brazeiro et al., 2008).

Another trend is linked to the variations in mortuary practices. In the Pampas region, primary burial is the main interment mode until 3,000 B.P., where secondary burials appear and increase in number, drastically so in later years. While secondary interments are only found in Arroyo Seco 2 between 8,000 and 3,000 B.P., after 3,000 B.P. this type of burial is found in 19 sites, and with a greater number of individuals. In considering secondary burials, special mention should be made of the presence of urn interments in the Paraná Delta, which has been linked to the expansion of Guaraní groups (Bonomo et al., 2015).

On the other hand, in Patagonia from 1,300 B.P. up to post-colonial times, secondary burials are recorded, with a striking similarity to the ones described for Pampa (Gómez Otero and Dahinten, 1997–1998; Della Negra and Novellino, 2005; Martínez et al., 2007; Bernal, 2008; Gordón, 2011; Mariano, 2011; Flensburg, 2012). These burials are spatially restricted to the northeast, which suggest closer relationships between Pampa and northern Patagonia than between the latter and southern Patagonia.

Secondary interments with various arrangements are found both in the East and the West of Uruguay; there is no direct dating for this interment mode in the West, as the three available dates come from primary interments. In the East, the chronology of the secondary burials is varied. Although Gianotti and López Mazz (2009) attribute an age of  $2,700 \pm 150$  B.P. to a secondary burial in Los Indios based on stratigraphy, this should be viewed

as a strictly *terminus post quem* date as it was obtained from the context of the burial rather than from the remains themselves. We find it more cautious to use the  $1,470 \pm 90$  B.P. dating from the PSL site (Pintos and Bracco, 1999) as a maximum age for the secondary mode in the East. On the other hand, the recovery of glass beads in close association with one of the urn burials in CG14E01 has allowed the attribution of a post-Hispanic age to this interment (Cabrera, 2004), although an earlier age for the second urn cannot be ruled out. Furthermore, the Tupiguaraní style of the urns suggests a link to the “*guaranizado*” (i.e., Guaraní influenced) features of the populations in the area, according to the ethnohistorical record (Cabrera, 2007).

The increase in number and variability of the secondary interments in later periods has been linked to factors such as demographic growth, increased social complexity, territorial behaviors, and ideological manipulation of the groups (Barrientos, 1997; Berón and Luna, 2007; Bernal, 2008; Gianotti and López Mazz, 2009; Martínez, 2010; Gordón, 2011; Flensburg, 2012). Furthermore, the presence of other burial modes (e.g., arrangements, incomplete primary burials, isolated elements) is part of a spectrum of disposal practices chosen by these populations, the meaning of which is still largely unknown.

A third trend in all three regions is the increased persistence in Late Holocene of the use of certain spaces as burial grounds, often throughout millennia. In the Pampas region, Arroyo Seco 2 is an exceptional case of early and reiterated use of a place for more than 3,000 years, contrary to the single or low-density burial events typical of the early periods (e.g., Arroyo Frías, El Guanaco 2, Monte Hermoso 1, La Tigra, Chocorí, and Laguna de los Pampas). The adoption of spaces used exclusively for the disposal of the dead (e.g., Paso Alsina 1 or Chenque I) is another characteristic of later periods, although the custom of burying the dead within domestic areas persisted (e.g., La Petrona, Los Tres Cerros 1) (Martínez, 2010).

Of particular interest is the bioarchaeological record of northwestern Patagonia, where two sites (Aquiñuecú and Hermanos Lazcano) were found to have a high density of individuals. This suggests an important change in social organization towards 4,000 B.P. The antiquity of these sites in comparison to other areas of northern Patagonia, where this type of record is dated to after 3,000 B.P., is remarkable (e.g., lower Negro River valley, ancient Laguna del Juncal) (Bernal et al., 2008; Prates and Di Prado, 2013). In southern Patagonia, particular structures known as “*chenques*,” are dated to 1,500 B.P. In this type of burial, the dead are covered with rocks of various sizes. Certain authors have proposed that the regularity of the *chenques* is indicative of mobility circuits shared by the hunter-gatherer groups of north-central Patagonia in the late Holocene (Zilio, 2013).

In Uruguay, the most notable regular feature is the use of mound structures as burial grounds. Artificial mounds are a ubiquitous and varied feature in South America. In eastern Uruguay, although mounds are present starting at about 5,000 B.P., they do not always include burials and when they do, they are dated to later periods. Therefore, it is possible that the use of the

mounds as burial grounds in the East was a late custom in the area. On the other hand, considering the variety of practices observed (Cabrera, 1999, 2004; Pintos and Bracco, 1999; Gianotti and López Mazz, 2009), the possibility of more than one group using the structures for the disposal of the dead, or their incidental use for that purpose, should be considered.

In western Uruguay, the available data are too scarce to establish a link between the burials found in the mounds and their construction (Maruca Sosa, 1957, Maeso Tognochi, 1977). The burials that have been dated, which were not recovered from mound structures, date to the earliest phase of the ceramic period in the area, which spans from 1,850 to 500 B.P. (Figueiro, 2014). This time frame is consistent with the chronology of the archaeological record of the Paraná Delta, along the opposite coast of the Uruguay River (approximately 2,100 to 300 B.P., Bonomo et al., 2011).

In this chapter, we attempt to present an integrated view of the spatial and temporal distribution of the bioarchaeological record in Pampa and Patagonia in Argentina, and in Uruguay. This perspective has demonstrated not only a series of patterns in the use of space and the mortuary practices through the Holocene, but also the heterogeneity of the research in each region. Undoubtedly, the disparate character of the information is related both to the population history of these regions as well as to the difference in number and magnitude of the studies conducted. What we have presented here is a summary of the information available to date; it is our hope that this summary becomes relatively outdated in short order, as future advances continue to complete the picture of bioarchaeological research in the Southern Cone of South America.

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# South-Central Andean Area Settlement, Evolution, and Biocultural Interactions

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**ABSTRACT.** This article integrates a series of studies carried out with the aim to illustrate important aspects of the biology of the prehistoric human population that lived in the south-central Andean area, a key region of South America. These studies include (1) biological characterization of the local populations through analysis of a set of factors such as sex, age, and artificial deformation; (2) description of the structure of the populations at local and regional levels; (3) investigation of their genetic relationships; and (4) definition of the factors that determined their evolution. A synthesis of the cultural development of northern Chile and northwestern Argentina is also included to understand the natural and social historical circumstances associated with the colonization and occupation of the region.

**RESUMEN.** El presente trabajo integra una serie de experiencias realizadas con la finalidad conocer aspectos relevantes de la biología de la población humana prehistórica que habitó en el Área Andina Centro Meridional una región clave de América del Sur. Los trabajos citados incluyen (1) la caracterización biológica de las poblaciones locales mediante el análisis de un conjunto de factores como el sexo, la edad y la deformación artificial; (2) la descripción de la estructura de las poblaciones a nivel local y regional; (3) inferir sus relaciones genéticas; y (4) establecer los factores que determinaron su evolución. Además, se incluye una síntesis del desarrollo cultural del Norte de Chile y del Noroeste Argentino para permitir la comprensión de las circunstancias históricas sociales y naturales asociadas con la colonización y ocupación del territorio regional.

**RESUMO.** O presente trabalho integra uma série de experiências realizadas com a finalidade de conhecer aspectos relevantes da biologia da população humana pré-histórica que habitou na Área Andina Centro Meridional uma região chave de América do Sul. Os trabalhos citados incluem (1) a caracterização biológica das populações locais mediante a análise de um conjunto de fatores, tais como sexo, idade e deformação artificial; (2) a descrição da estrutura das populações a nível local e regional; (3) inferir suas relações genéticas; e (4) estabelecer os fatores que determinaram sua evolução. Ademais, incluíse uma síntese do desenvolvimento cultural do Norte de Chile e do Noroeste Argentino para permitir o entendimento das circunstâncias históricas, sociais e naturais associados à colonização e ocupação do território regional.

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Manuscript received 28 April 2016; accepted 10 November 2017.

## INTRODUCTION

Research carried out for the reconstruction of the biological history of the populations of northern Chile and northwest Argentina was based on information obtained about the local and regional phenotypic structure. Results of analysis for sexual dimorphism, age

variation, artificial deformation, quality of life, and survival of populations from different sites are presented for the following regions: northern arid Chile (Arica, Pisagua, Caleta Huelén, San Pedro de Atacama), northern semiarid Chile (El Cerrito, Punta de Teatinos), and northwestern Argentina (Puna de Jujuy, Quebrada de Humahuaca, Valle Calchaquí and Pampa Grande). We mention experiences that allowed us to determine the environmental and genetic components of the phenotypic characters, as well as the reconstruction of several local models that helped to explain the regional evolutionary process and its relations with the other regions of the south-central Andean area.

## NORTHERN CHILE

### COMPOSITION AND STRUCTURE OF THE POPULATION

As of 1980, research has focused on studies of the structure of ancient populations, their biological relationships, and their evolution. This involved an important change from a theoretical, methodological, and technical point of view. From a theoretical perspective, change resulted from the unconditional adherence to the theory of evolution. From a methodological perspective, a key factor was the application of contrasting experimental designs based on explicit assumptions, consistent hypotheses, and appropriate evidence to support rational scientific knowledge. Technological advancement included application of protocols and analytical processes allowing researchers to obtain relevant information, as well as the use of statistical and numerical techniques to measure phenotypic and genetic information (Cocilovo, 1981; Cocilovo and Rothhammer, 1990; Cocilovo and Varela, 1999).

Reconstruction of the biological history of a population requires adequate information to be able to measure phenotypic differences in space and time without the influence of other effects associated with age, sex, and the artificial deformation of individuals. When research designs include heterogeneous samples from a wide territory, it is necessary to explore the magnitude of those effects, as they represent specific properties of the inhabitants of each locality. For this reason, determination of sex, age, and artificial deformation was a preliminary step in the studies of biological relationships among different groups. Having that information facilitated study of population structure at the local and regional levels, including the biocultural characteristics of each group. This included research carried out on materials dated between 3000 BC and AD 1450 from localities in or near Arica, Camarones 14, Pisagua, Caleta Huelén, San Pedro de Atacama, Punta de Teatinos, and El Cerrito, Chile (Figure 1; Cocilovo et al., 1982, 1999a; Varela et al., 1991, 1993; Cocilovo, 1994; Cocilovo and Costa-Junqueira, 2001; Quevedo et al., 2003; Manríquez et al., 2006; Rhode and Arriaza, 2006). These studies measured the magnitude of the effects of sexual dimorphism, age variation, and artificial deformation of the skull and estimated the paleodemographic parameters, ultimately

providing a synthesis of the distribution (Cocilovo and Varela, 2010) and effects of artificial cranial deformation at a regional level (Cocilovo et al., 2011a).

A set of environmental, cultural, economic, and social factors determined the quality of life and survival of the ancient population of Arica in northern Chile. For example, tuberculosis was endemic to the Andean region, affecting respiratory and skeletal systems (Arriaza et al., 1995; Lombardi and García Cáceres, 2000). From 9000 BC to AD 1800, Chagas disease affected a wide area that included southern Peru and northern Chile (Aufderheide et al., 2004, 2005; Arriaza et al., 2008). Nonvenereal Treponematoses (yaws) were detected both in the Azapa Valley and along the coast of Arica (Standen and Arriaza, 2000a). Diseases related to intestinal parasites were found in Arica and the Valley of Lluta (Arriaza, 1995; Reinhard and Urban, 2003; Santoro et al., 2003).

Poor hygiene and health conditions as well as the prevalence of pulmonary diseases negatively impacted quality of life and infant mortality (Arriaza et al., 1988). Lobar pneumonia was identified by Fontana et al. (1983) in remains of the Early Intermediate and Middle periods in Arica and regions to the south (Aufderheide et al., 2008). Iron deficiency anemia was detected through porotic hyperostosis in groups of fishermen and agropastoralists (Arriaza, 1995; Costa-Junqueira et al., 2000). Analysis of trace elements in skeletal remains revealed information about the type of diet. For example, in Morro 1 (coastal Archaic) the preference was vegetal food, and in the Azapa valley (site AZ140) protein-rich animal food was prevalent (Razmilic et al., 1987).

Signs of forceful blows in the Chinchorro population (Acha 2–3, Maderas Enco, Morro 1, Morro 1/6, and Playa Miller 8 sites) evidenced a high frequency of trauma to the skull (25%) and upper limbs (9%) in adult individuals, which seemed to result from violent situations rather than everyday accidents (Standen and Arriaza, 2000b). In samples from Chinchorro, Uhle collection (calibrated radiocarbon dates: 3550 3300 BP, 3450 3200 BP, and 3520 3220 BP), the environmental impact was analyzed by growth and development factors, as well as by health, diet, daily activity, and demographic properties (Costa et al., 2000; Costa-Junqueira et al., 2000).

A topic of interest in evaluating conditions of life in ancient and modern populations is the expression of sexual dimorphism. Its variability may reflect conditions of a quality of life that determines the survival and persistence of the population. The cultural diversity of Arica over ten thousand years and the quality of available osteologic material found there have together provided an excellent opportunity to study variation of sexual dimorphism in space and time. Higher mean values were found in males than in females for most cranial measurements (average sexual dimorphism index [SDI], 5%). In general, the magnitude of sexual dimorphism is comparable with other pre-Hispanic groups, suggesting that this population, using the available technology at hand (hunting, fishing, grazing, and agriculture), was able to obtain sufficient food resources to ensure adequate growth and





FIGURE 1. Map of the south-central Andes region showing many localities where samples were obtained.

development according to the local way of life. However, this situation varies between the coast and the valley and, more remarkably, between cultural periods. Specifically, in the Middle and Late periods there were no gender differences, which indicates harsher conditions of life then (Cocilovo and Varela, 2014).

The town of San Pedro de Atacama in arid northern Chile is 2,430 m above mean sea level (AMSL) (Figure 1). North of the Salar de Atacama, the oasis area surrounding the town allows the practice of agriculture and llama breeding. This locality has long been exceptionally well situated in the south-central Andean area; archaeological evidence indicates it was an obligatory way station for caravan traffic and human groups that migrated from the neighboring regions of northern Chile, Peru, Bolivia, and Argentina. Studies of the area's began population biology in 1990 and were published by Varela et al. (1990a, 1995), Cocilovo et al. (1995), Varela and Cocilovo (1996), and Varela (1997). At the site of Coyo Oriente 3 (AD 910–960), biological and cultural indicators were studied to determine the style and quality of life (Costa and Llagostera, 1994). The cemetery of Coyo Oriental, 5 km south-southeast of San Pedro de Atacama, allowed the definition of a specific phase (AD 600–900) in which the Tiwanaku culture was more dominant (Berenguer et al., 1986; Berenguer and Dahuelsberg, 1989). This led to study of the biology of the Tiwanaku by Cocilovo et al. (1994, 2011b), Cocilovo and Zavattieri (1994), and Costa et al. (2008).

Quality of life in the prehistoric population of San Pedro de Atacama was assessed by analyses of pathologies, traumas, state of dentition, personal violence, and other bioanthropological aspects (Costa, 1988; Costa and Llagostera, 1994; Costa-Junqueira et al., 1999; Costa et al., 2004; Lessa, 1999; Torres-Rouff et al., 2005; Torres-Rouff and Costa Junqueira, 2006; Lessa and Mendonça de Souza, 2007; da-Gloria et al., 2011; Torres-Rouff, 2011; Hubbe et al., 2012; Nado et al., 2012). As in Arica, sexual dimorphism was studied as a possible indicator of the predominant quality of life in San Pedro de Atacama through analysis of 624 individuals and 35 craniometrical variables. Most measurements showed mean values higher in men than in women (average SDI, 4%). Sexual dimorphism did not vary through time. This would indicate that the reported changes in life condition throughout 60 generations with other markers (pathologies, trauma, and violence) did not have a substantial impact on the normal growth and development of the skull in both sexes (Cocilovo et al., 2014).

In the semi-arid north (of Chile), archaeological studies have established a series of Archaic period stages for the coastal sites of Complejo Huentelauquen, Guanaqueros and Punta Teatinos (Schiappacasse and Niemeyer, 1986). Relationships and biological affinities were investigated in materials from different stages of cultural development in this region (Quevedo et al., 1985), and the findings provide a primary explanation for the population structure and its ancestral relationships. Strange et al. (1991) added to the analyses in a similar study. Punta de Teatinos is an archaeological site located on Coquimbo Bay 12 km north of La Serena; the site is on a coastal terrace comprising a shell midden and an Archaic period burial ground. The cemetery there dates to

two periods:  $4905 \pm 100$  BP and  $4560 \pm 95$  BP (Quevedo, 1976; Schiappacasse and Niemeyer, 1986). The study of these materials represents the most complete biological anthropology research at a regional level (Quevedo, 1998). Dentition, pathology, chemical analysis of trace elements, population dynamics, and paleodemography were analyzed. This study also presents demographic statistics and their relationships with other sites in the region (Quevedo, 1998; Quevedo Kawasaki, 2000). A later review and update of available information focused on the numerical and genetic properties of the group buried in this locality (Quevedo et al., 2000).

Studies carried out at Punta de Teatinos provided a wealth of information about bone markers indicating nutritional and infectious diseases as well as physical activity of individuals (Quevedo, 1998; Quevedo Kawasaki, 2000; Quevedo et al., 2000). These findings established a certain profile that could be linked with variations of normal growth and development. Therefore, to obtain more information about quality of life and the adaptation process experienced by the population, investigation of bilateral asymmetry of the metric variables of the skull and postcranial skeleton was undertaken. Calculation of bilateral asymmetry allows for partition of the phenotypic variance into two components: (1) the so-called maximum genetic variance and (2) the special environmental variance. Although no significant variations of environmental variance were observed in the postcranial skeleton, variations of the skull were found (perhaps associated with plagiocephaly and artificial deformation) as well as in maximum and minimum width of the ascending ramus, which were linked to functional alterations of the masticatory apparatus (Cocilovo et al., 2006). A more complete analysis was performed by calculating the value of repeatability ( $r$ ) and the special environmental variance (Varela et al., 2006).

#### EVOLUTION OF THE POPULATION, LOCAL DIFFERENTIATION, AND REGIONAL RELATIONSHIPS

The discovery of changes to average phenotype of individuals in the same locality over time was a significant contribution to establishing a theory about settlement of the south-central Andean area. Experiments in Arica, Quebrada de Humahuaca, San Pedro de Atacama, and Pisagua revealed the existence of several microevolutionary models as well as the existence of a set of factors influencing composition and genetic structure of the population.

A series of studies in Arica established the existence of statistically significant phenotypic differences between the groups of the coast and of the Azapa Valley during different archaeological periods. These differences were evaluated by metric and nonmetric traits of the skull and showed a high correlation with chronological distances among groups of different periods (80%). An analysis of associated phenotypic and chronological distances through application of the method proposed by Relethford (1980) over a period of 6,500 years showed an increased kinship within groups and a decreased kinship over time both for males and females. From a population genetics point of view, for the first time in the south-central Andean area this analysis indicated the effect of a

microevolutionary process produced by a set of factors such as genetic drift and medium- and long-range migration (Rothhammer et al., 1982, 1984; Cocilovo and Rothhammer, 1996a, 1996b, 1999). A review of this model and explanation of the theory and methods were presented by Cocilovo and Varela (1999).

Subsequently, significant spatial and temporal differences between the coastal groups and those of the Azapa Valley were confirmed through analysis of a more complete database (245 individuals and 18 craniometric variables). The information was evaluated by means of multivariate statistical analysis (discriminant analysis, Mahalanobis  $D^2$  distance, and cluster analysis). The results show that differences are greater among different periods on the coast than in the valley. This evidence can be explained by the existence of two major settlement events, one during the Archaic period by fishermen–hunter groups and another during the Early Intermediate or Formative period by shepherd–farmer groups. Both groups would have originated from an ancestral Andean population of individuals who were among the first settlers of the region. They would have differentiated gradually when they occupied specific niches suitable for their subsistence, due to the effect of various evolutionary (systematic and random) and cultural factors that continued to operate in the new scenario (Cocilovo et al., 2001a). Subsequently, a close relationship between the central plateau and the San Miguel and Alto Ramírez phases of the Azapa Valley was proposed, based on six craniometric variables (Rothhammer et al., 2002).

Whereas the phenotypic divergence of groups living in Arica has been increasingly demonstrated, other research offered contrary evidence suggesting uniformity of the population. This led to important debate about unity versus diversity of the ancient population of Arica and the Azapa Valley. Indeed, through use of nonmetric characters of the skull and dentition, deviating results were obtained by Sutter (2000) and Sutter and Mertz (2004) in samples from the valleys of Moquegua (Peru) and several sites on the coast and in the Azapa Valley (Chile). These authors found that the calculated distances (Mean Measure of Divergence or MMD) in the Azapa samples were not statistically significant. Thus, they concluded there would be a direct ancestor–descendant relationship between the Archaic period groups of the coast (Morro-1, Morro-5, Morro-6, and Plm-8) and the Formative period groups of the valley (Alto Ramírez: Az-71, Az-14, Az-70, and Az-115) and the coast of Arica (Laicho: Plm-7).

Controversy raised by the cited research about settlement of the Azapa coast and valley based on skeletal remains is most likely due to the use of different data (metric versus nonmetric traits) and samples of different sizes from various sites. The discrepancies prompted a note from Rothhammer et al. (2006) in response to the study of Sutter and Mertz (2004), a new response from Sutter (2006), and finally a complete evaluation of evidence presented by each opponent on the differentiation process that occurred in Arica (Rothhammer and Cocilovo, 2008).

Explanation of the evolution of northern Chilean groups saw significant progress through the application of key concepts of population genetics. Although understanding the evolutionary process in a region is dependent on analysis of chronological

variation, it is also necessary to adequately explain the variable gene frequencies that determine changes in the mean values as well as the variance of quantitative traits. To address this, models with estimations of the genetic divergence between groups or average within-group kinship (Wright's  $F_{ST}$ ) were applied. This parameter can be calculated using the method proposed by Relethford and Blangero (1990).

A significant study in Arica was based on the theory of repeated measurements (Becker, 1975; Falconer and Mackay, 1996; Lynch and Walsh, 1998). Using bilateral craniometric variables, phenotypic variance was partitioned into genetic and general environmental variance, and into another special environmental variance. The repeatability ( $r$ ) of a metric trait is the ratio between the genetic variance (plus environmental general variance) and phenotypic variance, and it is considered the upper limit of heritability ( $h_m^2 \approx h^2$ ). It is calculated as the correlation between characters measured on both sides of a symmetrical structure. The special environmental component is obtained by the difference  $1 - r$  (Varela and Cocilovo, 1999).

Also for Arica, the  $F_{ST}$  value was calculated by using  $r$  ( $\approx h_m^2$ ) as an estimator of  $h^2$ . This last parameter is involved in the model of Relethford and Blangero (1990) and Relethford and Harpending (1994). The  $F_{ST}$  value allows for deductions with regard to the population structure based on quantitative traits, as well as on evolutionary factors such as genetic drift and migration. Studies demonstrated that 82.5% of the total phenotypic variation is explained by the maximum genetic variance. In the Early Intermediate population of the valley an excess of extraregional gene flow was found. In addition, differentiation between coastal groups of Archaic and Early Intermediate periods was reduced. From the Middle period there is a substantial increase in genetic differences between both areas. These findings indicate that external gene flow was lower on the coast than in the valley, whereby the minimal  $F_{ST}$  estimated for the total population (coast and valley) amounted to 0.02, with  $F_{ST} = 0.01$  for the coastal population and  $F_{ST} = 0.006$  for the valley. The results are discussed by Varela and Cocilovo (2002) according to the ethnohistorical and archaeological evidence of the region, proposing a model explaining the genetic history of the population. Findings of genetic flow associated with low inbreeding in the Early Intermediate period of the valley (Alto Ramírez) indicated an increase of immigrants (Varela and Cocilovo, 2002). This could support the hypothesis of long-range migration across the highlands and tropical forest (Rivera and Rothhammer, 1986; Moraga et al., 2001; Rothhammer and Santoro, 2001; Rothhammer et al., 2002), but it does not discard the incorporation of genetic variability as a result of middle-range migration from other valleys and intermediate basins of northern Chile.

Subsequently, Rothhammer et al. (2009) reaffirmed the relationships between northern Chile, the highlands, and the rainforest by using a broad register of ancient and modern mtDNA from the Azapa Valley, Amazonas, Tiwanaku, Quechua, Aymara, and Atacameños samples. An  $F_{ST}$  value of 0.157 ( $p = 0.002$ ) was obtained, which indicated a significant process of genetic divergence beyond the connections and relationships implied by the

discovery of tropical products in a local framework with nonsignificant genetic distances between Amazonia and Azapa Valley group samples.

Another important step allowed for establishment of the nature of early settlement based on divergence of Archaic human groups of the northern Chilean coast: Arica (Morro 1, Morro 1/6, and Morro Uhle) and semiarid north (El Cerrito and Punta Teatinos). The study was conducted using 29 metric (177 nondeformed individuals) and 25 nonmetric traits (288 individuals). Analyses of  $D^2$  distances for the first study and MMD for the second study indicated significant differences among the four groups. This evidence is significant with regard to the process in which an ancient coastal population differentiated itself while migrating southward, causing spatial segregation of four different phenotypes due to evolutionary forces such as migration, drift, and reproductive isolation (Cocilovo et al., 2004). Later, evidence of a north–south coastal Archaic settlement was enhanced with incorporation of the Caleta Huelén-42 sample for analysis of their relationships with the Archaic groups mentioned above. Evaluation of the differences ( $D^2$ ) showed they were significant among localities. However, distances between Arica and Caleta-Huelén were lower than between the latter group and the semiarid north, confirming the existence of a dispersive process regulated by migration. It is possible that the inhabitants of Caleta Huelén 42 share a proportion of genetic variation derived from an ancestral population, with the migratory contribution of other regions, possibly from intermediate basins (Cocilovo et al., 2005).

A key issue was also the explanation of genetic relationships between Archaic and Formative groups of Arica, both along the coast and in the valley. Materials from the sites Morro-Uhle, Morro 1, and Morro 1/6 (coast Archaic), Playa Miller-7 (coast Formative), and Alto Ramírez (Azapa Valley Formative) were analyzed. The total sample included 181 individuals and 29 metric variables, excluding effects of sex, age, and artificial deformation. The four subsamples showed significant differences. The most divergent group was Alto Ramírez, whereas Morro 1 and Morro1/6 appeared to show the least differentiation. A gradual phenotypic change on the coast was observed, proving the genetic contribution of the Archaic fishermen to the Formative group of Playa Miller-7 and their differentiation from the Alto Ramírez group of the valley. The  $F_{ST}$  value of 0.04 reflects the effect of a dispersive process regulated by a large or medium-range migration (Varela et al., 2006), which differs from the biological homogeneity proposed by Sutter (2000) and Sutter and Mertz (2004).

In Pisagua in northern Chile, however, the process was different. The results indicated that for the duration of 48 generations, genetic composition of the population fluctuated through increased local kinship and less interaction with bordering areas. This conclusion is based on analysis of the nonlinear correlation between the  $D^2$  chronological values and the distances between cemeteries explained by a kinship bioassay model (Morton et al., 1971; Morton, 1977; Relethford, 1980). Indeed, phenotypic changes correspond to a population with an effective size of 200 individuals per generation, a migration

rate of 2.2%, and a kinship average of 5.4% (Cocilovo, 1994; Cocilovo et al., 1999a).

In the population of San Pedro de Atacama, chronological differentiation was also studied from a sample of 120 individuals and 32 metric variables of the skull, excluding the effects of sex, age and artificial deformation. Analysis of 11 variables demonstrated significant differences among the chronological phases, covering approximately 70 generations (Cocilovo and Varela, 2002). This study resulted in the proposal of a local evolutionary model (Varela, 1997, Varela and Cocilovo, 2000) together with the studies of Arica (Rothhammer et al., 1982, Cocilovo et al., 2001a), Pisagua (Cocilovo, 1994), Semiarid North, and Central Chile (Cocilovo and Quevedo, 1998). Thus, the reconstruction of local biochronological sequences allowed an advanced knowledge of the settlements in northern Chile and their relationship with other regions of the central-southern Andes.

The results in San Pedro de Atacama encouraged the idea of assessing variability over time in the same community, or ayllu, with a larger sample. In the Quito cemetery, the phenotypic difference between the Formative period (300 BC–AD 400), Tiwanaku period (AD 400–1000), and Regional Development period (AD 1000–1470;) was studied with data obtained from 326 individuals and 37 metric characters; temporal differentiation was evaluated by means of univariate and multivariate statistical analyses. Average estimated kinship ( $F_{ST}$ ) for this ayllu was 0.046 ( $h^2 = 0.55$ ), and it was higher in women than in men. According to this value, inhabitants of Quito lived in greater isolation than did the Azapa Valley agricultural groups ( $F_{ST} = 0.013$ ). Also in the Middle Horizon period (Tiwanaku), a moderate increase of phenotypic variance was observed caused by a greater gene flow from neighboring regions (Varela and Cocilovo, 2009).

The existence of chronological variation established for this locality, and in particular for the site of Quito (Varela and Cocilovo, 1996; Cocilovo and Varela, 2002; Varela and Cocilovo, 2009), gave rise to a new study testing chronological differentiation with a larger sample of different cemeteries (Varela and Cocilovo, 2011). A group of 622 individuals from seven ayllus dating to the Early Intermediate, Middle Horizon, and Late Intermediate periods was studied. Differences were tested using 37 craniometrical traits excluding effects of sex, age, and artificial deformation. Multivariate analysis of variance, canonical discriminant analysis, and Mahalanobis  $D^2$  distance was applied. Genetic divergence was measured using  $F_{ST}$  statistics according to Relethford and Blangero (1990) for the total population and for each period. Significant differences among samples, including spatial and temporal variation, were verified. The average  $F_{ST}$  of 0.05 showed a process of genetic divergence that explains the differences between the mean values of all groups with respect to the regional average. Statistics  $F_{ST}$  for the Early Intermediate period of 0.11, for the Middle Horizon period of 0.005, and the Late Intermediate period of 0.03, revealed an interesting variation of the differentiation process in time (Varela and Cocilovo, 2011), which had already been noted in the ayllu of Quito (Varela and Cocilovo, 2009).

The  $F_{ST}$  values per cultural period provide a higher resolution and a more appropriate explanation of settlement in the Atacama oasis. During the Early period, an  $F_{ST}$  of 11.4% is explained by a strong divergence among groups (Quitor 8, Larrache, and Toco-nao) due to the small population size and a greater reproductive isolation. During the Middle period, the value of 5 % indicates a considerable growth of the local population and an increased gene flow (medium- and long-range), and these factors contribute to greater homogeneity in the physical aspects of individuals. In the Late period, the situation is partially reversed by the 3% divergence between Quitor (Q1 and Q9) and Yaye, indicating a reduced population and a higher isolation of groups. Temporal and spatial variation was produced by factors that influenced the bio-social history of the population. These factors include the origin of the founding groups, effective size, mating patterns, kinship, genetic drift, and migration. Also, economic relations and the exchange of products through medium- and long-range networks (along the coast, valleys, and highlands, including more distant regions such as Bolivia and northwestern Argentina) played an important role (Varela and Cocilovo, 2011).

## NORTHWEST ARGENTINA

Northwestern Argentina includes several geographical sub-regions which were inhabited beginning approximately 8000 BC (Fernández Distel, 1975; Aschero, 1984, 2011) by hunter-gatherers, who were carriers of lanceolate and triangular points. In layer 6 of the Pintoscayoc-1 site located north of Quebrada de Humahuaca, periods dating between 10,889 and 8176 BC were delineated. In the Inca Cueva and the caves of Huachichocana located along the lateral ravines of Quebrada de Humahuaca, the dates range between 6720 and 7670 BC (Ruiz, 1995–1996; Aschero, 2011). At around 2500 BC there is evidence of specialized gathering and handling of plant species in Cave III in Huachichocana. The presence of pottery, monticular structures, circular housing distributed among crops fields, and other clusters in villages characterizes the Early Formative period. In Jujuy, dates between 2042 and 1505 BC are obtained for El Alero Unquillar, 1500 BC for Abra de los Morteros, 1008 BC for Cueva de Cristóbal, between 1300 and 230 BC for Alero de Tomayoc, 950 BC for Inca Cueva (Alero I), and 440 BC for Estancia Grande. This period is present in Tafi (Tucumán), in the Sajuil valley and Alamito sites (Catamarca), in Campo Colorado (Valle Calchaquí, Salta), in the sites of La Cuevas and Cerro El Dique, and in Quebrada del Toro dating to between 600 and 400 BC (Ruiz, 1995–1996; Yacobaccio et al., 2000). The cultures of Candelaria (Las Pirguas, east and south of Salta and northern Tucuman), Ciénaga (Valle Calchaquí, Catamarca, La Rioja, and northern San Juan), and Condorhuasi (Catamarca and northern La Rioja) characterize the Formative period.

During the Middle Horizon period (AD 650–1000), the Aguada culture was developed in the valley of Catamarca, La Rioja, and north of San Juan. The relationship between this culture and the Tiwanaku culture as well as the possible Tiwanaku

influence on the Isla culture of Jujuy is highlighted. Isla pottery with Tiwanaku elements was found in San Pedro de Atacama, northern Chile (Ruiz, 1995–1996).

The beginning of the Late Intermediate period (AD 1100) is related to decline of the Tiwanaku in the south-central Andes, disappearance of the Aguada culture, robust local entities, population growth, and differentiation of ethnic groups with territorial autonomy. The presence of pukará would be associated with a new stressful situation and the organized exchange of routes. During this period the cultures of Santa Maria, Humahuaca, and “Complex Puna” in the Valliserrana, Humahuaca, and Puna subregions were identified, respectively. The end of the Late Intermediate period occurs around AD 1470 and is associated with arrival of the Incas in the region (González and Pérez, 1987; Ruiz, 1995–1996).

## PUNA DE JUJUY

This subregion is a high plateau with elevations that range between approximately 3,500 and 4,500 m AMSL in the north and west of Jujuy province (Figure 1). It is characterized by large depressions and sedimentary basins of endorheic drainage and surrounded by hills and salt flats or significant lagoons, such as in Pozuelos, Vilama, and Guayatayoc.

Analysis of sexual dimorphism with 31 craniometrical variables indicated sex differentiation. Only nose width and orbit height did not differ between men and women. The latter feature is shared with other populations of the south-central Andean area, such as San Pedro de Atacama (Varela, 1997), Pisagua (Cocilovo, 1994), Morro de Arica (Cocilovo et al., 1982), Las Pirguas (Baffi and Cocilovo, 1989), and Cochabamba (Cocilovo et al., 2013), and it may be related to similar growth in the regions of olfactory and visual systems in both sexes. Correct assignment was 86% for observations of either sex by discriminant function.

Analysis of age variation of the population in this subregion showed that metric variables vary significantly among age groups (infant, juvenile, adult, mature, senile). Age classes that contributed most to this variation were infant and juvenile, which differed from postreproductive ages. Furthermore, the characters that involved the alveolus, such as maxillo-alveolar width, showed a decrease in average values in mature and senile ages as a result of tooth loss and alveolar resorption. These results are consistent with other studies in prehistoric populations (Varela et al., 1990a; Cocilovo et al., 1994; Varela et al., 1995; Varela, 1997; Quevedo, 1998).

The most frequent artificial deformation in this subregion was found to be the oblique tabular (68.7%), and less common were the erect tabular (4.5%), oblique circular (1.9%), and erect circular (0.2%). Furthermore, nondeformed skulls were represented by 24.6%. The effect of artificial cranial deformation occurred with greater magnitude in the vault and base and with less influence with regard to the facial region (Cocilovo and Varela, 2010).

In a preliminary study, Mendonça et al. (1990) observed no differences in skull morphology among different sites in the Puna de Jujuy. In an exhaustive study by Fuchs (2014), biological

relationships between groups of this subregion were evaluated by increasing the sample size and the amount of skull metric traits and then using discriminant and cluster analysis. The results showed phenotypic differences between Agua Caliente and Casabindo, between Agua Caliente and Doncellas, and between Agua Caliente and Queta; among Casabindo, Doncellas, and Queta; and between Sorcuayo and Queta. The other comparisons did not reveal any differences between sites; in particular, Río Negro was morphologically similar to the other five samples studied.

Queta and Sorcuayo represented the most isolated groups; in these, the phenotypic variance was lower than expected for a balanced model between genetic drift and gene flow, indicating less migration than expected. In Agua Caliente, a higher variance than expected was observed, indicating a higher than expected average gene flow. Genetic divergence ( $F_{ST}$ ) represents 2.5% of the total genetic variation, using quantitative characters and an average heritability of 0.55 (Fuchs, 2014). Similar estimates were obtained for San Pedro de Atacama and Azapa Valley in northern Chile (Varela and Cocilovo, 2002, 2011).

A bioarchaeological study of groups that inhabited the Puna de Jujuy has been developed by Fuchs (2014) with samples from different archaeological sites. The combined collections in the Juan B. Ambrosetti Ethnographic Museum (University of Buenos Aires) and La Plata Museum (National University of La Plata) contain 371 skulls. With radiocarbon dates determined from teeth, the combined sample was identified as from the Late Intermediate period (AD 1029–1497; Fuchs and Varela, 2013), which coincided with results of other archaeological studies (Alfaro and Suetta, 1970; Alfaro, 1988; Ruiz and Albeck, 1997; Albeck and Zarbulín, 2008).

As demonstrated by sexual dimorphism, low values of developmental instability evaluated in the bilateral characters of the skull, and low frequency of diseases of the metabolic and masticatory system (Miranda de Zela and Fuchs, 2014), this population was not exposed to extreme environmental conditions that affected normal growth and development of individuals. Furthermore,  $\delta^{13}C$  and  $\delta^{15}N$  values showed that the inhabitants of Puna de Jujuy maintained a mixed diet with an important meat component in the composition (Fuchs, 2014). These latest results were in accordance with those obtained by Perez and Killian Galván (2011) and Killian Galván et al. (2012).

#### QUEBRADA DE HUMAHUACA

The deep and narrow valley of Quebrada de Humahuaca in the province of Jujuy (Figure 1) is 2000–3500 m AMSL, runs in a north–south direction, and is crossed by the Río Grande; it is approximately 150 km long and is associated with side ravines connecting with the adjacent areas.

According to Nielsen (2001), for each site of the Quebrada de Humahuaca it is possible to establish highly probable ranges of occupation. For El Alfarcito, from the Late Formative (Early Horizon) period to the Middle Horizon period; for La Isla, to the Middle Horizon period; for Juella, to the Late Intermediate

period; for Los Amarillos, Yacoraite, Campo Morado, La Huerta, Pukara de Tilcara, Peñas Blancas, El Volcán, and Angosto Chico, from the Middle Horizon period to the Inca (Late Horizon); and for Ciénega Grande, from the Late Intermediate period to the Inca (Late Horizon).

Ranges of occupation for additional sites were determined by several other researchers. El Volcán's range of occupation falls in the period between AD 1168 and 1533 (Cremonte and Garay de Fumigalli, 1997). Occupation ranges for other sites are as follows: Pucara de Tilcara, AD 1100–1530 (Zaburlín, 2009); Los Amarillos, AD 1000–1600 (Nielsen, 1996; Rivolta, 2007); Juella, AD 1284–1442 (Nielsen, 1996); and La Huerta, AD 800–1470 (Rivolta, 2007).

In an initial study using characters of the skull, differences between Pukará de Tilcara and the Isla groups were observed by Dillenius (1913). According to artificial deformation, a certain affinity between the Isla groups and groups of the northern region of Humahuaca was suggested, while Pukará de Tilcara is more similar to Valle Calchaquí (Dillenius, 1913).

For better insight into the bioanthropological profile of the Quebrada de Humahuaca population, existing phenotypic variation within and between sites was evaluated (Cocilovo et al., 1999b, 1999c, 2001b) using 416 skulls from the Ambrosetti Ethnographic Museum. The material belongs to several sites (Peñas Blancas, Yacoraite, Campo Morado, Los Amarillos, Angosto Chico, La Huerta, Juella, La Isla, El Alfarcito, Pukara de Tilcara, Ciénega Grande, and El Volcán) associated with the Early, Middle, Late, Inca, and Hispanic cultural periods. The type of artificial cranial deformation is differentially distributed among sites. A predominance of skulls show oblique and erect tabular deformation, whereas the circulars and nondeformed are less frequent (Cocilovo et al., 2001b). Similar results were obtained in a sample of 153 skulls from the Yacoraite, Los Amarillos, and La Huerta sites (Seldes and Botta, 2014). The predominance of oblique tabular deformation in this subregion agrees with findings obtained in the Puna (Cocilovo and Varela, 2010; Fuchs, 2014).

In Quebrada de Humahuaca, a high proportion of skull metric traits vary among the different localities. Distances between groups in multivariate analysis showed a biological heterogeneity greater than was expected for a limited geographic region (Bordach and Cocilovo, 1991; Cocilovo et al., 1999d). In addition, a cluster analysis proposed a first cluster associated with the northern sector of Quebrada de Humahuaca (Peñas Blancas, Yacoraite, Campo Morado, Los Amarillos, Angosto Chico, and La Huerta) and two additional clusters associated with the southern sector (Pukará de Tilcara and Ciénega Grande; Juella and El Volcán). El Alfarcito and La Isla may be the earliest samples of the system in which the tabular erect deformation is predominant. Materials that were excavated in the Til-20 site by Mendonça et al. (1991) show the exclusive use of the tabular erect deformation in earlier times.

The magnitude of phenotypic differentiation observed in ancient inhabitants of Quebrada de Humahuaca represents a microevolutionary process that determined a strong structuring of the local population, with a significant migratory contribution of other differentiated human groups in neighboring regions.

The biological structure generally obtained for this population is in accordance with the settlement systems during the Late Intermediate and Inca (Late Horizon) periods studied by Nielsen (1989). The Los Amarillos site, west of Quebrada de Humahuaca in the Quebrada de Yacoraite, was a complex polynuclear center with an estimated population of 2,000 people. It is located in the central sector and was associated with other sites called mononuclear complexes (400–1000 inhabitants), such as Yacoraite, Campo Morado, La Huerta, and a set of simple settlements, all integrating a Maximum Subsistence Unit. Los Amarillos was an important point for the exchange of products between Puna (via the Quebrada de Yacoraite) and the eastern valleys. Analysis of phenotypic distances effectively established this relationship (Cocilovo et al. 2001b). Furthermore, in Los Amarillos, Yacoraite, Peñas Blancas, Juella, Ciénega Grande, and El Volcán, the oblique tabular deformation is more frequent than the erect tabular deformation (Cocilovo et al., 1999b).

The Pucara de Tilcara was another complex polynuclear site located south of Quebrada representing an enclave of exchange with Puna and the eastern valleys. Ciénega Grande and El Volcán, located further south, constituted key connection points with Puna and with the Yunga and the eastern valleys, respectively (Nielsen, 1989). The phenotypic cluster analysis (Cocilovo et al., 2001b) demonstrated the integration of Ciénega Grande and El Volcán with components the origin of different from the previous system controlled by Los Amarillos. The analysis of the quality of life and health status of the inhabitants of the Quebrada de Humahuaca was initially studied using 30 skeletons from the Late Intermediate period of the Pukará Tilcara. The observation of traits associated with nutritional, functional, infectious, and traumatic pathologies demonstrated that this population would represent a functionally adapted community (Mendonça et al., 1993).

In a first approximate finding, using individuals of the sites of the Late Formative (500–900 A.D.) (TIL20 and Flores-1), Regional Development I periods (900–1250 A.D.) (Muyuna), and the Regional Development II period (1250–1430 A.D.) (Los Amarillos and Hornillos), there is no evidence of nutritional stress. Additionally, significant evidence of increased occupational stress was found in the Regional Development period, as well as a high presence of caries, due to a diet rich in carbohydrates and sugars, and significant incidence of tooth wear (Seldes, 2006). Later, a high frequency of interpersonal violence related with trauma was determined at three Regional Development sites (Los Amarillos, La Huerta, and Yacoraite) of the Quebrada de Humahuaca (Seldes and Botta, 2014). In a larger Late Intermediate sample of the Valle Calchaquí and the Quebrada de Humahuaca (ca. AD 1000–1432), 14% of individuals showed traumatic injuries, with a higher frequency found in individuals from Quebrada de Humahuaca (Gheggi and Seldes, 2012).

#### VALLE CALCHAQUÍ

The Valliserrana region includes a group of valleys and ravines at 1,500–3,000 m AMSL in the provinces of Catamarca,

La Rioja, northern San Juan, western Tucuman, and western Salta, including the Valle Calchaquí (Gonzalez, 1977; Baffi and Cocilovo, 1989–1990).

The first research specifically dedicated to study of ancient inhabitants of the Valle Calchaquí was performed by Ten Kate (1896), and subsequent studies followed by Thibon (1907), Dillenius (1910), and Marelli (1915), among others. Constanzó (1942) analyzed bone material and classified it as *ándidos* following the criteria established by Imbelloni (1938), using racial morphological characters. This genetic homogeneity *ándida* was questioned by Cocilovo (1981).

The site of Santa Rosa de Tastil is located in northwest Salta at more than 3,000 m AMSL (Cigliano, 1973). Marcellino and Ringuet (1973) performed morphological descriptions of the individuals collected from this site. The sample of 39 skulls included 19 individuals with oblique tabular deformation and 9 with erect tabular deformation; in other individuals the type of deformation could not be established due to the poor state of conservation. These researchers also carried out an osteological analysis of the postcranial skeletons.

Cocilovo and Baffi (1985) examined local phenotypic variability at La Paya, a locality of Valle Calchaquí, as well as relationships with neighboring populations, by studying a sample of 55 skulls from the Ambrosetti Ethnographic Museum and using 41 metric characters. The erect tabular artificial deformation was most common, and a smaller proportion of skulls exhibited oblique tabular deformation, which agreed with findings by Constanzó (1942).

In the Valle Calchaquí population comprising the sites of Fuerte Alto, Payogasta, La Poma, La Paya, Tacuil, Luracatao, and Cachi, 87% of skull metric characters varied between sexes. Variables that did not change with sex are the orbit, nose, and palate areas. A predominance of skulls exhibited erect tabular deformation. The results showed that only 10 traits differed between adult and mature ages. A significant loss of teeth and alveolar resorption was observed, likely the result of diet and prevalent infectious diseases in this population (Baffi, 1992).

To assess phenotypic unity or diversity in various groups of the Valliserrana region using quantitative traits of the skull, an estimate was made of the biological distances between groups located in Valle Calchaquí and elsewhere in the same region (e.g., Santa Rosa de Tastil and Belén; Baffi and Cocilovo, 1989–1990). The results showed a biological unity in the Valle Calchaquí during the Late period, coinciding with the cultural homogeneity proposed by archeological research. There is also a morphological differentiation between groups from Belén and Santa Rosa de Tastil and between these two sites and Valle Calchaquí (Cocilovo and Baffi, 1985; Baffi and Cocilovo, 1989–1990).

#### PAMPA GRANDE (LAS PIRGUAS)

Las Pirguas is located at the boundary between Valliserrana and the *selvas occidentales* (western forests) regions. It is situated in the area known as Pampa Grande, Guachipas department, Salta province. The first archaeological and

bioanthropological studies in this area are from Ambrosetti (1906), Aparicio (1941), and Constanzó (1941). Thanks to later excavations carried out by Rex González from 1969 to 1971 in the mountain caves of Las Pirguas, an exceptional archaeological collection was obtained and is now housed at La Plata Museum. The Las Pirguas site corresponds to the Candelaria culture of the Early period in northwestern Argentina (Baffi and Cocilovo, 1989) and dates back to BP 1310 ± 40 (Carnese et al., 2010). Two new dates, BP 1327 ± 44 and BP 1501 ± 41, were determined for materials from Las Pirguas (University of Arizona's Accelerator Mass Spectrometry Laboratory, 2012/07/11, personal communication).

The Las Pirguas sample is composed of 80 individuals (55 adults and 25 subadults); 45 present erect tabular deformation, 2 present oblique tabular deformation, 29 are nondeformed, and 4 are undetermined. Analysis of 31 nonmetric traits revealed that none of the variables changed between sexes, one varied with artificial deformation, and three varied with age (Baffi et al., 1996).

Studies using 38 metric variables of the skull showed little sexual dimorphism—only 17 of them varied between sexes. For this group there is evidence of a low life expectancy at birth (22 years). Numerous pathologic features (porotic hyperostosis, cribra orbitalia, sinking of the maxillary bone) and a high proportion of indicators of aggression (rupture and healing of nasal bones, blows to parietal and other sectors of the vault) were observed (Baffi and Cocilovo, 1989; Baffi et al., 1996). Additionally, higher values of developmental instability were estimated for this group as compared with those calculated for other ancient populations in northern Chile (Varela and Cocilovo, 1999; Varela and Cocilovo, 2002; Cocilovo et al., 2006; Varela et al., 2006) and Puna de Jujuy (Fuchs et al. 2014). This was evaluated from the proportion of the special environmental component (26%) using bilateral metric variables of the skull. This information suggests that the inhabitants of Las Pirguas lived in an environment of great social tension, with prolonged and severe nutritional stress, and in conditions that influenced the complex processes that regulated a stable development (Baffi and Cocilovo, 1989; Baffi, 1992; Baffi et al., 1996; Medeot et al., 2008).

#### EVOLUTION OF THE POPULATION, LOCAL DIFFERENTIATION, AND REGIONAL RELATIONSHIPS

In a comparative analysis of samples from a wide region covering southern Peru to Tierra del Fuego, the formation of three groups was demonstrated by using metric traits of the splanchnocranium as well as discriminant and cluster analyses: one Andean group was integrated into the samples of Peru, Bolivia, northern Chile, and northwestern Argentina; a second group was of Fluvial Litoral and Patagonia; and a third insular group in Tierra del Fuego. The Andean group consists of two clusters—the first formed by Peru, Bolivia, and Quebrada de Humahuaca, and the second formed by Valle Calchaquí, Santa Rosa de Tastil,

and San Pedro de Atacama (northern Chile). Thus, this model represents the first hypothesis about spatial structure and kinship relationships in the studied prehistoric groups (Cocilovo, 1981). Subsequently, settlement of northwestern and northern Chile was investigated through the study of biological relationships among different samples of the south-central and southern Andean area (Cocilovo and Di Rienzo, 1984–1985; Rothhammer et al., 1984; Cocilovo and Rothhammer, 1990).

Assuming that the metric and nonmetric traits are selectively neutral with a random distribution of the nongenetic (environmental) effects, we can see that the observed phenotypic variability in the subregions of northwest Argentina is the result of evolutionary factors such as genetic drift and particular mating patterns within subpopulations, moderated by medium and long-range migration.

In a sample of 961 individuals and different statistical analyses, a marked morphological difference was demonstrated among the four subregions of northwest Argentina (Puna de Jujuy, Quebrada de Humahuaca, Valles Calchaquíes (Vallieserrana), and Las Pirguas (Selvas Occidentales)). The Puna is the most representative group of the total population because it is closest to the regional average. The formation of two clusters is observed, one associated with the Puna de Jujuy and Quebrada de Humahuaca and the other related to Las Pirguas and Vallieserrana (Varela, et al., 2004a; Paschetta, 2005).

This same pattern of geographic variation among the four subregions was obtained in the analysis of 27 nonmetric traits of the skull in 673 individuals. Furthermore, a detailed analysis of the relationship of each trait was performed according to sexual dimorphism, age, and artificial cranial deformation (González, 2004; Varela et al., 2004b). These results are consistent with previous findings (Cocilovo, 1981; Rothhammer, et al., 1984; Cocilovo and Rothhammer, 1990). There were differences between the Valle Calchaquí (Valliserrana) and the groups of Quebrada de Humahuaca (La Isla and Pukará de Tilcara). The relationship between Puna and Quebrada de Humahuaca and a greater differentiation for Vallieserrana had been observed by Varela et al. (1999) and Cocilovo et al. (2001b). On the basis of Relethford and Blangero's (1990) model for quantitative traits, a high phenotypic divergence ( $F_{ST} = 0.14$ ) was found between the four subregions of northwest Argentina (Varela et al., 2008).

According to the results obtained, the ancient population that inhabited the Argentine northwest would have originated from the same ancestral population of Andean origin, with subdivision into smaller groups that settled in different environments (Varela et al., 1999). Over the course of time and due to influence from biological and cultural evolutionary factors, the subpopulations were differentiated until they obtained the configuration that is observed in the Late period. This explanation does not exclude their possible participation in the genetic composition of groups coming from other neighboring regions such as northern Chile (medium-range migration) or from more distant regions such as the Bolivian highlands and the tropical forests (long-range migration).



Studies of ancient mtDNA show a differential distribution of haplogroup frequencies, with a predominance of B2 (47.37%) and D1 (42.11%) in Pampa Grande (Las Pirguas), A2 (72.22%) in Los Amarillos (Quebrada de Humahuaca), and C (44.45%) and A (33.33%) in Doncellas and Agua Caliente de Rachaite (Puna de Jujuy). The genetic differentiation ( $F_{ST}$ ) was 0.16 between Los Amarillos and Agua Caliente de Rachaite, 0.23 between the latter and Pampa Grande, and 0.35 between Los Amarillos and Pampa Grande (Carnese et al., 2010; Dejean et al., 2014; Fuchs, 2014; Postillone et al., 2015).

Mendisco et al. (2014) analyzed 32 individuals from different sites in the Regional Development period (A.D. 750–1500) of the Quebrada de Humahuaca and found the following distribution of mitochondrial haplogroups: 46.9% A2, 25% B2, 12.5% C1, and 15.6% D1. Genetic divergence between this group and Pampa Grande was  $F_{ST} = 0.12$ . Mendisco et al. (2014), based on the initial results of ancient mtDNA analysis, agree with the biological relationship model for northwestern Argentina previously proposed on the basis of quantitative traits from the skull (Varela et al., 2004a, 2004b, 2008; Cocilovo et al., 2009).

The greatest phenotypic affinity demonstrated between Las Pirguas and Valle Calchalquí is associated with the relationship between the ceramics of Candelaria culture observed in Las Pirguas, and the ceramics of Condorhuasi and Ciénega cultures during the Early period (Gonzalez and Perez, 1987). In addition, the observed biological affinity between Puna de Jujuy and Quebrada de Humahuaca is related with the communication and exchange between both subregions during the Late period (Otonello and Lorandi, 1987).

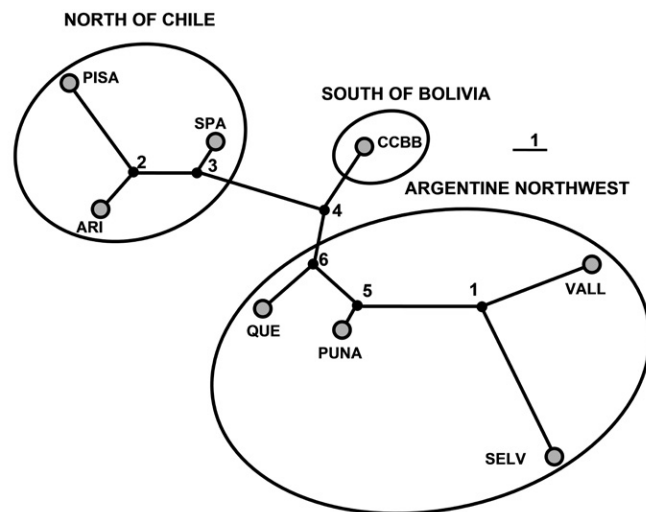
## EVOLUTION OF THE SOUTH-CENTRAL ANDEAN AREA POPULATION

The results obtained in the study of the local population structure stimulated a series of studies at the regional level covering the south-central Andean area. This research demonstrated with sufficient certainty that settlement was determined by ecological, cultural, economic, and biological factors that caused a particular dispersion of gene frequencies and differentiation of local and regional groups.

With the information available from northern Chile, northwest Argentina, and the valleys of Cochabamba in Bolivia (Figure 1), the variation between regions and subareas within each region was studied. In this study 16 skull metric traits and 1,586 adults of both sexes were used. The analysis of Mahalanobis  $D^2$  distances showed two main directions of interaction, one between the Cochabamba valleys and northern Chile and another between Cochabamba and northwestern Argentina. A higher average genetic divergence was observed for the entire region ( $F_{ST} = 0.195$ ); northwestern Argentina showed the highest spatial isolation ( $F_{ST} = 0.143$ ), and northern Chile displayed the lowest ( $F_{ST} = 0.061$ ). The findings revealed a settlement pattern based on the dispersion of several lines from a common

ancestral population. During 400 generations, these lines differed in space and time, originating human groups that inhabited the region (Varela et al., 2008). Possibly, the population of the Cochabamba valleys retained much of the original genetic variation.

To test the above evidence, a similar model based on the distribution of cranial nonmetric traits was proposed. A sample of 1,416 individuals representing both sexes and encompassing a range of 4,500 years was analyzed. Twelve cranial discrete traits recorded as presence–absence were used. Differences between subareas were evaluated by means of MMD and Mahalanobis  $D^2$  distances calculated from main components. Both phenotypic distance matrices were highly correlated, indicating a significant differentiation at the regional level. The greatest distance was observed between northwestern Argentina and northern Chile, whereas Bolivia holds an equidistant position between the two regions. There is a closer link between Cochabamba and northwestern Argentina and a greater divergence between these two regions and northern Chile (Figure 2). The previous results were consistent with the settlement pattern established by Varela et al. (2008), based on the existence of several lines gradually differentiating towards the South during the exploration of new environments, because conquest and colonization ensured the survival of the population (Cocilovo et al., 2009).



**FIGURE 2.** Neighbor-joining tree obtained from a pair-wise Mahalanobis  $D^2$  distance matrix illustrating directions of interaction between the Cochabamba valleys and northern Chile and between Cochabamba and northwestern Argentina (Varela et al. 2008). Abbreviations: ARI, Arica; CCBB, Cochabamba; PISA, Pisagua; PUNA, Puna Jujeña; QUE, Quebrada de Humahuaca; SELV, *selvas occidentales* (western forests); SPA, San Pedro de Atacama; VALL, Valliserrana.

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# Paleopathology in Southern South America: Recent Advances and Future Challenges

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**ABSTRACT.** Despite disparities among countries, paleopathology experienced a remarkable development in South America in recent years, including current theoretical approaches and new methodological procedures. More specialists in bone and dental paleopathology offered relevant information in local, regional, and international journals and conferences. Some southern South American countries, particularly Chile and Argentina, are leaders in the recent progress of paleopathology in the Americas. This paper summarizes the recent past and present of paleopathological research in southern South America and offers additional considerations about the challenges that need to be confronted in the near future.

**RESUMEN.** A pesar de una serie de diferencias existentes entre países, la paleopatología tuvo un notable desarrollo en Sudamérica durante los últimos años, incluyendo la incorporación de enfoques teóricos modernos y la aplicación de nuevas metodologías. Una mayor cantidad de especialistas en paleopatología ósea y dental han ofrecido información relevante, presentada en revistas y conferencias locales, regionales e internacionales. Algunos países del sur de Sudamérica, en especial Chile y Argentina, tienen una influencia fundamental en el reciente progreso de la paleopatología en América. En este trabajo analizamos el pasado reciente y presente de las investigaciones paleopatológicas en el sur de Sudamérica y ofrecemos consideraciones adicionales acerca de los retos que deben ser enfrentados en el futuro próximo.

**RESUMO.** Apesar das diferenças existentes entre os vários países, a paleopatologia teve nos últimos anos um notável desenvolvimento na América do Sul, tanto pela incorporação de abordagens teóricas atuais como pela aplicação de novas metodologias. O aumento do número de especialistas em paleopatologia óssea e dentária teve como consequência a produção de informações relevantes, apresentadas em revistas e conferências, locais, regionais e internacionais. Em especial o Chile e a Argentina tiveram uma influência fundamental no recente progresso da Paleopatologia na América do Sul. Este capítulo sintetiza o passado recente e o presente da pesquisa paleopatológica no sul da América do Sul, fornecendo considerações adicionais sobre os desafios que devem ser enfrentados no futuro próximo.

## INTRODUCTION

As in other regions in the world, paleopathology has seen considerable development in South America since the second half of the twentieth century. New theoretical and methodological approaches have been introduced to the study of social, cultural, and

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Manuscript received 28 April 2016; accepted 10 November 2017.

biological influences on the health of past societies both before and during the colonial period. Primary results of this progress in paleopathological research include a greater number of specialists in interpreting evidence of past health; more scientific studies being undertaken at local, regional, and worldwide levels and more numerous international collaborations, which usually result in a higher quality of resources, broader knowledge and more broadly accepted interpretations.

South America is a large and heterogeneous continent with marked differences in economic and educational status between countries. In the past, the continent was inhabited by numerous human societies with profound biological and cultural differences, from highly stratified societies like the Incan Empire in the Andes, to small bands of hunter-gatherers like Selk'nam in Tierra del Fuego (Steward, 1963; Poole, 2008). This variability means that research in paleopathology is also amply diverse, depending on available resources and focusing on different aspects of past populations according to local and academic interests.

In this chapter, we describe and analyze the current status of paleopathology in Chile, Bolivia, Paraguay, Uruguay, and Argentina, the southernmost countries of South America. As is usual in this kind of review, it is a great task to gather all the published results from every country. For that reason, we opted to include only the most relevant investigations, particularly those reported during the last three decades, although in some cases previous research is included considering its importance in later local developments. It is not our intention to summarize the history of paleopathology in these countries, since this approach was partially or fully conducted in the recent past (for example, Castro and Aspillaga, 2004; Guillén, 2012; Mendonça de Souza and Guichón, 2012). On the contrary, we offer an integrated interpretation of recent investigations and, in our opinion, the most important challenges that paleopathology will deal with in this part of the world in the near future.

## PALEOPATHOLOGY IN CHILE

Chilean paleopathology is one of the most developed in southern South America. Past populations from northern Chile received extraordinary attention, stimulating the current paleopathological perspective (Verano and Lombardi, 1999). This is probably because stratified and unequal Andean societies developed in this region over the course of about two millennia, and its climate promotes preservation of a great number of mummified and skeletal remains (Verano, 1997). A considerable number of studies were also performed on the remains recovered from southern Patagonia, including current Chilean and Argentinian territories. Regrettably, populations from other Chilean regions received less attention (Castro and Aspillaga, 2004). Some reviews of the most relevant results were presented by Munizaga (1974), Allison (1984), Moreno et al. (1993), Castro et al. (1997), Verano (1997), Castro and Aspillaga (2004), and Rothhammer and Llop (2004).

The studies in northern Chile were mainly centered on skeletal and mummified remains from the Arica and Tarapacá regions. As in other South American countries, like Peru or Ecuador, paleopathological research was initially led by foreign physicians and physical anthropologists, such as Aleš Hrdlička, Marvin Allison, Enrique Gerszten and Arthur Aufderheide, who stimulated the study of several collections of skeletons and mummies, offering much relevant information about cultural and biological aspects related to human health in pre- and post-Hispanic times. Most of these investigations continued with modern approaches by local or foreign researchers (Verano and Lombardi, 1999).

The studies of health mainly focused on evidence of several infectious diseases in northern Chilean populations. The detection of remains with signs of tuberculosis (Arriaza et al., 1995) was extremely important to explain its presence in pre-Columbian Andean populations. Chagas disease (Guhl et al., 1997, 1999, 2000; Ferreira et al., 2000; Aufderheide et al., 2004; Orellana-Halkyer and Arriaza, 2010), treponematosi (Allison et al., 1982; Standen and Arriaza, 2000a), leishmaniasis (Costa-Junqueira et al., 2009; Marsteller et al., 2011; Costa-Junqueira and Llagostera, 2014), pulmonary diseases like pneumonia (Aufderheide et al., 2002; Aufderheide et al., 2008), and non-specific infectious diseases (Kelley and Lytle, 1995; Aspillaga et al., 2006; Varela et al., 2006; Tótora Da-Glória et al., 2011) were also reported in several archaeological contexts. Paleoparasitological studies of internal and external parasites were also conducted in the last several decades (Ferreira et al., 1984; Goncalves et al., 2003; Reinhard and Urban, 2003; Arriaza et al., 2010a, 2012, 2013, 2014; Araújo et al., 2011; Rodríguez et al., 2011).

As in other stratified and highly populated societies, trauma was frequently evaluated in populations from northern Chile, where evidence of accidental, ritual-based, and violent injuries were studied, mostly from a paleoepidemiological and biocultural approach (Costa-Junqueira et al., 1998; Standen and Arriaza, 2000b; Lessa and Mendonça de Souza, 2004, 2006, 2007; Rosado and Vernacchio-Wilson, 2006; Torres-Rouff and Costa Junqueira, 2006; Varela et al., 2006; Standen et al., 2010; Torres-Rouff, 2011; Castelleti Dellepiane et al., 2014; Lessa, 2014; Lessa and Gaspar, 2014; Pacheco and Retamal, 2014). These papers show a process of increasing violence in certain strategically located areas of the landscape (such as the Atacama desert during the Middle Horizon [600–950 A.D.] and Late Intermediate Period [950–1400 A.D.], Lessa and Mendonça de Souza, 2004, 2006; Torres-Rouff and Costa Junqueira, 2006; Standen et al., 2010; Torres Rouff, 2011, Lessa, 2014), which affected individuals differently by sex, age, and social hierarchy, with traumatic lesions being more prevalent in young and middle adult males.

The effects of arsenic poisoning on the health of past human populations from Atacama was first suggested three decades ago, in studies showing teratogenic consequences on skeletal and mummified remains (Figueroa et al., 1988; Silva-Pinto et al., 2010; Boston and Arriaza, 2009; Arriaza et al., 2010b; Byrne et al., 2010). Other studies with important consequences analyzed



the impact of diseases related to activity patterns in northern Chilean populations, including auditory exostosis (Standen et al., 1995, 1997; Ponce, 2010), osteochondritis dissecans (Kothari et al., 2009; Ponce, 2010), and osteoarthritis (Silva-Pinto et al., 2013). Pathological conditions such as neoplastic (Sawyer et al., 1988, 1990; Gerszten and Allison, 1991), neurological (Gerszten and Martínez, 1995; Appenzeller et al., 2000; Gerszten et al., 2001; Carod-Artal and Vázquez-Cabrera, 2004), and oral diseases (Linossier et al., 1988; Rosado, 1998; Costa-Junqueira et al., 2004; Meller et al., 2009; Hubbe et al., 2012; Watson et al., 2013), as well as related paleodemographic analyses (Arriaza et al., 1988; Quevedo et al., 2000, 2003), also were documented and offered very valuable contributions to the comprehension of the variability of human adaptations.

In contrast, studies of health in past populations from southern Chile were less thoroughly analyzed, mostly with bioarchaeological or physical anthropological approaches. A review of this kind of information in southern Chile and Argentina, reported during the last three decades, was recently published by Suby (2014a). In general, due to the absence of cemeteries in pre-historical times and areas of inhumation with low numbers of individuals, mostly one per site, many researchers have studied skeletal collections from different archaeological sites, with or without chronological and geographical information. In contrast to the studies conducted in the north of the country, these analyses were mainly focused on the general health status of human populations. Pérez-Pérez and Lalueza Fox (1992), Guichón (1994), Aspíllaga et al. (1999, 2006), Morano and Bucarey (2009), and Castro and Aspíllaga (1991) described or quantified metabolic, oral, and articular diseases in human collections from southern Chile. Moreover, Constantinescu (1999, 1997) presented descriptive analyses of enthesal changes and articular disease in a skeletal collection from the insular and continental portions of the Magellan region. Paleopathological analyses of anemia (Suby, 2014b) and vertebral joint disease (Suby, 2014c) were carried out in skeletons recovered in the southern territories of both Chile and Argentina.

Several descriptive and quantitative analyses of oral health, metabolic disease, trauma, and osteoarthritis in human remains were published during the last decade, such as the studies of the skeletons recovered in Cabo Nose (Alfonso-Durruty et al., 2011), Cañadón Leona 5 (L'Heureux and Amorosi, 2009), and Cerro Sota (L'Heureux and Amorosi, 2010), located in the Magellan region of Chile. Regarding infectious diseases, Saez (2008) documented possible cases of tuberculosis in native populations from Chiloé as a result of contact with European settlers during the colonial period and suggested that this disease was a primary cause of morbidity and death.

## PALEOPATHOLOGY IN BOLIVIA

Paleopathological research in Bolivia is much less developed. A review of the most important paleopathological analyses

was summarized by Rio Dalenz and Vincenty (2007). As with others from southern Peru and northern Chile, remains from western Bolivia were initially studied by foreign scientists in the nineteenth century. Bandelier (1904) recovered and anthropologically studied trephined skulls from Aymará sites, which were sent to the American Museum of Natural History (New York) and were later studied by Aleš Hrdlička. Most current paleopathological studies continue to focus on human remains from the Aymara populations, mainly through studies of mummies. For example, Suarez Morales (1967) reported serologic analyses of 10 mummies housed in the National Museum of Archaeology in La Paz, all corresponding to blood group 0, which is similar to other findings in Latin America. More recently, Mendonça de Souza et al. (2008) studied a mummified body of a seven-year-old child, with the possibility of perimortem trauma and tuberculosis. Moreover, Vincenty (2004) offered descriptive macroscopic, radiological, and histological results of five pre-Inca mummies from Potosí and Oruro, and identified cases of thyroid goiter, congenital anomalies (probable atrophy), infant hydrocephaly with trepanation, scoliosis, fibroma, and a sharp trauma with hemorrhage. Virus HTLV-1—responsible for leukemia and lymphoma in adults and for tropical spastic paraparesis—was molecularly identified in bone marrow of mummies of ca. 1500 BP housed in the Archaeological Museum R. P. Gustavo Le Paige of San Pedro de Atacama (Li et al., 1999).

Céspedes and Villegas (1976) visually and radiographically studied 418 pre-Columbian non-adult and adult skulls housed in the National Museum of Archaeology of La Paz, Regional Archaeological Museum of Tiwanaku, and Anthropological Museum Eduardo López Rivas of Oruro, in order to identify dental and cranial pathologies. The authors described and quantified several types of dental anomalies, such as transpositions, supernumerary teeth, teeth displaying gigantism and dwarfism, retentions, caries, dental calculus, granulomas, antemortem tooth loss, and attrition. They also described trepanations and the frequencies of wormian bones.

The study of infectious diseases was also explored in Bolivian remains. Paleoparasitological studies mention that Chagas disease—an infectious illness with great implications for sanitation in South America even today—originated in the Bolivian highlands as a consequence of the adoption of sedentary habits by prehistoric human groups (Araújo et al., 2013). Moreover, a study performed by a German-Bolivian team on 123 pre-Hispanic skeletons from the Loma Salvatierra site in the northern lowlands (Prümers et al., 2012) showed a high degree of degenerative joint disease, absence of evidence of violence, frequent indicators of anemia (i.e., cribra orbitalia and porotic hyperostosis) and signs of bone infections. Two of those skeletons showed sabre-shin tibiae and signs of Hutchinson's disease in the incisors, which was interpreted as being caused by a treponemal disease, possibly venereal syphilis, based on morphological and molecular results (Prümers et al., 2012). Ponce Sanjinés (1982) interpreted humped figures of ceramic iconography from the Americas as cases of vertebral tuberculosis. Finally,

some paleopathological analyses of camelid and bovine remains recovered from colonial sites in Potosí showed degenerative changes to phalanges, vertebrae, tarsals, limb elements, and ribs (Defrance, 2008). Most of the scarce paleopathological research in the country is primarily descriptive in nature, although this trend is starting to be reversed through the development of more integrative and interpretative research.

### PALEOPATHOLOGY IN PARAGUAY

Despite the many anthropological studies on populations of the Aché and other related ethnic groups (e.g. Hill et al., 1984, 1985, 1987, 1997, 2007; Bribiescas, 2001; Gurven et al., 2001; Hurtado et al., 2003; Tsuneto et al., 2003; Walker and Hill, 2003; Dornelles et al., 2004; Schmitt et al., 2004), very little paleopathological data are available for indigenous groups from Paraguay. Among the most important is that of a postcranial skeleton of a 15-year-old girl known as “Damiana,” who was kidnapped after the assassination of her family in 1896 and died of tuberculosis. In 2010, the Natural Science Museum of La Plata, Argentina, returned her remains to the Aché community. Later, the skull of this skeleton was identified in the anatomical collection of Charité, in Berlin (Koel-Abt and Winkelmann, 2013). Paleopathological analyses were conducted, showing signs of stress-like cribra orbitalia and dental enamel hypoplasia, as well as endocranial impressions that were interpreted as the result of tuberculous meningitis (Koel-Abt and Winkelmann, 2013).

### PALEOPATHOLOGY IN URUGUAY

Anthropological disciplines, including paleopathology, are quite recent in Uruguay (Figueiro, 2014). The main focus of skeletal research comprises mortuary practices, age and sex estimation, diet and molecular analyses for studying biological distance among populations, and in some cases, descriptive references of bone and dental pathologies (for example, see Sans et al., 1997, 2012; Moreno et al., 2014; chapters in López Mazz and Sans, 1999). However, systematic paleopathological studies, as in Paraguay and Bolivia, are still uncommon.

The studies produced in the last twenty years were mainly concerned with establishing the health status of past populations. Most studies used samples from east and west regions of the country, analyzing oral stress indicators (e.g., caries and linear enamel hypoplasia), signs of non-specific bone infections, anemia (cribra orbitalia and porotic hyperostosis), Harris lines, and muscular stress markers (Portas and Sans, 1995; Sans et al., 1997; Sans, 1999; Calabria, 2001). Some studies on osteoarthritis, Schmorl's nodes (Sans, 1999) and trauma (Pintos and Bracco, 1999; Gascue, 2009; Gianotti and López Mazz, 2009; Cabrera et al., 2014) were also reported, most of which are mainly descriptive because of small sample size. However, efforts for systematization appeared in recent years (for example see Figueiro, 2014).

The general trends identified show few differences between sexes, with an increase in mechanic and oral pathologies with age and trauma through time (Gianotti and López Mazz, 2009; Cabrera et al., 2014). Some exceptions are highlighted considering oral health for late pre-Hispanic societies, with variations inferred in diet composition between males and females, and among different individuals buried in the same site (Sans, 1999). Finally, a recent contribution from forensic anthropology about rights violations also adds relevant information about perimortem lesions (López Mazz et al., 2014).

### PALEOPATHOLOGY IN ARGENTINA

As in Chile, paleopathological studies of past populations from Argentina have seen remarkable progress since 1980, especially during the last two decades. In contrast to research developed in northern Chile, research in Argentina is strongly influenced by the North American bioarchaeological approach (e.g., Buikstra, 1977; Buikstra and Cook, 1980; Buikstra and Beck, 2006; Cook and Powell, 2006), probably due to the development of important and numerous long-term archaeological programs, as well as the number of grants awarded in Argentina. In fact, most of the students working in paleopathology in the country are archaeologists. For that reason, taphonomical and mortuary issues are constantly included as part of paleopathological studies (Aranda and Luna, 2012; see chapters in Luna et al., 2014a).

Mendonça de Souza and Guichón (2012) offer a review of the history of paleopathology in Brazil and Argentina. Also, the most recent advances of bioarchaeological studies of past human populations from Argentina were recently summarized (Aranda and Luna, 2012; Luna and Suby, 2014). As described in those articles, paleopathological research received increasing attention during the last two decades as part of bioarchaeological studies, focusing on the health of past populations from a biocultural approach in all regions of Argentina. Many of them include modern methodological and analytical procedures, together with regional and anthropological approximations. The investigations are very prolific, so the articles mentioned in this section are only a small part of the whole body of paleopathological research in the country. In the last two decades, Argentinean research in paleopathology reached international scientific standards, and, as a consequence of that, it began to gain recognition in the rest of the world. As an example of this process, many studies were published in international journals, encompassing the analysis of multiple lines of evidence, including those from the northwest (Arrieta et al., 2014; Seldes and Botta, 2014; Luna et al., 2015; Gheggi, 2016), the center of the country (Fabra and González, 2015; Fabra and Salega, 2016), the western center (Bernal et al., 2007; Gómez Otero and Novellino, 2011; Ponce and Novellino, 2014), the Pampa (Luna et al., 2008; Luna and Aranda, 2014; Scabuzzo, 2012), northern Patagonia (Flensburg, 2011a; Flensburg, et al., 2013; Gordon, 2015), the central coast of Patagonia (Gomez Otero and Novellino, 2011), and southern Patagonia

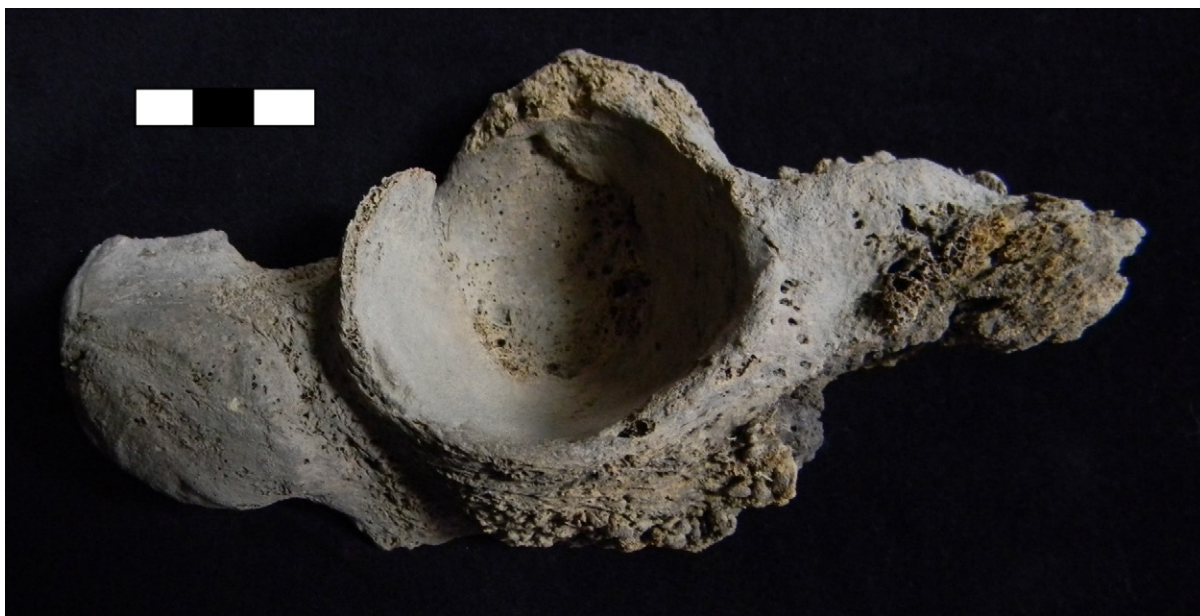
(Suby and Guichón, 2009; Suby et al., 2009, 2017; Suby, 2014b, 2014c). Paleopathological studies in all these regions were usually oriented to the study of the health status of past human populations through metabolic and oral diseases, in some cases considering current theoretical and methodological approaches and integrating different variables on a comparative perspective (García Guraieb, 2006; Seldes, 2006; Luna, 2008; Suby et al., 2013; Suby, 2014b; González Baroni, 2014).

In addition, some studies were aimed at specific diseases. Tuberculosis was suggested in pre-Columbian remains from the northwest and south of Argentina (Arrieta et al., 2011, 2014; García Guraieb 2006; Guichón et al. 2015) and treponematosi in southern Patagonia (García Guraieb et al., 2009; Castro et al., 2008), as well as cases of osteomyelitis (Flensburg et al., 2013). Degenerative joint disease of the vertebrae was specifically studied in the center of the country (Fabra et al., 2014) and in Patagonia (Suby, 2014b). Oral pathologies were frequently studied in different areas of the country, including analyses of oral pathologies such as caries, periodontal disease, abscesses, calculus, antemortem tooth loss, dental wear (L'Heureux, 2002; Novellino, 2002; Novellino et al., 2004; Bernal et al., 2007; Menéndez, 2010; Bernal and Luna, 2011; Flensburg, 2011a; Gómez Otero and Novellino, 2011; Luna and Bernal, 2011; Gheggi, 2012; Miranda, 2012; García Guraieb and Maldonado, 2014; Luna and Aranda, 2014; Miranda and Fuchs, 2014) and physiological stress (enamel hypoplasia; e.g., Novellino and Gil, 2004; Luna and Aranda, 2010). In general terms, the results are compatible with trends identified in other regions of the world:

hunter-gatherer societies show high wear rates, periodontic reactions, calculus, antemortem tooth loss, and low prevalence of caries; on the other hand, individuals from agricultural societies exhibit lower dental wear and a higher frequency of caries. In both types of societies, differences between sexes are minimal.

In recent years, systematic research about violence patterns from a paleopathological perspective were fulfilled in different regions of Argentina (Barrientos and Gordon, 2004; García Guraieb et al., 2007; Flensburg, 2011b; Gheggi and Seldes, 2012; González Baroni, 2013; Berón, 2014; Gordón, 2015; Politis et al., 2014). Finally, analyses about neoplastic (Luna et al., 2008, 2015; Figure 1) and congenital diseases (Fabra and Salega, 2016) are very scarce but have been recently published. The comparative results usually show striking differences between hunter-gatherer and agricultural societies, as expected, but also a high variability within them, related to sex and age variation in some of the variables considered, mainly degenerative joint disease and oral health. Some divergent trends were identified related to the second line of analysis (e.g., Miranda, 2012; Fabra et al., 2014; Luna and Aranda, 2014), which offer support for the high diversity of each mode of subsistence. In this sense, more integrative paleopathological research is needed in order to better comprehend the different pathways covered by the pre-Columbian societies in various temporal and spatial settings.

In contrast to studies of skeletonized remains, mummified remains were much less frequently analyzed (Fernandez et al., 1999; Previgliano et al., 2003; Wilson et al., 2007, 2013; Cortals et al., 2012), contrasting with the long-standing tradition



**FIGURE 1.** Left os coxae lateral view of a middle adult male from the Pukara de la Cueva site, Jujuy province, northern Argentina, showing nodular and irregular bone outgrowth probably corresponding to metastatic prostate cancer (see Luna et al., 2015). Photo: Leandro Luna.

of mummy studies from Peru and Chile. Identified modern skeletal collections, such as those of Chacarita (Bosio et al., 2012) and Lambre (Salceda et al., 2009, 2012), are being formed with individuals who died during the twentieth century and offer relevant results to the study of bone pathologies (Plischuk and Salceda, 2011; Plischuk, 2012; Plischuk et al., 2014), sex and age-at-death methods (García Mancuso, 2013; Desántolo, 2013), and differential preservation (Luna et al., 2012).

Directly related to paleopathology, forensic anthropology, working on the documentation of human rights violations, has had an outstanding development in Argentina since the 1980s as a result of the need to identify skeletal remains of individuals assassinated during the last military government of 1976–1983. The Argentine Forensic Anthropology Team (Equipo Argentino de Antropología Forense [EAAF]) is recognized worldwide as one of the pioneers and leaders in this field, also contributing to the identification of skeletal pathologies (EAAF, 1990, 2009; Olmo and Salado Puerto, 2008).

### **THE PRESENT STATE AND FUTURE CHALLENGES IN SOUTHERN SOUTH AMERICAN PALEOPATHOLOGY**

Paleopathological studies of southern South American populations made significant progress during the last century, with a great potential to continue contributing important data to the understanding of ancient diseases. Changes in theoretical approximations led to tremendous improvements in social and biological explanations from a bioarchaeological perspective since the 1980s. The examination of stratified and non-stratified societies from different historical contexts of the sub-continent offers invaluable insights about the evolution of many diseases that affect humankind and its relationship with social and biological factors in the present. Some evidence of that can be found in the important discoveries about tuberculosis during the 1970s and 1980s in South American remains, which forced reconsideration of the spread of this complex disease through time. In the same way, the information provided by the studies of mummies from Chile and Peru were, and still are, central to understanding some diseases only present in such remains.

As in other regions of the world, paleopathology had a promising beginning in the late nineteenth century. However, in some countries, studies were performed by foreign scholars, with or without local professional participation, and sometimes with relatively little involvement in the social problems of the working areas. In many cases, research was not sustained during the majority of the twentieth century. More constant and valuable data derived from fully scientific approaches began to emerge only in the last three or four decades. As a result, some countries show scarce paleopathological production, especially within the international literature.

The bright side is that the twenty-first century offers new opportunities to increase paleopathological research in South

America. In the first place, advances in internet communication allow bridges to be built between distant researchers much more easily than before. As a consequence, information travels and is shared faster with anyone with enough interest, and collaborative research projects among researchers of different countries from South America and all around the world is now a more affordable possibility. Travel is not always necessary, and academic efforts can be integrated with economic resources. This is a major issue for southern South American countries, whose economic resources are usually lower in comparison to North American and European countries.

During the last decade, new discussion forums were created. The Paleopathology Association Meetings in South America (PAMinSA) started in 2005 in Rio de Janeiro, Brazil, and provided a great opportunity not only to show the regional scientific research to foreign scholars, but also to spread paleopathological resources from more developed regions to others that need encouragement for their emerging efforts. The participation of internationally recognized specialists in paleopathology and bioarchaeology surely provide significant help to promote these meetings, and will probably be important to sustain them in the future. Chile and Argentina were hosted these meetings in 2007 and 2009 respectively. They returned to Argentina in 2015 and were held again in Chile in October 2017 and in Brazil in 2019. In between, Peru (2011) and Colombia (2013) hosted PAMinSA ([www.quequen.unicen.edu.ar/paminsa/](http://www.quequen.unicen.edu.ar/paminsa/)).

Disparity in production is not only regional, but also topic-related. In some cases, as in northern Chile, paleopathological studies are centered on specific diseases and cases. An exception is trauma analysis, which has been a very prolific focus of attention. In contrast, in southern Chile, Argentina, and Uruguay, energy was focused on the study of multiple stress markers to understand changes in the health status of human groups. Primarily, changes in health indicator prevalence in a spatial and temporal perspective were explored, in relation to the exploration and colonization of new ecosystems, demographic changes, dietary patterns (e.g., introduction of agricultural practices and new resources as result of the European conquest), and socio-cultural variations (e.g., those produced by the contact between natives and Europeans). Many of these results are published in international journals, while others are communicated in indexed local or regional publications, in many cases with free access by scholar networks such as [www.scielo.org](http://www.scielo.org), which gathers the information of a great number of scientific journals from Latin America, Portugal, and Spain.

Pre-Hispanic populations from South America were culturally and socially very diverse, varying from very stratified and unequal societies to low-density hunter-gatherers adapted to very different ecological settings. The stratified societies exhibited high demography dynamics, overcrowding, high prevalence of infectious diseases, interpersonal violence, and human sacrifices, while the hunter-gatherers demonstrated varying frequencies of non-specific stress indicators such as enamel hypoplasia, cribra orbitalia (Figure 2), porotic hyperostosis and Harris lines.

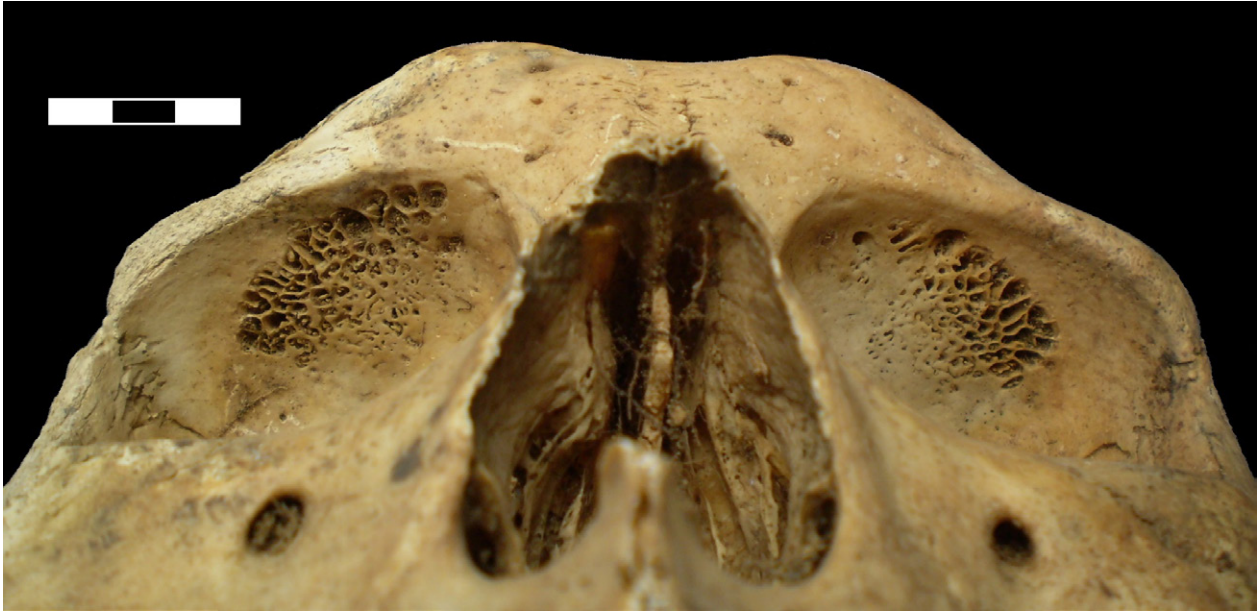


FIGURE 2. Active *cribra orbitalia* in a skull from Tierra del Fuego island, Argentina. Photo: Jorge Suby.

Because of this variability, bioarchaeological records of past societies are dissimilar in many regions of South America. While in some places hundreds of skeletons could be studied, in others, only a couple dozen are available, which forces the adjustment of aims, methods and perspectives. But even in those cases, valuable information has been reported and is enthusiastically welcomed in international meetings and journals.

New challenges will emerge in the coming years. High level and original scientific production is being created in some southern South American countries, such as Chile and Argentina, with increasingly higher international impact, although this goal still needs to be deepened and spread to the other countries in the region. In many cases, the most recent theoretical and methodological advances are systematically incorporated into bioarchaeological and paleopathological research, providing rigorous results. Interdisciplinary interaction in paleopathological studies needs to be deepened, although this is not exclusively a regional problem (Mays, 2012). In this matter, research groups completely oriented to paleopathological studies that include multiple kinds of data (archaeological, biological, medical, among others), are not yet common in southern South America and need to be addressed in the near future. More participation of South American scholars in international forums, such as the Paleopathology Association (PPA) meetings of North America and Europe, is another aspect required in order to create new collaborative bonds and to promote regional results and discussions, which in some cases are so isolated that they do not register on the international scene. Economic constraints of South American countries are an omnipresent obstacle to this aspect. Finally, another important issue to be highlighted is the need for

the creation of methodological consensus regarding the criteria for the evaluation of variables, in order to ensure that the results generated by different researchers are comparable (Luna et al., 2014b).

In conclusion, paleopathology in southern South America shows significant scientific dynamics, especially in countries like Argentina and Chile, and an accelerated development is expected in the coming years, with high-quality articles. In the remaining countries, research potential is remarkable, since they offer adequate samples, and the main goal is to achieve the formation of local specialized resources on the academic and societal levels that address paleopathological problems from a population perspective.

## ACKNOWLEDGMENTS

We would like to thank Sonia Colantonio and Douglas Ubelaker for their kind invitation to write this chapter, and Ana Luisa Santos for revising the abstract in Portuguese.

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# The Development of Forensic Anthropology in Argentina, Chile, and Uruguay: A Brief History

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**ABSTRACT.** This work describes the development of forensic anthropology in Argentina, Chile, and Uruguay, both as an emergent field of science and as it relates to the historical and political processes that have influenced its application. The need to recover and identify a large number of skeletal remains corresponding to missing persons in the decades of the 1970s and 1980s has honed this application of anthropology with a particular development that has been witnessed across Latin America. This development, which reaches beyond the normal scope of the state, is a salient feature of the integration of the three classical orientations of anthropology: social, biological, and archaeological. The increasing dependence on forensic anthropology by operators of social justice—judges, prosecutors, police, and other forensic specialists, as well as new generations of students—reflects the growth of the specialty and the need to continue its refinement.

**RESUMEN.** El objetivo del presente trabajo es describir el desarrollo que la antropología forense ha tenido en la Argentina, Chile y Uruguay, tanto en cuanto a sus orígenes como en relación con los procesos histórico/políticos que han influenciado su aplicación. La necesidad de recuperar e identificar un gran número de restos esqueléticos, correspondientes a personas desaparecidas en las décadas de los 70s y 80s, ha producido que esta aplicación de la antropología tenga un desarrollo particular, similar al de otros países del continente que pasaron por procesos similares. Este desarrollo, realizado dentro y fuera del ámbito habitual del Estado, tiene por característica más saliente, la integración de las tres orientaciones clásicas de la antropología, la social, la biológica y la arqueológica. El creciente interés en la antropología forense por parte de los operadores de justicia habituales—jueces, fiscales, policías y otros especialistas forenses—así como por las nuevas generaciones de estudiantes, refleja el crecimiento de la especialidad y su necesidad de continuar su consolidación y expansión.

**RESUMO.** O objetivo deste capítulo é descrever o desenvolvimento da antropologia forense na Argentina, Chile e Uruguai, tanto as suas origens como a sua relação com os processos histórico-políticos que influenciaram a sua aplicação. A necessidade de recuperar e identificar um grande número de restos humanos esqueletizados, correspondentes às pessoas desaparecidas nas décadas de 70 e 80, resultou na aplicação da antropologia com um desenvolvimento semelhante ao de outros países em situação semelhante. Este crescimento, feito fora e dentro do âmbito do Estado, tem como traço saliente a integração das três vertentes clássicas da antropologia, social, biológica e arqueológica. O interesse crescente pela antropologia forense por parte dos operadores de justiça, procuradores, polícia e outros especialistas forenses, assim como das novas gerações de estudantes, refletem o crescimento desta especialidade assim como a necessidade de continuar a sua consolidação e expansão.

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*Manuscript received 28 April 2016; accepted*

*10 November 2017.*

## INTRODUCTION

The origin and development of forensic anthropology in Argentina, Chile, and Uruguay did not result from a planned academic advance or a decision by the forensic services providing assistance to the judicial system. Rather, they were the result of the political situation prevailing in these countries during the 1970s and 1980s. After democracy was restored, the need emerged to investigate the fate of the thousands of persons who went missing due to the actions of the military dictatorships that governed them.

The most evident consequence of this unorthodox origin, similar to the case of Guatemala or Peru, was that the discipline of forensic anthropology would have a broader scope, integrating aspects more related to the work with the victims' families and thus providing the scientific analysis with a more holistic and richer perspective. In a way, the direction that forensic anthropology took in these countries involves the three major areas of anthropology: social, archaeological, and biological anthropology (Doretti and Snow, 2003; Fondebrider, 2009).

This distinct development of forensic anthropology has led to a practice that is somewhat different from that which generated the discipline in countries such as the United States, as well as from its subsequent development in England, Canada, Australia, and some European countries, in which a classical approach is applied, based on the analysis of the human skeleton from a biological perspective and on the recovery of remains in forensic (Fondebrider, 2009).

## THE POLITICAL CONTEXT

In Argentina, Chile, and Uruguay, democracy was interrupted by a series of military coups d'état (in 1976, 1973, and 1973, respectively), in the context of the Cold War and of revolutionary movements throughout Latin America between 1960 and 1970. The characteristics of the military dictatorships that ruled the three countries as well as their impact on the human, legal, economic, and political realms have been profusely documented (Robben, 2005; Roniger and Sznajder, 1999; Spooner, 1999). For the purposes of this paper, it is relevant to note that during the three dictatorships (which ended in 1983, 1989, and 1985, respectively) thousands of persons were kidnapped and subsequently killed with nothing known about their fate, which gave rise to the concept of "the disappeared" (approximately 30,000 persons in Argentina, 3,000 in Chile, and 150 in Uruguay). After the reestablishment of democracy, the need to conduct investigations in order to learn what had happened to the victims of enforced disappearance became a key element in the transition period.

Each country, with differences specific to their political context, used a method of investigation involving a combination of the so-called "Truth Commissions" and local judicial action,<sup>1</sup> seeking to determine what had occurred to the disappeared and to establish responsibilities for the crimes committed.

One of the primary tasks was to discern and describe the methods used to cause the disappearance of people as well as to determine the location of their bodies. Gradually, information became available indicating that after being kidnapped, people were killed and their bodies were buried in individual or mass unmarked graves at different cemeteries, burnt in clandestine graves, thrown into abandoned mines (as in the case of Chile), or into the Plata river or the sea (in the case of Argentina). It was also discovered that, on some occasions, the criminals returned to the place where the bodies had been buried to remove the remains and deposit them in another place or simply destroy them.

## THE FORENSIC SERVICES

Upon the beginning of the above-mentioned investigations into the fate of the disappeared, particularly the exhumation and analysis of skeletal remains, it was only natural for judges to resort to forensic officials from such services. In the three countries under analysis, the forensic services assisting the courts report to the Judiciary, although there are also forensic experts in the police. But this was affected by two facts that led to the emergence of independent alternatives. On the one hand, the victims' families did not trust the forensic professionals working for the state. In spite of the new democratic period, many of these physicians had been members of the forensic system under the dictatorships, and their reputations were questionable. On the other hand, there was a lack of training and expertise in handling skeletal remains. In light of such circumstances, it became necessary to find forensic alternatives independent from the official system.

## THE ACADEMIC SYSTEM

The disciplines naturally associated with the recovery and analysis of skeletal remains—archaeology, biological anthropology, and medicine—were well developed in Argentina, Chile, and Uruguay. In Argentina and Chile, there were numerous archaeologists working in different regions and many archaeology and anthropology university departments. Moreover, a number of archeological sites containing human remains were recovered and studied by biological anthropologists as part of their research projects funded by different State agencies.

In spite of such development, the forensic systems, with the exception of Uruguay, had not incorporated archaeology or biological anthropology into their usual services. Work was left to forensic physicians, and the recovery of bodies to firefighters, police officers, or directly to gravediggers at cemeteries.

Furthermore, when investigations into the fate of the disappeared began, the archaeology and anthropology departments, save for individual exceptions, had no institutional interest in joining in the activities, nor did anyone approach the organizations that brought together the victims' relatives, who requested

alternatives to the official forensic experts. A combination of lack of knowledge and fear led victims' relatives to be very much on their own during the first years of the new democracy regarding the scientists who could assist them. Thus, the origin of forensic anthropology in Argentina, Chile, and Uruguay was neither planned nor orderly—it was the consequence of the political context and the pressing needs of the victims' families and the judicial system.

## ARRIVAL OF CLYDE C. SNOW

Undoubtedly, the arrival in Argentina of Dr. Clyde Snow, an American forensic anthropologist, marked the beginning of a process that would give rise to forensic anthropology in Argentina and the region, but which had a far-reaching impact on Latin America as a whole. In 1984, Snow arrived in Argentina as a member of a delegation of forensic scientists from the American Association for the Advancement of Science (AAAS). Snow introduced forensic anthropology to the process of unraveling what had happened in connection with enforced disappearance, incorporating an anthropological and archaeological approach to the recovery of the bodies, in addition to the statistical analysis of information.

When Snow arrived in Argentina, he was already a renowned forensic anthropologist in the United States. However, he had never dealt with cases of human rights violations in which the state itself had caused the disappearance of many of its citizens. This reality, together with the relationship he established with the victims' families, deeply moved him and, in a way, was a turning point in his career and his life. Later, his pioneering work took him to Guatemala, Peru, and other regions of the world (Joyce and Stover, 1991).

## CHALLENGES

In the beginning, the application of forensic anthropology to cases of human rights violations posed different legal, scientific, and psychological challenges. Neither Snow nor the students he initially trained in Argentina and Chile were aware of this. The same can be said of their Uruguayan colleagues.

From the political perspective, investigating these cases in fragile democracies, in which the victimizers were free and still retained an important share of power, was extremely complex and risky. Working at a traditional archaeological site was very different from working at a cemetery surrounded by police officers and knowing that relatives were anxiously waiting to learn the results; and drafting a report that would have judicial consequences was a far cry from merely preparing an academic report of findings from an archeological site. Moreover, judges were not acquainted with the fact that an exhumation could take several hours, nor were they used to patiently waiting for archaeologists to finish their job.

From the scientific perspective, there were not many precedents or literature on how to excavate a mass grave with a hundred bodies or what reference tables to use in determining the age of an individual from a population other than that of the United States, which was the one usually included in the scientific reviews. On the psychological side, working under so much pressure in the presence of numerous journalists and with the need to give concrete answers to victims' families was not an easy task. In addition, at the university where archaeology and anthropology were taught there was no contact with the world of "forensics." Judges, police, and the usual institutions dealt with investigations, not university faculty. Indeed, the university studies had not prepared these young anthropologists to face such challenges.

## ARGENTINA

In Argentina, anthropology programs had majors in the three main fields, but these rarely had any connection with forensic practices except for the occasional collaboration request from a judge, museum, or university department to examine some skeletal remains they had received. Such cases of collaboration were quite unusual. Many judges and police officers did not have a clear understanding of what an anthropologist did, and most forensic physicians never thought of resorting to them (Fondebrider and Scheinsohn, 2015).

After Clyde Snow's arrival, this situation began to change with creation of the Argentine Forensic Anthropology Team (EAAF) and its integration into forensic practices, primarily in cases involving the search for victims of enforced disappearance. The EAAF emerged from Snow's need for counting on people to help him carry out an exhumation in a specific case in Buenos Aires in May 1984. A small group of students of archaeology, anthropology, and medicine agreed to assist him in the exhumation and subsequent analysis of the remains recovered. Snow returned to Argentina repeatedly during the next two years, and those students continued assisting him, thus gradually consolidating an initial team.

The process was slow, especially because the judicial system was slow to accept a discipline that traditionally had not played a role in the realm of forensic sciences. Even today, the academic community does not offer any bachelor's or master's degrees in forensic anthropology at any of its universities. In those early years, disputes with forensic physicians were frequent because many failed to understand it was better that exhumation of a mass grave be performed by an archaeologist rather than by a gravedigger. The same held with judges, who typically held the opinion that use of a backhoe was acceptable to accelerate an exhumation. In early 1984, hundreds of bodies were destroyed and important evidence lost due to such methods. Over the years, all agents of the law (judges, prosecutors, lawyers, forensic physicians, and police officers) gradually began to recognize the need to engage nontraditional disciplines such

as anthropology in their daily activities, and favorable changes eventually began to appear.

At the initiative of forensic physician Luis Bosio in 1995, the Forensic Anthropology department was created within the Forensic Medical Corps of the city of Buenos Aires. Shortly afterwards, the Legal Medicine and Thanatology department at the School of Medicine of the University of Buenos Aires also opened a space that favored research and offered a postgraduate introductory course in forensic anthropology taught by Bosio and EAAF (Fondebrider and Bosio, 2015). Thirty-one years after this initial period, the work carried out by the EAAF has helped raise awareness in the judicial system—and among the archaeologists and anthropologists who graduate from the university each year—of the fact that there are a number of disciplines that must be used in recovering and analyzing bone remains. Furthermore, since 2000, other archaeologists have created working teams in Tucumán, to deal with similar issues in that province, and in Buenos Aires to recover sites formerly used as clandestine detention centers (Leiton, 2009).

Perhaps the most important change in this discipline dates back to those early years, when an activity more related to social anthropology, involving work with the victims' families, the recovery of ante-mortem data, and the analysis of the context in which a person had disappeared, was added to the traditional roles (i.e., the recovery and examination of remains). Of equal importance was the closer integration of archaeology and anthropology, blurring the line between the tasks of the archaeologist and the anthropologist that is usual in other countries of the world, such as England.

## CHILE

Chile also had a rich tradition in archaeology and biological anthropology, but just as in Argentina, its relation to the forensic field was sporadic and nonsystematic. This situation began to change in 1989 when Snow and the young EAAF members visited Chile at the request of the Agrupación de Familiares de Detenidos Desaparecidos (Association of Relatives of the Detained–Disappeared), and a group of Chilean archaeologists, anthropologists, and dentists created the Chilean Group of Forensic Anthropology (Grupo Chileno de Antropología Forense, or GAF). Like the Argentine team, this new group began to provide assistance to the Chilean judicial system in searching for the disappeared. In 1994, GAF disbanded and some of its members became part of Chile's Legal Medicine Service (Servicio Médico Legal), the official entity responsible for forensic examinations. All this was supported by the local groups of relatives of the detained–disappeared (Padilla and Reveco, 2004).

The operations of the Identification Unit created within the Legal Medicine Service went on for many years until a crisis erupted over a possible wrong identification in the early 1990s of a number of bodies recovered in the case known as “Patio 29.” This led to a restructuring of the identification service with the

support of national and foreign experts. Although this identification team was created to deal with cases of enforced disappearance under the dictatorship, it is also concerned with ordinary criminal cases and mass disasters (Intriago Leiva et al., 2015).

At present, authorities are respectful of forensic anthropology and regard it as one of the disciplines that play a role in forensics. The judicial system in Chile, as well as bodies in charge of the investigation as police and the medico legal institute, incorporated forensic anthropology as another independent discipline in the forensic system. Each time that there is the need to investigate a scene involving skeletal remains or to analyze them, a forensic anthropologist is part of the team, and judges understand their role in the process.

## URUGUAY

Unlike Argentina and Chile, the Technical Forensic Institute (Instituto Técnico Forense, or ITF) of Montevideo, the official agency that provides assistance to the judicial system in forensic matters, already included a forensic anthropologist as part of its permanent staff. But it was only in 2005 that a forensic anthropology group was created: it was then that human rights violations during the dictatorship began to be investigated, thus creating the need to find bodies of the disappeared (presumably buried in premises belonging to several military units). The Uruguayan Forensic Archaeology Investigation Group (Grupo de Investigación en Arqueología Forense del Uruguay, or GIAF) was composed mostly of archaeologists from the Universidad de la República (University of the Republic; López Mazz and Lusiardo, 2015). Activities of this team focus almost exclusively on searching for bodies of Uruguayan victims of forced disappearance, possibly buried in the country's military areas, while the staff anthropologist at ITF works on ordinary criminal cases (although the ITF anthropologist occasionally participates in analysis of remains that may belong to victims of enforced disappearance).

## LATER DEVELOPMENTS

In the three countries, forensic anthropology as a branch of knowledge has been gradually incorporated into the judicial system as a distinct discipline—more institutionally in Chile, more independently in Argentina, and a combination of both in Uruguay. Unfortunately, this advancement was not accompanied by an interest in creating graduate programs in the discipline or in establishing an organic and formal relationship with the judicial forensic services on the part of academia. Forensic anthropology remained isolated and nonintegrated, unlike the cases of the United States and England, where interaction is greater.

On balance, the results of these thirty-one years of development are positive. The judicial system has acknowledged the value of other scientific disciplines in supporting its investigations. There is a blossoming interest among the youngest



generations of students; and forensic anthropologists from all over Latin America have an institution of their own: the Latin American Association of Forensic Anthropology (ALAF), which already has twelve years of experience and serves as a forum for discussion and promotion of the discipline. The challenges faced by forensic anthropology include the need for a greater number of specific studies on the contemporary population of each country, the development and adoption of common protocols in the region, and a greater interest from universities in creating programs in forensic anthropology.

## NOTE

1. In the cases of Argentina and Chile, legal proceedings against members of the armed forces and law enforcement agencies were also initiated in some European countries and in the Inter-American Human Rights System (the Inter-American Commission on Human Rights and the Inter-American Court of Human Rights).

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# Biodemography of Historical and Recent Populations in the Southeast Region of South America

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**ABSTRACT.** This chapter describes theoretical and methodological aspects of biodemographic studies performed in Argentina, Bolivia, Chile, Paraguay, and Uruguay. Although work in this area is scarce and previous studies are rarely available, there is an important volume of information which facilitates the inference of the effects of gene flow, natural selection, and genetic drift in both historic and contemporary local populations in the region. The effect of these microevolutionary factors can be estimated from the coefficients of reproductive isolation, homogamy, and inbreeding, as well as the rates of effective migration and opportunity for natural selection. Studies which estimate these coefficients and rates are considered, as well as demographic studies that may contribute to a better understanding of the conformation of the genetic pool in populations of the southeast region of South America. However, there is still much to be done: it is necessary to gain a deeper understanding of the methodological aspects in order to reconcile the strictly genetic perspective with the biodemographic.

**RESUMEN.** En este capítulo se puntualizan aspectos teóricos y metodológicos sobre trabajos realizados desde una perspectiva biodemográfica en Argentina, Bolivia, Chile, Paraguay y Uruguay. Si bien los estudios disponibles en esta temática son escasos, se cuenta con un importante caudal de información que permite inferir los efectos del flujo de genes, selección natural y deriva genética en las poblaciones locales tanto históricas como actuales de la región. El efecto de estos factores microevolutivos puede ser estimado a partir de los coeficientes de aislamiento reproductivo, homogamia y endogamia y las tasas de migración efectiva y oportunidad para la selección natural. Se consideran los estudios que estiman estos coeficientes y tasas, además de estudios demográficos que puedan contribuir a una mejor comprensión de la conformación del acervo genético de las poblaciones de la región Sud Oriental de Sud América. Sin embargo, hay todavía mucho por hacer: es necesario profundizar aspectos metodológicos, sobre todo aquellos que permitan vincular la perspectiva estrictamente genética con la biodemográfica.

**RESUMO.** Neste capítulo se puntualizam aspectos teóricos e metodológicos sobre trabalhos realizados desde uma perspectiva biodemográfica em Argentina, Bolívia, Chile, Paraguai e Uruguai. Conquanto os estudos disponíveis nesta temática são escassos, conta-se com um importante volume de informação que permite inferir os efeitos do fluxo de genes, seleção natural e deriva genética nas populações locais tanto históricas como atuais da região. O efeito destes fatores microevolutivos pode ser estimado a partir dos coeficientes de isolamento reproductivo, homogamia e endogamia e

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*Manuscript received 28 April 2016; accepted 10 November 2017.*

as taxas de migração efetiva e oportunidade para a seleção natural. Consideram-se os estudos que estimam estes coeficientes e taxas, além de estudos demográficos que possam contribuir a um melhor entendimento de a conformação do acervo genético das populações da região Sud Oriental de Sud América. No entanto, há ainda muito por fazer: é necessário aprofundar aspectos metodológicos, sobretudo aqueles que permitam vincular a perspectiva estritamente genética com a biodemográfica.

## THEORETICAL AND METHODOLOGICAL CONSIDERATIONS

The work of Hardy and Weinberg, which defines the conditions for the genetic equilibrium of a population, illustrates the direct link of population genetics with demography. Parameters such as the effective size, panmixis (random mating), migration, mortality, and differential fertility are crucial in the evolutionary process, and they integrate the basic assumptions of the equilibrium model. Biodemography allows a researcher to deduce the viability of factors in the past, to help explain the population structure in the present and to predict the probability of future developments. Therefore, this approach permits a comprehensive population study.

All demographic work can be considered biodemographic since it refers to studies of populations whose parameters are defined by their biological characteristics. In the case of our species, cultural characteristics and social organization are particularly important, but when it comes to mortality, fertility, marriage, sex ratio, and other factors, one cannot ignore the biological dimension.

According to Hammel and Howell (1987), the interdisciplinary proposal of biodemography is configured to the extent that demographic analysis includes biological, ecological, and sociocultural aspects. Halberstein and Crawford (1972), however, consider that demographic factors provide the observed genetic events in human populations with a different perspective. In this context, it is necessary to limit the scope of the discipline, which specifically targets contributions to the understanding of microevolutionary processes. Despite this, the important contribution of many demographic and historical works cannot be ignored, even if not based on this perspective.

In 1952, Lasker indicated the importance of demography in understanding the future of human evolution (Lasker, 1952), and Sutter (1958) stressed the importance of biological as well as cultural factors in the demographic study of populations. Conterio and Moroni (1974), in turn, indicate that genetic analysis of demographic data is a key factor in the study of the adaptation of the human population to its environment. Jacquard (1970) also noted that the biological history of a population could be interpreted by the set of changes in the genetic structure that results from the action of natural selection, mutations, genetic drift, crossbreeding, and migrations systems.

Fuster (2003) highlighted the four main differences between biodemography and demography:

1. Biodemography concerns the study of small, local communities, no more than a few thousand individuals, while demography considers the population at regional or national levels. The populations under biodemographic study are usually well defined geographically and culturally. Fuster (2003) believes that because of its size, “*même si les données sont de bonne qualité, l’apparition de variations aléatoires de naissances et de décès ne peut être écartée* (Fuster, 2003:405).” In fact, in this approximation, microevolutionary processes analyzed at the local level are fundamental and an aspiration for bioanthropology, firstly because they approach the most frequent type of aggregates along the evolution of the species, and secondly because to estimate genetic drift, for example, one must know the limits of breeding units. In this sense, the information available for both current and past populations is a source of difficulties. In many cases, the implementation of this approach is necessary from the beginning of the research. Otherwise, the development of methodologies suitable to use with data with levels higher than local population aggregation is required. An additional difficulty may be that confidentiality laws usually protect local sources so it is easier to use official sources with aggregate data (Reher, 2000).
2. Demography is usually founded on the processing of socio-cultural data (births, deaths, marriages) limiting the analysis to the relationship of these variables together. In biodemography, from nominative information (names) it is possible to perform a non-aggregative analysis that consists of referring different demographic events to the same individual or couple (offspring produced, for example). This technique has been applied to historical demography and later to biodemography, arriving at exceptional rebuild, not only of nuclear families, but of the entire population (genealogical demography), which is useful for the study of microevolutionary processes of human populations. The main methodological difficulty in biodemography is that those human populations more attractive from the biological point of view (geographically and numerically bounded, with well-defined environmental conditions, etc.), in which analysis of the microevolutionary processes is easier, are usually those for which there is poor demographic information and sometimes even a lack of written records. In these cases, the analysis should be done based on data provided by informants from memory.
3. In demography, chance intervenes only in random sampling processes and thus can be corrected by appropriate statistical procedures. On the other hand, in biodemography, random variation may be especially important as an integral part of the system. For example, the shape of the age distribution of fertility and mortality (reflecting individual differences) is important in itself, since the genetic consequences of these demographic variables, expressed as biological fitness, will depend on the inter-individual variability in both fertility and mortality (Leslie and Gage, 1989).

4. As the study of human populations in an evolutionary context requires analyzing the variation in vital rates (both at the intra- and interpopulation level), the demographic characteristics of the population variation relate to biological characteristics. Populations can vary significantly in their reproductive and survival patterns, sex and age distribution, growth rate, and other factors. This is part of the existing variability for human populations, considered from a biological point of view. This perspective differs from that of population growth, which often treats populations as biologically homogeneous, their differences due solely to cultural or environmental factors.

In 1995 in Florence, Italy, the international meeting on “Biodemography and Human Evolution” took place, stating that the objectives of biodemography are “to collect historical-regional data on populations and environments to be integrated with ethnographic and socioreligious information in order to facilitate the comprehension of current demographic issues with an anthropological perspective” (Chiarelli, 1997:1).

Biodemography is not simply an aggregate of the biological data as a transcendent cause of population events or the use of demographic data in the biological analysis of populations. Its importance lies in an interdisciplinary approach, which means the coexistence of complex notions in the study of populations such as those related to age or reproduction.

According to Sauvain-Dugerdil (1997), biodemography necessarily involves four dimensions that should be considered as intrinsic principles: interaction, dynamics, heterogeneity, and multiplicity of levels. The principle of interaction is based on the concept that the biological dimension has no meaning in itself: biology is expressed in interaction with the environment and human nature cannot be dissociated from culture. The natural processes of human life (birth, reproduction, aging, and death) can only be understood in terms of the function of a society within the framework of values and beliefs, the weight of history, and the conditions of the physical environment. In the synthesis suggested by Sauvain-Dugerdil (1997), the complex phenomenon of interaction between biological and nonbiological dimensions is stressed. For example, with reference to the biological dimensions involving the aging process, he considers different points of view: the specific feature of a disease (referring to diabetes), the condition of the elderly and how they are seen in different societies, the duration of life and the reproductive cycle (focused with a gender perspective), the composition of the population, and the notion of generation.

The principle of dynamics implies that demographic events have to be inserted in a perspective of life history and human evolution, that is, the continuation of previous experience of the individual or of the population (Sauvain-Dugerdil, 1997). In this dimension, for example, an early experience in the life of the individual may have a significant role in later stages. Various authors consider that a specific lifestyle (urban or rural), parental

education, or the activity of the mother, among other issues, can play an important role in events such as the expression of a disease, the quality of life in old age, roles within a community affected by migration, generational clash, age at marriage, number of children, and many others.

The principle of heterogeneity is one of the essential characteristics of anthropology (and its different subfields). It is the effort to integrate the diversity dimension. Diversity is not only a source for change, but also the result of the change, though both aspects have been undervalued for a long time in scientific research. For example, Ellison (1994) shows that inter- and intravariability of a trait such as fertility in a population is generally regarded as constant in demographic models. This principle involves multiple levels of demographic events that should be analyzed taking into account the importance of different levels. This refers mainly to the methodological aspect: the relevance (or lack of meaning) of the questions asked regarding the level, that involves the individual, the basic social unit (family, clan), the local population (community, town, province), the nation, the region, and other factors.

In fact, two problems are found here: the selection of the unit of study, or, in other words, the reference population for the subject studied; and the relationships between the individual and the group.

Biodemographic studies are conducted in indigenous and mixed populations as well as in immigrant communities in different regions. Populations are defined geographically, culturally, as well as by other characteristics (linguistically or socioeconomically, for example). Population size, age and sex variation, fertility and mortality, migration, reproductive behavior, marriage patterns, in- and out-breeding, and consanguinity are among the main interests. In addition, the degree of similarity between populations may be estimated using isonymic methods.

Populations of both the present and the past are included. Demographers and historians are involved in the production of data about the latter, in order to apply the techniques developed for demographic analysis (Reher, 2000). The importance of this information in shaping the genetic structure of existing populations is evident, but only recently has been incorporated into research practice. Largely, the delay in this inclusion is due to the limitations of the available sources. Part of the limitations can be overcome only through the development of appropriate methodologies, arising out of the conceptual basis of the theoretical framework of population genetics. Among the problems the researcher faces in the use of historical data is the geographical scope, which is most easily demonstrated by the juxtaposition of colonial administrations and modern governments. On the other hand, some units may have had a particularly significant historical development at the time, deserving special treatment (Morales Vergara, 1972).

Moreover, the societies formed from admixture, with important migratory contributors, especially Africans and Europeans, have made it very difficult to estimate the number of ethnic

subgroups. To reduce them to four or six major divisions necessitates dangerous generalizations. From this point of view, societies depicted in censuses are oversimplified. The problem lies in how those simplifications were created (Arretx et al., 1983).

The serious problem of the dispersion of data was improved in the 1990s when data compiled by the Genealogical Society of Utah (SGU) (created in 1894 in the United States) were released on microfilm by the Church of Jesus Christ of Latter-day Saints (Mormons). This data set is available on the website of the church (Siegrist, 2011). As a result, access to the information in the sacramental records and documentation related to the history of ethnic groups, marital problems, civil and ecclesiastical trials, pastoral visits, founding churches, monasteries, and civil censuses, provided a step forward in studies that focus on analysis of families, individuals, and groups (Siegrist, 2011). As Siegrist (2011) states, the contributions of databases such as Familysearch.org are invaluable to extend the theoretical and methodological frameworks for the humanities and social sciences including aspects of history, anthropology, ethnography, law and its related items, genealogy, biodemography, and demography.

In the case of contemporary populations, although data processing at the level of local populations requires a greater effort, this difficulty can be overcome by collecting primary data on the level of aggregation required. In historical populations this solution is impossible, and one must choose more complex strategies such as the cross-referencing of different sources. There is agreement among Latin American specialists that a proper statistical period involving population data began well into the nineteenth century (Arretx et al., 1983), and in South America the earliest demographic studies originate in the current century.

## DEVELOPMENTS IN THE REGION

From the demographic perspective, developments in the region gained impetus after the creation of CELADE (Centro Latinoamericano de Demografía) in 1957, the result of an agreement between the United Nations and the Government of Chile. From this center in 1967, courses in historical demography were conducted, and the work “Chile: Estimación del nivel de mortalidad para el periodo 1885–1895” [Estimation of mortality for the period 1885–1895] was published. In the second half of the 1960s, a researcher at CELADE, sponsored by the Instituto Torcuato di Tella, investigated fertility in Argentina in the nineteenth century, samples of the 1869 and 1895 censuses, internal and international migration, and the population growth of Buenos Aires (Morales Vergara, 1972).

The prevailing avenues of study in biological anthropology did not explicitly include biodemography until the second half of the past century. At the regional level, in the southeast sector of South America, most of the research with this focus was developed in Argentina, and to a lesser extent in Chile; in Paraguay and Bolivia, there are few studies in this field, while in Uruguay the application of the biodemographic approach is very recent.

In Argentina, early in the development of bioanthropology, work focused on the study of bones, mainly at a morphological level, aimed at description and systematization. Since 1960, studies in this field are characterized by the integration of the neo-Darwinian view, assuming paradigm shifts already established internationally, opening the way for the incorporation of the assumptions related to biodemography, as is pointed out by Carnese and Pucciarelli (2007). However, several Argentine researchers addressed population issues through different approaches. The paradigm shifts and the emergence of new leaders in the discipline eventually consolidated intellectual discontinuities in the field of anthropology (Soprano, 2009).

In the 1960s, Palatnik created the Unidad de Genética Serológica en la Facultad de Ciencias Exactas de la Universidad Nacional de La Plata [Serological Unit in Exact Faculty, National University of La Plata]. A group of researchers trained in different aspects of science formed the interdisciplinary team responsible for one of the most complete works in the area, consisting of a comprehensive study of the Toba community of Fortin Lavalle (province of Chaco, Argentina). Unfortunately, political changes have disrupted the continuity of workgroups such as the one mentioned here. The cited work includes genetic typing-serum markers used to obtain biomedical, clinical, anthropometric, demographic, and sociocultural information (Carnese et al., 1975; Fink de Cabutti and Palatnik, 1975; Palatnik, 1975, 1976; Carnese and Pucciarelli, 2007).

Population studies in Uruguay, with a genetic and anthropological approach, are relatively recent, only beginning in the late twentieth century. However, some background research was conducted early in the nineteenth century, and this has become an important source of data in the absence of systematic surveys of the pre-statistical period. The “Noticias Estadísticas de la República Oriental del Uruguay,” conducted by Dr. Andrés Lamas in 1850, is a true synthesis of population information (Lamas, 1850).

In the case of Paraguay, the work of Salzano et al. (1970) in populations of Maca is relevant as the only study so far undertaken with a genetic and demographic focus. There are others works, always referring to indigenous populations, comprising purely social or genetic issues. Richards (1996) analyzed the impact of family migrations to rural and urban areas, mainly to the provinces of Formosa and Misiones as a prelude to Buenos Aires.

The understanding of microevolutionary processes in populations, from the approaches of demography and population genetics, allows the estimation of three of the five factors that cause the change in gene frequencies: gene flow, natural selection and genetic drift.

## THE EFFECT OF MIGRATION ON GENE FLOW

The directional evolutionary factor known as gene flow is a consequence of migration, but it should be noted that for this

factor to act in a population, migration must be effective. Research areas emerging from social anthropology and history are important, especially those addressing the processes of integration of different groups of immigrants.

Studies of migration processes in Argentina (external and internal migration, from neighboring countries, etc.), the dynamic of different groups of migrants, and their insertion into the host society were conducted since the middle of the twentieth century. Researchers like Savorgnan (1950), Baily (1980, 1996, 1998), Sapelli and Labadie (1989), and Balazote and Radavich (1990) studied the importance of migration. Moya (1996), Lattes and Bertoncello (1997), and Otero (1998) also analyzed the demographic behavior of European immigrants.

Palatnik (1976) considered the Criollos and Tobas populations of the Argentine Chaco; Caratini et al. (1996b) analyzed various parameters of genetic interest from a population census of Mapuche aborigines, concluding that there was an important gene flow from non-Indian men to aboriginal women (75%). The biodemographic study of Carnese and Caratini (1991) deals with the characteristics of a Toba population migrating from Chaco province in Argentina to Buenos Aires. Carnese et al. (2002) analyzed the Tehuelche populations in Patagonia by considering demographic and genetic characteristics and inter-ethnic relations, and they compared the data with those obtained in similar studies of Mapuche populations. Welsh migrants to Chubut (Argentina) from 1865 to 1920 were identified and their contribution to the gene pool of the colony was estimated from genealogies (Crognier et al., 2007).

In the Uruguayan population, the works of Bentancour (1997), Camou (1997), González Risotto and Rodríguez Varese (1990), Marenales Rossi and Luzuriaga (1990), Odonne (1966), Samuelle (1990), Vidart (1969), Vidart and Pi Hugarte (1969), Zannier (1994), Zubillaga, (1994, 1997a, 1997b) are significant. On the other hand, recent migration processes in this country were studied by Cabella and Pellegrino (2007), and Fortuna et al. (1987) among others. Basque immigration to Uruguay, considering both genetic and cultural aspects, confirmed a founder effect in some lineages detected in the city of Trinidad (Egaña et al., 2005).

Bert i Fibla (2005) includes biodemographic aspects of Bolivia Macro-Pano groups analyzed in conjunction with the genetic characterization of the Aymara, Quechua, and Mosestén Chimane populations. He also analyzed the structure of populations and relevant aspects of migration and fertility. Gil Montero and Massé (2004) centered their work on Los Toldos (Santa Victoria, Salta, Argentina), which was part of the province of Aniceto Arce (Tarija, Bolivia) until 1938. Data sources correspond to nineteenth-century parish registers and twentieth-century vital statistics, revisits of indigenous peoples, and national population censuses (Bolivia, 1900; Argentina, 1869–2001). They conclude that the population dynamics of this sector of the northwest of Argentina is not just a consequence of what did not happen (the anticipated arrival of immigrants), but it has its own story of evolution from the colonial period and the early nineteenth century.

The work of Colantonio et al. (2010) takes surnames from the 1813 Census in Córdoba as an indicator of genetic diversity of the population. They also estimate migration (historical and modern), concluding that migration was based on familial ties, with women shifting as frequently as men, comparing historical and genetic findings.

The inclusion of indigenous people and those of African origin is recent. In this regard, studies have been conducted, especially pertaining to the eighteenth and nineteenth centuries. Goldberg's work (1976) on slaves in Buenos Aires was one of the first. It is important to mention the contributions of Guzmán (2010) on Africans in La Rioja and Catamarca, Argentina. In Córdoba, Colantonio (2000) studied ethnicity and consanguinity, kinship, and migration of the population based on census data by analyzing surnames in rural populations as well as in the city of Córdoba (Colantonio et al., 2006).

In spite of all this information, the way that immigrants integrate into recipient societies has been discussed for decades, mainly from the perspectives of the social sciences. American countries received different waves of European immigrants, although the details of the process of assimilation, when it did occur, are unclear.

## MARRIAGE PATTERNS – HOMOGAMY

Whether through personal preference or through societal pressure, individuals play a role in genetic transmission when choosing a spouse (Bourgeois-Pichat, 1978). From a methodological standpoint, coupling provides a lot of information about the integration between populations and the assimilation of immigrants. The possibility of making inferences about marriages is critical in understanding assimilation (Rosenfeld, 2002).

The integration of immigrants and the Hardy and Weinberg restriction of random mating underscore the importance of marriage patterns in populations. A condition for a population to be in genetic equilibrium is panmixis. Random mating between all individuals is rare because generally mates can manifest preference for individuals who are carriers of certain characters. These traits may not be genetically determined, but nonetheless may indirectly influence a scenario that inhibits equilibrium. In the case of preferential mating, couples can be formed with individuals who share a particular trait. This situation leads to homogamy measured by the correlation between the shared traits of the pair.

Silberstein (1991) and Miguez et al. (1991) analyzed the models of melting pot and cultural pluralism from marriage patterns in Italian and Spanish immigrants. In a study of marriage patterns of Peruvians, Bolivians, and Argentines in Tarapaca (Chile), Calle Recabarren (2008) concluded that by analyzing the frequencies of inbreeding and intermarriage the melting pot theory is a relevant explanation.

In the province of Salta (Argentina) the hypothesis of amalgamation was studied using data from censuses conducted in 11 villages (Santa Rosa de los Pastos Grandes, Olacapato,

Chañarcito, Cobres, Tolar Grande, Cachi, San José, El Barrial, Chicoana, San Agustín, and La Isla). Effective migration rates and the coefficients of reproductive isolation, inbreeding, and homogamy were estimated. In the city of Salta, the coefficients were estimated based on the 1865 census and from the marriage records of the Civil Registry from 1899 to 2001. In accordance with genetic data, it was concluded that small populations are reproductively isolated, that couples formed in them are homogeneous, and that migration is largely internal to the geo-structural units in which populations are located. (Acreche, 2006; Acreche and Albeza, 2010). The values obtained for the coefficient of differentiation between subpopulations (FST) from classical and molecular markers confirmed in all cases that the differentiation is at the level of local populations (Acreche, 2006; Albeza et al., 2010).

From 1996 on, in Uruguay, researchers began to systematically collect data from Parish archives as part of a project whose main objective was to determine inbreeding and consanguinity of the various contingents of immigrants. From the results of this investigation, it was established that there was a real “cultural pluralism” and not a “melting pot”—according to the terminology used by Baily (1980) and Miguez et al. (1991). Until the second generation, marriages have high rates of inbreeding, and therefore the Uruguayan society of the past was not as “integrated” as stated by Oddone (1966) for example (Sans et al., 1996; Sans, 1998; Barreto Messano, 1999, 2000, 2001; Barreto Messano and Sans, 2000, 2003; Sans and Barreto Messano, 2003; Barreto Messano et al., 2004; Lusiardo et al., 2004).

In Uruguay, Sans and Barreto Messano (1997) and Portas et al. (1994) considered demographic variables (mobility, structure, average age at marriage, the relationship between foreign and local population) involved in shaping historical populations. Caratini et al. (1996a) considered the spatial and temporal variation of inbreeding and outbreeding of Spanish immigrants in Argentina.

### FERTILITY, MORTALITY, AND NATURAL SELECTION

Birth and death rates are key parameters in the action of natural selection. The opportunity indexes for natural selection give an approach to the possible subjection to selection in populations. The overall index is formed by fertility and a differential mortality index.

The evolution and decline of fertility in Argentinian populations were addressed most clearly by Pantelides (1992), who describes how fertility has declined in the past 100 years and criticizes the lack of systematic data given the fragmentary nature of vital statistics. Crognier et al. (1996) analyzes the reproductive behavior of the Mapuche population, while Arias and Colantonio (2003) studied the behavior of fertility in rural areas and in the capital of the province of Córdoba, considering the distribution by age and marital status of women. Arias and Colantonio

(2004) and Arias et al. (2004) studied fertility of contemporary and historical populations of Córdoba. Celton (1993, 2000), analyzes the fertility of African slaves in Córdoba as well as the social characteristics of this group during the colonial period, concluding that, although rates are lower than those of other groups, they are relatively high if the condition of slavery is taken into account.

The work of Sanchez (2004) is an exhaustive study of the fertility and reproductive history of women in Tierra del Fuego (Chile). He considers marriage, birth, and death in relation to the physical environment and the demographic evolution of the population.

In Uruguay, analysis or diagnosis of fertility was studied by Pellegrino (1998), Pellegrino and Pollero (1998), Pollero (1994), and Varela (2007), among others. Uruguayan mortality was studied by Damonte, (1994), Macció and Damonte (1994), and Migliónico, (2001).

Bejarano et al. (1999) studied the decline of infant and adult mortality, including the epidemiological aspects, age, and sex distribution in Argentina's Puna. Celton (1998) analyzes the incidence of disease and mortality crisis in Córdoba from documentary sources, and Viglione et al. (1998) consider the incidence of smallpox mortality in the Pago de los Arroyos population, the impact of this disease, and its subsequent decline. Colantonio et al. (2000) describes the behavior of infant mortality in an isolated region with progressive population decrease during the second half of the twentieth century.

Albeza et al. (2004, 2002) and Caro et al. (2010) estimate rates of opportunity for natural selection in local populations in three different levels of altitude above sea level (Puna, Valles Calchaquíes, and Valle de Lerma) in Salta.

Caruso et al. (1999) studied the semi-isolated populations of Tolar Grande and Cobres in Salta province, considering demographic parameters (fertility, migration, and mortality) and blood groups, estimating the rate of opportunity for selection and genetic diversity among populations. In these populations, natural selection is activated by differential fertility.

### THE RELATIONSHIP BETWEEN POPULATION SIZE AND GENETIC DRIFT

The semi-isolated populations generally are subject to the action of genetic drift, a factor that is estimated from the coefficient of reproductive isolation, which in turn is calculated from the effective population size ( $N_e$ ) and the actual migration rate ( $m_e$ ). Panmixis deviations can cause drift effects, hence the formation of couples is a very important element in the evaluation of this evolutionary factor. In this aspect, studies of kinship can provide essential information to explain the genetic structure of populations. Studies in semi-isolated populations that integrate demographic and biological aspects, of particular interest in this topic, were developed by Colantonio (1995), who took into consideration the immigration and marriage behavior of the



population of the Department of Pocho (Córdoba). Colantonio and Celton (1996), Colantonio and López (1997), and Colantonio (1998), analyze the structure of these populations, considering variables such as reproduction, natural selection, and genetic drift. Demarchi and Colantonio (2000) studied the population structure, using the surnames present as a polymorphic allele system.

In Bolivia, the European and African migrations in the fifteenth century produced a reduction in population size which is important for the study of the actual population structure (Berti Fibla, 2005). Inbreeding and consanguinity are directly linked to genetic drift, both for its direct relationship to the magnitude of the effective population size as well as for its deviations from panmixis. The estimation of these population parameters, therefore, is of central importance both to explain the current values of variability and to predict the future of populations.

Colantonio et al. (2002) estimated inbreeding by isonymy from marriage records, while Dipierri et al. (1994) considered the degree of relationship among 67 towns in the Quebrada de Humahuaca and Puna (province of Jujuy), through isonymy coefficient for intra- and interpopulation, and correlation between them and the linear geographic distance among locations. Alfaro and Dipierri (1996) discuss inbreeding marriages in the Puna populations, and Morales et al. (2003) analyzed the association between surnames and Rh (D/d) in Jujuy populations. In Bolivia and Chile, Chakraborty et al. (1989) found agreement between ethnic classification by names and genetic markers in Aymara populations.

According to Otero (2009), historical demography went through a profound transition to a history of the population that is less systematic but more comprehensive, in which demography still has an important role. Along this line, following Siegrist (2009), the records of consanguinity and exemptions clearly demonstrate the limits that the demographic market and socioethnic and socioeconomic barriers imposed on exogamous marriage.

From a demographic perspective, Ferreyra (2009) reconstructs the main indicators of marriage, through the comparative analysis of the condition of spouses, the incidence of inbreeding and migration, and the analysis of the presence of living parents at marriage. In addition to the parish and census records, the author uses marriage records and abundant contextual data derived from the geneological history of Córdoba in the eighteenth century (Otero, 2009).

Frías (1998) deals with marriage, family, and illegitimacy in Buenos Aires, while Ghirardi (1998) considers the *family* category as a plastic concept, analyzing the biological ties linking its members. Torrado (1998) describes the changes in the dynamics of family formation by analyzing procreative behavior. Ferreyra (1998) analyzes the illegitimate births in urban and rural areas of Córdoba during the eighteenth century. All of these constitute important contributions to understanding the configuration of populations.

For the area of Córdoba, Celton (1993) contributes a sociodemographic analysis of the population in the 1778 and 1840

censuses by ethnosocial groups, sex, and age, considering levels and structure of mortality, marriage and fertility, and mixing.

Siegrist (1995) reconstructed Argentinian social genealogies, inter-ethnic marriages, and genetic admixture from parish sources. She also evaluated the African population from scanned documents (Siegrist, 2010). In her 2009 study, she combined the demographic with the anthropological perspective, analyzing dispenses and classifying the causes (Siegrist, 2009).

Zuñiga (1980) studied inbreeding in the Elqui Valley (Chile) using data drawn from the marriage dispenses granted by the Catholic Church (impediments of consanguinity).

Ferreyra (1998, 2005) revealed that the marriage market for indigenous people and slaves was not as much a determining factor in choice of partner as previously thought. Likewise, she found that mortality in the black group varied with sex and condition and that mixture frequently appeared in conditions of illegality.

Exploring the conformation of the slave family, Ghirardi et al. (2010) analyzed marriage choices, differences by sex, color, and rural or urban residence, fertility and illegitimacy, domestic service, and features of family interaction.

Ghirardi (2008) included important information about marriage, family systems and indigenous populations, parental ties, relations and gender identity, childhood, family and co-residence, and family and social change.

## CONCLUSION

More work has been done in the various fields of biodemography than can be discussed here. Demographers, historians, and anthropologists have contributed to a better knowledge of human populations in the southeast region of South America. In spite of this, there is more work to do. Large gaps remain: there are important populations about which little is known, historical time periods should be included to guarantee advancement in these topics, and more methodological work is needed. Genetic markers are useful to understand the processes experienced by populations. More studies designed to combine genetic and biodemographic perspectives are needed.

## ACKNOWLEDGMENT

We thank Irene Meninato for reading the manuscript.

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# Growth and Development, Health and Nutrition in the Southeast Region of South America

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**ABSTRACT.** We describe the history and current status of research in child growth and development, one of the main thematic units of biological anthropology in the South American countries of Argentina, Bolivia, Chile, Paraguay, and Uruguay. Although studies on the subject in most of the region are scarce (as is the case in Paraguay and Uruguay, and to a lesser extent Bolivia and Chile), research in Argentina has been substantially developed. Analysis of information gathered suggests that the process of growth and development is a complex network of socioeconomic and socio-environmental factors influencing biological conditions, such as nutritional status and population health. Accordingly, future epistemological strategies of the discipline should lie in promotion of interdisciplinary, multi-national, and regional studies.

**RESUMEN.** En este capítulo se describen la historia y la situación actual de los estudios sobre crecimiento y desarrollo infantil, uno de los núcleos temáticos centrales de la Antropología Biológica, en los países sudamericanos Argentina, Bolivia, Chile, Paraguay y Uruguay. No obstante, los estudios realizados en esta temática son escasos. Este es el caso de Paraguay y Uruguay y, con menor intensidad de Bolivia y Chile. Argentina en cambio, exhibe un importante desarrollo. El análisis de la información reunida permite afirmar que el proceso de crecimiento y desarrollo reconoce una compleja trama de factores socioeconómicos y socioambientales que influyen en condiciones biológicas como el estado nutricional y la salud de las poblaciones. En función de la complejidad mencionada es posible concluir que la estrategia epistemológica de la disciplina, con proyección futura, radica en la promoción de estudios interdisciplinarios y multicéntricos nacionales y regionales.

**RESUMO.** Neste trabalho, descrevem-se a história e a situação atual dos estudos sobre o crescimento e o desenvolvimento infantil, um dos núcleos temáticos centrais da Antropologia Biológica em países da América do Sul, como a Argentina, a Bolívia, o Chile, o Paraguai e o Uruguai. Contudo, os estudos realizados sobre a temática na região são escassos. Este é o caso do Paraguai e do Uruguai e, em menor medida, da Bolívia e do Chile. A Argentina mostra um desenvolvimento significativo. A análise da informação recolhida permite afirmar que o processo de crescimento e desenvolvimento reconhece uma complexa teia de fatores socioeconômicos e socioambientais que influenciam as condições biológicas, tais como o estado nutricional e de saúde das populações. Dependendo da complexidade mencionada, pode-se concluir que a estratégia epistemológica da disciplina, com projeção de futuro, reside na promoção de estudos interdisciplinares e multicêntricos nacionais e regionais.

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## INTRODUCTION

Juan Comas was one of the first anthropologists interested in the history of anthropology, particularly biological anthropology, a discipline concerned with quantitative bibliographical and statistical methods (Comas et al., 1971). Comas surveyed researchers in this discipline and found two main tendencies: physical anthropology, with strictly biological purposes and objectives, and biological anthropology, with emphases on environmental and cultural factors, which are essential to explain evolutionary processes and differentiation in human populations.

Globally, the discipline of biological anthropology has developed greatly in the last thirty years. In Latin America, one of the most important advancements was the creation of the Latin American Association of Biological Anthropology in 1989 in Santiago, Chile. The purpose of the Association was to encourage studies and research for the advancement and diffusion of expert knowledge in biological anthropology throughout the continent, and to promote these scientific advances with similar associations and researchers worldwide (Carnese and Pucciarelli, 2007).

However, according with Rodriguez

the progress of Biological Anthropology in Latin America should refer to the contributions of physical anthropologists integrating interdisciplinary academic and research teams, that is, with anthropological training in the biological and cultural fields. Further, any attempt to include all Latin American countries could be thwarted by the scarcity and, occasionally, the lack of information thereon (Rodriguez, 1996:79).

In this sense, the history of the process of child growth and development in the region shares the general characteristics of biological anthropology. For instance, studies performed in Bolivia and Chile provided scarce information, whereas those in Uruguay and Paraguay dealt with child growth and development from a biomedical approach, far from the biological, social and cultural view of biological anthropology. In Argentina, such an approach was more complex, since child growth and development were tackled as a set of socioeconomic and socioenvironmental factors affecting biological conditions, such as nutritional status and population health.

Accordingly, we describe herein the history and progress of studies in the area of child growth and development as a core concept of biological anthropology in the South American countries of Chile, Bolivia, and Argentina.

## CHILE AND BOLIVIA

The scientific characterization of the differences between Andean and non-Andean peoples began more than a century ago, and efforts to understand the anatomical, biochemical, and physiological bases of their adaptation have increased in the last

half century. However, these studies were based on medical research. The early stages of biological anthropology began with multinational studies.

The Multinational Andean Genetic and Health Program was organized in 1972 in the Department of Arica, Chile. It involved professionals from Bolivia (University of San Andres), Chile (University of Chile, University of Tarapacá, and the National Health Service), Ecuador (Central University of Ecuador), Peru (University of San Marcos), and the United States (universities of Michigan and Texas, and the Mayo Clinic). The objectives of this program were to appraise the impact of differences in atmospheric oxygen pressure, temperature, and humidity upon disease in inhabitants of 14 villages and localities in northern Chile and western Bolivia, the disabilities of the Aymara, and the role of genetic variation in the adaptation to altitude hypoxia (Mueller et al., 1978a,b; 1979; Schull and Rothhammer, 1990).

The Quechua Indian Project was started by Paul T. Baker from Pennsylvania State University. He studied residents of the Nuñoa District, Peru, mainly in the Quechua highlands, living at altitudes of 4,000–4,800 m (Baker, 1969; Baker and Little, 1976). From 1964 to 1976, this project was continued by the International Biological Program (IBP) developed by the International Council of Scientific Unions. Human biologists, biological anthropologists, epidemiologists, and physiologists from more than fifty countries carried out research under the Human Adaptability Section, coordinated by Joseph Sidney Weiner in London (Weiner, 1965). Weiner's research included in the IBP proposed the study of human growth and development, physique and body composition, physical fitness, climate tolerance, genetic constitution, and nutritional status. Other defining characteristics of the IBP human adaptability research were standardization of methods, multidisciplinary projects, international cooperation, and a concern for human health issues. Some observers have suggested that this research contributed to the ongoing transformation of physical anthropology and related fields from a largely descriptive to an analytical science (Little and Garruto, 2000).

From the end of the IBP until the present day, a number of research trends have emerged, such as the Tsimane' Amazonian Panel Study (TAPS). Researchers included mostly cultural and biological anthropologists from the Bolivian Center of Research and Social Integrated Development (a local nongovernment organization specializing in developing investigations among native Amazonians in Bolivia), Northwestern University, the Autonomous University of Barcelona, University of Georgia, Cornell University, International Crops Research Institute for the Semi-Arid Tropics, and Brandeis University (Leonard and Godoy, 2008).

The issues addressed and the main researchers engaged in biological anthropology in Bolivia are summarized as follows:

- A. Functional adaptation at high altitude (Frisancho et al., 1995, 1997; Beall, 2007; Frisancho, 2013)
- B. Physical growth and development of children living at high altitude (Mueller et al., 1978a; Haas et al., 1980;

Stinson, 1980, 1982, 1983; Greksa et al., 1984; Greksa, 1990; Bennett et al., 2008)

- C. Body size and shape (Stinson, 1985, 1990)
- D. Growth, nutritional status, body composition, and parasitic infections (Stinson, 1980, 1982, 2009; Haas, 1981; Haas et al., 1982; Foster et al., 2005; Tanner, 2005; Tanner et al., 2009; 2014a,b; Godoy et al., 2010a; Undurraga et al., 2012)
- E. Growth in relationship to the environment (Godoy et al., 2008a,b)
- F. Chest and lung morphology (Greksa, 1986; Frisancho et al., 1995, 1997)
- G. Health in the adult population (Godoy et al., 2006, 2010b; Tanner et al., 2013)

In Chile, studies on growth and human development have not differed historically from those in other South American countries. Research is mainly concerned with the tradition of biological anthropology, recognized as a pre-scientific stage by Rothhammer and Aspillaga (1996) that would have ended in 1882. The first population studies of modern human beings were carried out by Carlos Henckel. He contributed anthropometric information about indigenous groups from Chile, among other data, to the *Handbook of South American Indians* (Henckel, 1950).

The Anthropology Center was founded at the University of Chile in 1954, and it became the Anthropology Department in 1960. Bioanthropological studies improved under the leadership of Juan Munizaga, who furthered his knowledge in the field at the Smithsonian Institution (Rothhammer and Aspillaga, 1996). Lines of research developed during those years were concerned with erythrocyte molecular markers in indigenous populations, bioarcheological studies, and biological relationships among pre-Hispanic populations from Chile. After his return from the United States, Munizaga and Roberto Rona started researching growth and development (Rona, 1972; Rona and Pierret, 1973; Rothhammer and Llop, 2004), which Rona continued in London (Rona and Altman, 1977). At the request of Corporación de Fomento de la Producción (CORFO), Munizaga carried out a comprehensive bioanthropological study of the populations from Chiloe Island that included growth data (Munizaga, 1978). Around the same time, physicians and nutritionists began research on growth at the Center of Nutrition, Growth and Development, under the direction of Alfredo Patri (Patri et al., 1973). One of Patri's most relevant disciples was Carlos Valenzuela, who focused his consolidated medical research in human growth in Chile, with an emphasis on sexual dimorphism (Valenzuela 1975, 1997; Valenzuela et al., 1978; Valenzuela and Avendaño, 1979).

Within the Multinational Andean Genetic and Health Program, the most important publications were related to growth in high altitude populations (Mueller et al., 1978a,b; 1979; Palomino et al., 1978). This research has continued (Rothhammer et al., 2015).

## ARGENTINA

In the first years of the twentieth century, particularly in Buenos Aires, research on growth and development focused on pediatric medicine, with an emphasis on typology (Agüero et al., 2012). In this context, anthropometry was used for assessing the characteristics of the “average school child” of a city or region. The first research work on schoolchildren from Argentina was Paulino Fernández's doctoral thesis about school hygiene (Fernández, 1880), and the first anthropometric study was on the anthropometric characteristics of Argentinean schoolchildren (Cassinelli, 1916). A year later, Cassinelli published a more ambitious paper about the physical and psychological development of schoolchildren aged 6–14 years (Cassinelli, 1917). These founding publications were followed by the anthropometric studies of schoolchildren carried out by Sisto (1918) and Garrahan and Bettinotti (1922). In the latter study, the authors stated that their results did not have absolute value and that their objective was to catch the attention of teachers and physicians who should assess whether a child is in normal or deficient physical condition.

During 1943 and 1944, Perlina Winocur published her studies on preschool children and schoolchildren from the twenty districts of Buenos Aires. These works were outstandingly modern compared with those of her predecessors. Not only were sample size and selection important, but also the accurate statistical treatments were applied (Winocur 1943; 1944). Her studies allowed the establishment of a weight and height band within the normal range against which it was possible to compare the measurements of children from the Buenos Aires (Soprano, 2009).

An important stage in the development of physical anthropology began at the National University of La Plata School of Natural Sciences and Museum when Milcíades A. Vignati incorporated the use of morphoscopic and morphometric techniques and the typological method of comparative anatomy. He began researching on the American fossil man in the context of paleopathology and somatic anthropology. In 1944, Manuela García Mosquera de Bergna, a student of Vignati, wrote her doctoral thesis on the cephalic index, height, and proportions in schoolchildren from La Plata (García Mosquera de Bergna, 1944). Her approach was based on the traditional physical anthropological methodology developed by Herman Ten Kate and Roberto Lehmann Nitsche at the end of the nineteenth century, and by Vignati in 1930. García Mosquera considered that neither the lifestyle, social conditions, nor eating habits of the child could “modify any organic character permanently and visibly” when determining the descriptive characteristics surveyed in schoolchildren (Soprano, 2009:73).

In line with international scientific progress in the 1960s, some paradigmatic changes began to take place in Argentine anthropology, and these were the origins of modern biological anthropology. The discipline became integrated in the curriculum at the School of Natural Sciences and Museum as a result of changes introduced to the bachelor's degree in anthropology, allowing

biological anthropology to be offered as one of the three major fields of anthropology. This, together with the emergence of new anthropological leadership, consolidated strong intellectual and institutional discontinuities between Vignati's physical anthropology and the new biological anthropology (Soprano, 2009).

In the same decade, the Growth and Development Center was created in the city of La Plata. The first results of the research were published in 1966 by physician Marcos Cusminsky and anthropologist Lilia E. Chávez de Azcona. Their longitudinal study of child growth and development in La Plata (Cusminsky et al., 1966) was awarded the Fernando Schweitzer Prize in 1972. Cusminsky was recognized not only for the excellence and accuracy of his research but also for the training of human resources. One of his disciples, Luis Manuel Guimarey, continued the task at La Plata city in the Children's Hospital "Sor María Ludovica."

Scientific research continued in the 1970s at the Museum of La Plata in the Anthropology Division directed by Chavez de Azcona. In 1974, Susana Ringuet carried out a comparative auxological study between two populations of different ancestry and presented it as her doctoral thesis supervised by Alberto Marcellino. Her study samples were from San Antonio de los Cobres (Salta) and La Plata city (Buenos Aires) and resulted in a number of publications (Ringuet, 1972, 1974, 1977).

In 1976, the academic renovation was abruptly interrupted by the military dictatorship. During this process, Argentine institutional functioning deteriorated, particularly at universities. Massive numbers of layoffs of researchers from the National Scientific and Technical Research Council (CONICET) and university professors occurred. The anthropology career track was terminated in the universities of Rosario, Mar del Plata, and Salta, and changes in the syllabus were introduced at the University of Buenos Aires. In the National University of La Plata, anthropology became a postgraduate course and the syllabus was replaced by a heterogeneous set of subjects, completely unaligned with the new paradigm (Carnese and Pucciarelli, 2007).

In 1983, the return of democracy was accompanied by the reintegration of several professors and researchers to the universities. The career track was reopened in the universities in Rosario and Salta and it was introduced in the universities of Jujuy and Olavarría. At the University of Buenos Aires, Alberto Rex González, as advisor of the Culture Secretariat of the Nation, reorganized the Section of Biological Anthropology in the Institute of Anthropological Sciences. As a result, new lines of research in population genetics, demography, and growth were developed (Carnese and Pucciarelli, 2007).

In 1984, Marta G. Mendez presented her doctoral thesis about morphological and physiological variations in infant through adolescent populations of different socioeconomic levels, at the National University of La Plata School of Natural Sciences and Museum, supervised by Alberto J. Marcellino. Then Mendez, together with Susana Alicia Salceda, carried out studies on child growth in different regions of the country (Mendez, 1984; Salceda and Mendez, 1987; Mendez et al., 1997; Salceda et al., 1997). Marcellino, together with other researchers, continued this line of research at the Department of Anthropology,

National University of Córdoba School of Exact, Physical, and Natural Sciences (Marcellino and Colantonio, 1999, 2010; Demarchi and Marcellino, 1999; Demarchi et al., 2001; Colantonio and Marcellino 2002; Bajo et al., 2007).

In 1990, at the National University of La Plata's School of Natural Sciences and Museum and the Engineer Fernando Noel Dulout Institute of Veterinary Genetics, María Cristina Terreros presented her doctoral dissertation about the effect of malnutrition on the response to mutagenic agents, supervised by Fernando Dulout. Later, Gisel Padula together with specialists in genetics analyzed the contribution of protein-calorie malnutrition to increases in the frequency of chromosomal structural alterations (Terreros, 1990; Padula and Seoane, 2008; Padula et al., 2009).

The conceptualization of biological anthropology was thus recovered in the anthropology career track of the National University of La Plata—that is, the study of processes rather than things that enabled the recognition of thematic units characterizing the objectives of each disciplinary boundary. In this sense, Pucciarelli (1989) stated that biological anthropology studied all the processes of differentiation among human populations resulting from the dynamic and systemic interaction between intragroup variations and the context of specific environmental factors. Two essential elements emerged from this definition: biological variation, expressed through multiple intra- and interpopulation differentiation processes, and interaction with the environment, necessary to understand such processes. Thus, modern biological anthropology is primarily concerned with ecological studies. Further, this definition allowed the delimitation of the following thematic units: (1) evolution; (2) adaptation; (3) ontogeny; and (4) phylogeny. It also resulted in these characteristic combinations of the discipline: (1a) ontogenetic evolution, comprising the study of individual growth and development as part of intra- and interpopulation variations; (1b) phylogenetic evolution, covering the biological aspects and criteria necessary for the understanding of human evolution; (2a) ontogenetic adaptation, including phenotypic changes that cannot be passed on to descendants because they do not affect individual genetic constitution (we refer to physiological or extragenetic adaptation); and (2b) phylogenetic adaptation, comprising genetic and adaptive processes of existing and extinct populations. In summary, this is the theoretical framework that characterizes current biological anthropology in Argentina.

An important milestone for the development of biological anthropology was the creation of the Argentine Association of Biological Anthropology (AABA), during the First National Meeting of Biological Anthropology held in La Plata in 1993. This meeting contributed to strengthening national research groups, integrating with international groups, and formulating interinstitutional projects. In addition, the AABA produces *Revista Argentina de Antropología Biológica*, a nationally and internationally renowned journal (Carnese and Pucciarelli, 2007).

This institutional context favored the contact of the biological anthropology research team from UBA with researchers from UNLP and later with those at the Centro Nacional Patagónico (CENPAT, CONICET) to promote studies on growth and



development in indigenous and cosmopolitan populations (Guimarey et al., 1993, 1995; Pucciarelli et al., 1993, 1996; Carnese et al., 1994; Torres et al., 1999, 2000; Oyhenart et al., 2000). Likewise, those links extended to other provinces and cities in Buenos Aires province. For instance, research in the Municipio de la Costa (Buenos Aires Province) established the phenotypic modifications induced by environmental factors, especially nutrition (Bolzán and Guimarey, 1992a, 1992b).

In 2002, Evelia Oyhenart organized a research team at the School of Natural Sciences and Museum (at UNLP) and IGEVET (at UNLP-CONICET), School of Veterinary Sciences, whose main objective was the study of human growth resulting from biological-environmental interactions, considering the environment as a set of biophysical, socioeconomic, and cultural factors. The studies that were carried out in the provinces of Buenos Aires, Entre Ríos, Mendoza, and Misiones are described below.

#### BUENOS AIRES PROVINCE

The first research was carried out in the city town of Brandesen to determine the nutritional status of schoolchildren at social risk. Subsequently, the analysis was deepened by extending the original sample to children from urban areas and incorporating the analysis of intestinal parasitism in preschool children; these analyses were performed by parasitologists from the Center of Study on Parasites and Vectors (CEPAVE, UNLP-CONICET; Oyhenart et al., 2006; Cesani et al., 2007, 2010, 2013; Zonta et al., 2007).

Parallel studies were performed in La Plata city in a sample of 6,351 schoolchildren aged 3–15 years. Results showed a high prevalence of excess weight, obesity, and central fat distribution patterns in children living in both favorable and unfavorable residential conditions. Undernourishment, although present to a lesser extent, was more prevalent under less favorable socioenvironmental conditions (Oyhenart et al., 2005, 2007, 2012; Torres and Oyhenart, 2009; Bergel Sanchís et al., 2011; Torres 2012). The La Plata population analysis progressed towards a more thorough study of schoolchildren from eleven communities. The results showed a marked heterogeneity in child nutritional status and parasitic infections, depending on the socio-environmental characteristics of residence. Whereas parasitism and infant undernourishment coexisted in communities with deficient environmental conditions and parents of low educational level and without formal employment, the prevalence of excess weight among children was higher in communities with less coverage of basic urban services but with parents of higher educational level and having formal employment (Oyhenart et al., 2013).

#### ENTRE RÍOS PROVINCE

In this province, studies focused on (a) nutritional status and body composition in children aged 3–6 years; (b) socioenvironmental conditions of residence; (c) practices and representations about health and family nutrition; (d) practices and representations about children's nutrition and physical activity; and (e)

perception of food security (with respect to access) at home. The possible association among malnutrition, socioenvironmental conditions of residence, and practices and representations about food were also investigated. Three areas could be distinguished: urban, periurban, and rural. The results indicated that the higher the socioeconomic level and more adequate the environment where families lived, the higher the perception of food security regarding access, as well as higher prevalence of infant excess weight. In the periurban areas, characterized by unstable incomes, the levels of parental education and health coverage were low, families were large, overcrowding was high, the perception of food insecurity at home was higher, and the prevalence of malnutrition and excess weight much higher. Finally, the rural areas, characterized by production of food for self-consumption and by local social dynamics promoting greater social cohesion and inter- and intra-support nets, provided a more protective environment for infant growth (Bergel Sanchís et al., 2012; Bergel Sanchís, 2014). As a complement, a parasitism follow-up study was carried out during 2010 and 2011, which revealed that 58.6% of children were parasitized by at least one species of parasite, with *Enterobius vermicularis* and *Blastocystis hominis* being the most prevalent ones (Zonta et al., 2013).

#### MENDOZA PROVINCE

In this province, the infant-juvenile populations were studied in the departments of General Alvear and San Rafael. In General Alvear, the categorical principal components analysis (catPCA) was used for the first time to avoid a priori urban and rural categorization. Thus, the study was carried out on subpopulations defined as a function of the socioenvironmental characteristics of residence of each child. The results indicated that although the prevalence of excess weight was similar in all groups, that of obesity was higher in children from middle-income urban areas, and undernourishment was more prevalent in rural areas. Body composition changes were observed in both undernourished and obese children. These results were interpreted in relation to the deepening of structural poverty and impoverishment of non-poor sectors as a result of unemployment and underemployment as consequence of the Argentine economic crisis (Oyhenart et al., 2008a, 2010). In San Rafael, children from the urban area showed higher excess weight whereas children from the periurban area showed stunting together with high intestinal parasitism. The socioenvironmental variables that most influenced the nutritional status of children were low maternal education level and deficient environmental sanitation (Garraza et al., 2011, 2014; Garraza, 2013).

#### MISIONES PROVINCE

The studies in this province included research in the indigenous Mbyá Guaraní communities as well as in the urban and rural populations of Aristóbulo del Valle. The results indicated that indigenous populations lived in conditions of extreme poverty and were among the most marginalized in this country.

Severely stunted growth and parasitic infection were still quite common among Mbyá children; almost half of them were affected by both of these conditions, which were accompanied by significant changes in body composition and proportions (Oyhenart et al., 2003; Navone et al., 2006; Orden and Oyhenart, 2006; Zonta et al., 2010, 2011).

However, similarities in the prevalence of stunting between rural and middle urban groups indicated that cities were not healthier than rural environments. On the contrary, the finding that rural groups presented the lowest prevalence of excess weight reinforced indications that poverty and malnutrition were progressively moving from rural into urban areas. In addition, rural children still had more diverse and healthier diets favored by the consumption of homemade products (e.g., via orchards, animal husbandry), placing them at an earlier stage of the nutritional transition (Zonta et al., 2014).

The research group currently directed by Evelia Oyhenart continues biocultural and interdisciplinary studies regarding the characterization of growth patterns and nutritional status of infant–juvenile populations of different socioeconomic and socioenvironmental contexts of Argentina, with an emphasis on variations in body composition and proportions and sexual dimorphism.

#### CATAMARCA PROVINCE

Growth studies in Catamarca began in the early 1980s, when the health ministry of the province requested the intervention of a biological anthropologist to assess the nutritional disposition of children in relation to assistance offered by the Program of Social Nutritional Promotion. The research was carried out during 1982–1984 in the context of an institutional project designed and supervised by Delia Lomaglio titled “Anthropometry of Schoolchildren from Catamarca,” of the Government of Catamarca, Ministry of Social Welfare. The anthropometric measurements included weight, height, sitting height, and head circumference of 2,142 school-aged children from urban and rural areas from different geographical regions within the province. This information became the first growth database in Catamarca. Results were presented in two workshops in 1983: “The Food Problem in Latin America and the Caribbean” (Lomaglio et al., 1983) and “Nutritional State of Children in Argentina” (Lomaglio, 1983), both held in Buenos Aires and published in *Archivos Argentinos de Pediatría* (Lomaglio, 1985).

From that moment, a research track was developed at the University of Catamarca, which has continued under the Center of Studies of Biological Anthropology (CEABi) since its creation in 1993, directed by Lomaglio. Currently the multidisciplinary team of CEABi carries out research in the field of nutritional epidemiology, including markers, analysis techniques, and evolution of body composition, excess weight and obesity, body image perception, disorders in food behavior at different stages of ontogeny, growth and nutrition, and environmental effects on growth and nutritional condition of human groups, with special

emphasis on high-altitude populations (Lomaglio, 1992, 1997, 2012; Lomaglio et al., 2007; Mesa et al., 2013; Candelas et al., 2015; López Barbancho et al., 2015).

#### CHUBUT PROVINCE

Systematic studies in the infant–juvenile populations from Chubut began in 2001 when Silvia Dahinten developed the Project Biedma (PROBIEDMA) project in the Research Unit of Anthropology and Archeology (CENPAT–CONICET). The main objective of the project was to study the growth and nutritional status of schoolchildren from the Department of Biedma (Chubut), with emphasis on the city of Puerto Madryn. The results showed a high prevalence of excess weight or obesity and provided the starting point for a health intervention plan based on physical education activities as part of the program “Healthy Municipalities” of the National Health Ministry (Dahinten et al., 2001, 2005; Dahinten and Zavatti, 2003; Botterón et al., 2005). Interestingly, this population presented more excess weight compared with other populations (Dahinten et al., 2011a, 2011b). On the other hand, the secular trend in height of the adult male population from Chubut was studied using primary sources of information. Apart from height, the personal data, skills, jobs, and education level of 4,185 individuals born in 1909, 1919, 1929, 1939, and 1949 were obtained and analyzed. The results indicated an average positive secular trend in height at provincial level (+4.08 cm) between the first and last studied years. At the regional level, significant secular differences were detected, with an annual increment of 0.09 cm on the coast and 0.04 cm on the plateau and cordillera. Further, skilled workers showed steady height increments compared with unskilled ones. The same applied for literate and illiterate individuals. The secular variation in height clearly reflected the incidence of the eco-geographical, socioeconomic, demographic, and nutritional conditions of the region (Dahinten et al., 2008; Gavirati et al., 2013). This phenomenon was comparatively analyzed with the military district of another province, Jujuy. The sample included 8,262 and 3,707 individuals recruited in Jujuy and Chubut, respectively, from 1910 to 1950. Results showed that average height was greater in Chubut soldiers, reflecting that this phenomenon was far from being homogeneous at interprovincial level (Dahinten et al., 2012a, 2012b).

#### FORMOSA PROVINCE

Since 1997, the Program of Reproductive Ecology of the Argentinean Chaco (ProERCA) has developed research activities, mainly in the province of Formosa. The program is directed by Claudia Valeggia and is aimed at contributing to the understanding of biological, ecological, and sociocultural factors that affect fertility in Great Chaco populations. Within this context, ProERCA carried out several growth studies in children from birth to puberty in the Qom (Toba) and Wichí communities of Formosa. The first studies on infant growth were carried out

in a peri-urban Qom population and centered on the evaluation of weight curves from newborns to two-year-old children using health center records (Valeggia et al., 2002). This study confirmed that the nutritional status of Qom children was optimal until about seven months of age, when typically the weaning process was begun. A more recent study on food after weaning (Olmedo and Valeggia, 2014) showed that complementary food was of scarce nutritional value in these populations, thus accounting for the worsening of nutritional status in these children.

In addition, various studies compared the growth of indigenous children from different ethnic groups with that of children from the same ethnic group but living in different environments (rural vs. periurban; Valeggia et al., 2005; Valeggia, 2010; Lagranja et al., 2015). At present, ProERCA is finishing a longitudinal follow-up study that began in 2010 with a group of Qom children (newborn and weaning stage) and a group of Qom girls during puberty transition. This study will provide detailed longitudinal data for a variety of growth correlations such as diet, physical activity, parasitic load and infectious diseases, family and social environment, and sociocultural aspects of these transitions.

#### JUJUY PROVINCE

Research on growth and human development began in the mid-1980s in the Genetic and Bioanthropology Section of the Institute of Altitude Biology (National University of Jujuy) with José Dipierri's study funded by CONICET. Dipierri analyzed the influence of altitude above sea level on both birth weight and menarche age in Jujuy, and then also the secular trend and regional variation of adult male height with data provided by the Argentine Army from 18-year-olds performing their compulsory military service.

Dipierri et al. (1992) and Alvarez et al. (2002) found regional variation in birth weight, with average weight lower in the highlands (Puna and Quebrada) than in the lowlands (Ramal and Valle). In 2008, Grandi and Dipierri analyzed the trend of different birth weight categories in Argentina during 1999–2002, observing a negative secular trend of average weight, with an increment of low (<2,500 g) and very low (<1,500 g) weight and a decrease of normal weight ( $\geq 3,000$  g).

Furthermore, Bejarano et al. (1996) evaluated the secular trend of adult height in soldiers during 1860–1960, verifying existence of a positive differential regional trend, with the highest values in the lowland regions (Valle and Ramal). Analysis of variance of surname (autochthonous/foreign), geographic altitude (regions), time (1860–1960), and height of Jujuy soldiers examined at Jujuy Military District revealed that, independent of year or geographical region, individuals bearing foreign surnames were significantly taller than those with an autochthonous surname, and regardless of ethnic group, the association between average height and geographical altitude was inverse (Bejarano et al., 2009).

Data from the First Height Census carried out in Jujuy in 1993 allowed analysis of height variations in primary schoolchildren aged 6–9 years from the four geographical regions. In both

sexes and in all age groups, children from Puna and Quebrada were significantly shorter than those from Valle and Ramal, and, at 6 years of age, the average height of children from Jujuy was significantly greater than the national standard (Dipierri et al., 1996). Height variations in schoolchildren aged 6–9 years with reference to the environment (rural/urban) and geographic altitude indicated that infant growth in Jujuy populations would be influenced by geographic altitude, regardless of environment (Dipierri et al., 1998).

From 2000 to the present, studies concentrated on the analysis of growth, development, and nutritional status of Jujuy populations through the combined interpretation of hematological and anthropometric indicators. The evaluation of anemia and iron deficiency in pregnant women and their newborns living at 1,200 m above sea level indicated the prevalence of anemia in 67% of term pregnant women and 46% of their newborns, with iron reserves in newborns being independent of maternal ones (Buys et al., 2001). On the other hand, Bejarano et al. (2003) reported that average hematocrit values in the age groups 4–6 years and 10–22 years coincided with those of the reference group fitted for altitude, regardless of age, sex, and socioeconomic level. However, Buys et al. (2005) determined the prevalence of anemia and iron deficiency in a population of 2,405 12-year-old schoolchildren living at 1,200 m above sea level, and although anemia prevalence was very low and did not constitute a population risk, iron deficiency was remarkable.

Using several criteria, Bejarano et al. (2005) analyzed the prevalence of malnutrition and its evolution during 1995–2000 in schoolchildren from San Salvador de Jujuy, observing an increased prevalence of both excess weight/obesity and undernutrition, thus confirming the nutrition transition paradigm. On the other hand, Alfaro Gomez et al. (2008) analyzed the growth pattern of children from Jujuy living at 1,200 m above sea level by means of the height and weight percentiles calculated with the LMS method (Cole and Green, 1992). Comparisons with the international references (CDC and WHO) showed that growth and nutritional conditions of Jujuy populations should be evaluated with the WHO reference as this more accurately reflects the growth pattern.

Currently, studies on growth patterns and nutritional status and their relation with nutritional status based on anthropometric and biochemical indicators (hematological and metabolic profiles) in infant through juvenile populations living at different altitude levels are in an advanced stage of implementation. The characterization of somatotype and fat distribution patterns in children, teenagers and adults, the analysis of growth rates at different ages, and the evaluation of body image perception and satisfaction in teenagers and its relationship with disorders in food behavior are underway. Also, the geographic scope of analysis extended to populations from other provinces and even across the country. Finally, the progress of knowledge on several aspects of growth and human development due to DNA technological advances has opened numerous analysis perspectives that are intended to be implemented soon.

## COLLABORATIVE STUDIES CARRIED OUT IN ARGENTINA

In 2005, different research teams began the task of coordinating the techniques, methodologies, and references used in Argentina in order to compare the prevalence of malnutrition in different regions. For instance, a team supervised by Evelia Oyhenart, José Dipierri, Delia Lomaglio, and Silvia Dahinten, analyzed the nutritional status of the infant through juvenile population from six Argentinean provinces using the same methodologies to obtain variables that could be contrasted. The sample included 15,011 schoolchildren, aged 3–18 years, and the results indicated that the prevalence of malnutrition showed regional differences with clinal variation; thus, malnutrition decreased from north to south, and the chance of being overweight or obese was higher in the south and lower in the north. The prevalence of malnutrition was consistent with the socioenvironmental indicators. The northwest region showed the lowest levels of economic activity, the highest rates of poverty and indigence, the highest rates of maternal–infant mortality and the worst sanitary conditions (Oyhenart et al., 2008b).

Later, researchers of the Complutense University of Madrid (Spain) joined this group to calculate weight-for-age (W/A) and height-for-age (H/A) percentiles of schoolchildren from Argentina employing the LMS method, and to compare the obtained percentiles with those of international and national references. Their results indicated that the weight and height distribution in schoolchildren from most regions of the country differed from that of national and international references. A new national reference based on internationally recognized methodological criteria should be established to adequately reflect the biological and cultural diversity of the Argentine populations (Oyhenart et al., 2014).

## CHALLENGES AHEAD

Since its earliest stages, biological anthropology has been characterized by a dynamic development that propels it into the future. The strategy to renew this dynamism should be the promotion of multicenter and interdisciplinary investigations in order to make consistent comparisons for properly characterizing growth, development, and infant through juvenile nutritional status. Accordingly, some actions should be taken. First, biological anthropologists should be trained in the following fields: (a) Research and development, to promote and define multidisciplinary national strategies to study the growth and development of children and young people in relation to the socioeconomic and sanitary conditions in which they and their families live; (b) Teaching, to design biological anthropology curricula for all educational levels, to correlate graduate and postgraduate teaching with the current needs of society, and to develop collaborative agreements with national and international colleagues; (c) Outreach to the community, to promote the implementation of active policies and the commitment of the public health sector,

governmental authorities, universities, and local citizens, who will work together to discover viable solutions.

## ACKNOWLEDGMENTS

We thank our colleagues for providing relevant information for this chapter; Adriana Di Maggio for assistance with English language translation; and María Cristina Muñe for editing the manuscript.

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**BIODEMOGRAPHY AND EPIDEMIOLOGY**

Biodemography and epidemiology research deals with the components and codeterminants of biosocial processes. The field includes the study of genetic structure, genetic regulations and environment, and social patterns of health and disease, all in relation to the evolutionary processes.

Given the knowledge and specialized methodologies required, in the beginning, most research in Latin America was carried out by biologists, geneticists, and physicians, followed by domestic and foreign physical anthropologists who were interested in past and contemporary indigenous American populations.

In Latin America the first biodemographic approaches and the relationship to epidemiology originate in the 1930s in Mexico focusing on the structure of the Mexican population through demographic characteristics and genetic markers. Biodemographic research increased since the 1950s, mainly through studies of prehistoric populations. These advances and the studies on admixture had a considerable influence because of their great impact on populations, as well as their influence on health and disease processes in Latin America. Brazil followed in the 1950s, with studies on the genetic implications of demography, initiated by N. Freire-Maia, O. Frota-Pessoa, and A. Freire-Maia, who investigated especially the prevalence and consequences of inbreeding, the concept of isolates, and other aspects of human mating. Beginning in the 1960s, research conducted by Neel and Salzano on the Xavante population pioneered the development of parameters for testing genetic traits in order to evaluate the biological pressures on a hunter-gatherer society with incipient agriculture. Biodemographic research has been increasing in various Latin American countries since the 1970s, building the genetic structure of contemporaneous and historical micropopulations through historical demographic methods and the use of parish, civil, and vital statistical archives. Multiple genetic studies also contributed to the understanding of the role of polymorphisms in the susceptibility, expression, and progression of diseases.

Biodemography in Argentina started in the same way as in Brazil, a posteriori followed by Uruguay, and developing two main lines of research: one of them related directly to the structure of populations and the other focusing on the influence of evolutionary processes on populations. Biological structure was investigated in historical (Whites, Indians, Blacks, and Mestizos) and contemporaneous populations from different regions, mainly referring to mating patterns (legitimates and illegitimates), homogamy, inbreeding, and genetic flux, some of them applying isonymic methods. Isonymy studies also had an important development in the northwest region of South America, mainly in Venezuela.

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Manuscript received 28 April 2016; accepted 10 November 2017.

Estimates of fertility, mortality, opportunity for natural selection, genetic drift, and migration have been obtained mainly in rural populations, but also in aboriginal and in current populations from distinct regions and altitude levels, with some epidemiological approaches to the process of interethnic contact. But estimates depend on how and when the demographic transition has been produced in each region. Not all Latin American countries are at the same stage of the demographic transition because of industrialization and socioeconomic processes. For example, Cuba leads Latin American demographic transition, as demonstrated by the population in the Plaza de la Revolution, in the capital city of Havana, which has the lowest fertility rate and the highest rate of aging. On the other hand, in countries like Guatemala, the indigenous fraction is still in an incipient stage of transition, with both high fertility and high mortality rates from exposure to high-risk circumstances.

Like other lines of research, biodemographic and epidemiologic studies also add knowledge regarding the peopling of America. As Edwin Francisco Herrera Paz shows in chapter 12, micro differentiation throughout pre-Columbian America was led not only by isolation and interpopulation flow, but also by local adaptation to diverse environments. Once Europeans appeared, together with an indigenous and African labor force, this population experienced different patterns of demographic and mating processes. Subsequent mixing processes, habitat changes, isolation, and migration have occurred, and they persist today in Central America.

At present, biodemography still presents some difficulties. Referring to the studies of contemporaneous populations, some methodologies suitable for an anthropological data corpus are required. In respect to small populations, there is poor demographic information and, when data are available, estimates require the use of population models that do not always fit the reality of the groups being studied.

Recently, worldwide biodemographic research has been overshadowed by advancements in genetic research. But we should not forget that each form of approach enhances the other. Biodemographic researchers agree that future studies should include a combination of genetic and biodemographic perspectives.

## POPULATION GENETICS

Recent decades have witnessed the tremendous growth of research in population genetics, which also has a long historical development focusing on Latin American populations. Concerning population genetics, all the chapters in this monograph emphasize that countries and regions display unique disciplinary developments and population histories.

Disciplinary development followed a parallel course in Latin America, as Francisco Salzano describes in his chapter. Starting in the early twentieth century, antigenic differences in blood groups were the preferred way to interpret human population variability. The development of starch gel electrophoresis

and the enzyme identification procedure opened a new avenue to the study of protein variation in populations. Molecular research at the DNA level was introduced. Finally, the era of "next generation sequencing methods" began and is still the current trend.

Research in population genetics varied regionally. The earliest studies conducted in South America began in Brazil and Argentina in the 1920s, followed by Colombia, Venezuela, and Chile in the 1940s, and Uruguay in 1950. Other countries started later, some of them dependent on research carried out by foreign groups when it was economically feasible to access new techniques.

In the northwestern region of South America blood groups and protein polymorphisms in native populations (mainly from the Amazonian and Andean regions) were performed, followed by studies of abnormal hemoglobins, the Human Leucocyte Antigens system (HLA), and some proteins. The main questions came from research on the estimation of admixture in different geographical regions and populations that were ethnically classified according to their historical origins (aboriginal, Asian, African, or European). In the southwest, the same research ideas have developed (blood groups, HLA, and genetic or complex diseases) also pointing to the problem of admixture and genetic origins. Research followed along similar paths in Brazil through the development of population surveys on blood groups and sickle-cell anemia and of inbreeding studies with consideration of demographic data. In all these regions, as well as in the Caribbean, most research tended to characterize particular populations or substructures within them.

The results clearly demonstrated that further research should focus on relationships between populations through the study of respective origins and the processes occurring from prehistoric to present times. The main questions were which was the first aboriginal group and which groups contributed in each region to the genetic pool of the population, as well as in what different proportions they contributed, thus initiating the new era of molecular markers and the possibility to differentiate maternal, paternal, and biparental lineages. Each population tells a different story according to different variables such as time, archaeological evidence, geographic and demographic characteristics, main waves of migration, and their sociocultural traits.

The prehistory of Latin American populations has the same origin and moment of first occupation (around 14,000–15,000 years ago), but the main question debated extensively is the number of groups responsible for this prehistoric occupation. Then, the following process acting on the aboriginal populations had also some differences. In the historical period, Spain colonized almost all regions of South America, with the exceptions of British Honduras (Belize) and the Portuguese colonization of Brazil. The third influx to the Americas was represented by African slaves, who worked as laborers in domestic settings, agriculture, and mines. Other migrations configured genetic composition. As expected, results evidenced a close relationship with eastern Asian populations but, surprisingly, also with the genome

of Australian Aborigines, although we do not know the date of contact with Australia.

In the northwest region, indigenous and European components are variable. African lineage is the least important in urban populations but is significant in the rest, with this ancestry predominating over 50%, except in Peru and Ecuador, where the percentage of the Amerindian component is more than 70%. The Caribbean Islands were populated in several waves from South and Central America, including Mexico and Yucatán, with particular genetic and social processes acting in their configuration (e.g., slaves came from different regions of Africa, and various European empires colonized the islands).

Countries of South America's southern region also show various admixtures. In Argentina, where both cosmopolitan (i.e., inhabited by peoples from different countries) and indigenous communities have been analyzed, the urban areas have a predominant European component in the central area but a predominant indigenous component in the north and south. Other studies deal with parameters of heterozygosity and the proportion of polymorphic loci based on the data of genetic frequencies to calculate genetic drift and the components of intra- and interpopulation diversity. Emphasis in Chilean research mainly has been on paleo-American topics, and recently, as in Argentine investigations, analysis of ancient DNA has been incorporated. Researchers in Uruguay have focused on studies of admixture, with the African component appearing as significant.

Salzano shows that five countries constitute three groups according to historical ancestry: (a) Mexico and Peru have predominantly Amerindian components (57% and 68%, respectively); (b) Colombia and Brazil have mainly European influences (60%, 80%); and (c) in Chile the Amerindian and European ancestries are about equal (47%, 48%). The African component is always low, with a maximum of 11% in Colombia.

It is interesting to see that in almost all countries the asymmetric mixture appears in maternal, paternal, and biparental DNA analysis, showing Amerindian maternal lineage and either European or variable paternal lineage.

In Mexico, from the beginning it was important to sample bone collections to discover genetic markers. Such research was initiated to establish the variability of genes and earliest lineages in indigenous groups, as well as to analyze genetic frequencies and racial mixing in contemporaneous populations, sometimes in relation to the effects of environments on the prevalence of diverse illnesses.

At present, technological advancements are achieved so quickly that only access to data provided by a company or its website can furnish up-to-date information. Accessibility to databases of full genomes has allowed advances in issues of human evolution (chimpanzee, extant *Homo sapiens*, *Homo neanderthalensis*, and Denisovans) especially in Brazil, where local researchers have led the way. Together with investigators in other countries, they are presently engaged in the Consortium for the Analysis of the Diversity and Evolution of Latin America, which is investigating the complex interaction between sociocultural,

phenotypic, and genetic factors responsible for the perceived human variability in Latin America and the estimation of African, Amerindian, and European ancestry.

As Yeseña Peña Sánchez remarks in chapter 9, the demographic history of populations leaves an evolutionary track in hereditary molecular markers, both the neutral and those related to selection. The study of polymorphic molecules can elucidate the genetic structure, genetic regulations and environment in relation to the evolutionary processes.

Currently, several countries have initiated studies with databases of genetic profiles in diverse populations, particularly indigenous and mestizo, whose application can be useful in medical, anthropological, legal and civil cases, among many others. Moreover, economic and demographic processes in the present might be still modulating the cultural and genetic makeup of populations, facts also closely linked to the change in dietary patterns.

## **GROWTH, DEVELOPMENT, AND NUTRITION**

In research referred to as growth, development, and nutrition, the countries of Latin America have had a relatively similar history. Taking Mexico as a precursor, Peña Sánchez reports that the first clinical studies were focused primarily on the growth of children per se (height and weight). Intensified investigations and multinational studies with anthropological contexts began in the mid-twentieth century. Researchers in Colombia, for example, have been interested mainly in pre-Hispanic populations. In Brazil, indigenous groups are frequently studied. In other countries, such as Peru, investigators have focused on modifications that altitude produces from anatomical, biochemical, and physiological bases of their adaptation. Regional and national surveys of health and nutritional status emerged that included mainly measures of height and weight using morphoscopic and morphometric techniques, sometimes comparing rural versus urban populations, or maturation indicators when applied to distinct populations. More recently, the fields of nutritional anthropology and auxological epidemiology have developed, with an interinstitutional and multidisciplinary focus that promotes more collaborative studies from the biocultural perspective. Surveys of growth status over time were important in understanding the impact of change in social factors (nutritional, social, and economic condition) on well-being and biological variation.

Certain research questions were designed around specific and historic problems concerning the socioeconomic development of various communities in Latin America. For example, the need for differential standards to evaluate growth measures grew from widespread cases of severe under-nutrition and malnutrition problems, the worst of which were specifically related to mortality. The general problem has been the accelerating prevalence of the excess weight-to-height ratio and the negative consequences of a high-calorie diet, which becomes a major factor

underlying the increasing prevalence. Another very important research area investigates effects of the sociodemographic environment on nutritional status, in conjunction with the application of programs or policies concerning issues such as intestinal parasitism in preschool children, reproductive health, sport auxology, and changes in health and growth, which are affected by social mobility and migration processes.

A complex area of research involves the study of human growth as a result of the intersection of biological and environmental factors (biophysical, socioeconomic, and cultural factors, such as education level and employment), which has implications for investigations such as evaluating perception of body image, or the feeling of satiety and its relationship with disorders in food behavior. At present, growth, development, and nutrition studies have taken the first steps in explaining and managing interconnections between genetic, epigenetic, and environmental factors. However, ongoing work includes longitudinal studies into the relationships between age of maturity and general physical activity; growth standards; studies in multiethnic communities and in different environments according to altitude above sea level; up-to-date information on the growth and health status of the child and adolescent population; and developing strategies to promote physical activity among them, and in turn, to study the risk factors for cardio-metabolic diseases.

Currently, the progress of research on several aspects of growth and human development due to technological advances in DNA processing is stimulating numerous pathways for analysis (like plasticity and epigenetics) that are most easily implemented through cooperative institutional and interdisciplinary investigations.

Moreover, data on demographic history and environments have to be integrated with cultural characteristics in order to understand the current situation and the behavior of populations. Other epidemiological aspects, socioeconomic differences, and the current crisis of refugee migration are additional factors that must be considered.

Indeed, it can be seen throughout the chapters of this book that in the different regional histories, references regarding demographic characteristics, development processes, and population genetics overlap. These disciplines and the events they study are at a crossroads where both biology and genetics intersect with demographic processes through the interactions of cultural patterns within and between populations.

## BIOARCHAEOLOGY

The topics of bioarchaeology, skeletal biology, and paleodemography have been grouped together in this volume due to their related academic content and overlapping methodology. As noted by Carlos David Rodríguez Flórez in the chapter on the northern Andes, these terms are sometimes used almost synonymously although they each convey unique perspectives and emphases.

Roots of academic activity in this area of biological anthropology are closely linked with those of paleopathology. In Mexico, these disciplines were inaugurated with the founding of the national museum in 1825 and the establishment of skeletal collections from the monumental archeological sites of Alta Vista, Teotihuacan, Monte Alban, and Palenque. Activity in Mexico was also stimulated by foreign investigators such as the French mission in 1864, although many skeletal collections produced by these efforts left the country. Other key developments in Mexico included the creation of a physical anthropology department in the museum in 1887, exhibition of human remains in the 1892 exposition in Madrid, and the 1897 declaration that archaeological sites and specimens represented national heritage.

In Brazil, the development of the field dates back to the founding of the National Museum in Rio de Janeiro in the nineteenth century. Key investigators such as Joao Bastista Lacerda, Edgar Roquette-Pinto, and José Bastos de Avila initiated research into topics of interest at the time.

The first investigations of human remains in Colombia were conducted in the 1940s by E. Silva Celis. His work documented aspects of cranial morphology. He also reported on elements of a large skeletal sample from the site of Sogamoso, including a discussion of ages at death and other bioarchaeological variables.

During this early developmental period, topics of investigation varied throughout Latin America but were focused on racial typology, craniometric studies, cultural modifications, pathological alterations, and trephination.

The 1970s and 1980s witnessed a shift in interest toward more population studies, an evolutionary perspective and greater integration of biological and archaeological data. Most chapters on this topic also recognize the influence and positive impact of foreign researchers, especially those from the United States. The evolution of the field in Latin America is closely linked with similar developments in the international academic community. Topics of growing interest have been paleodemography, geometric morphometry, taphonomy, social mobility, gender roles, the impact of diet and disease on growth and development, morbidity, and mortality. New methodologies such as isotope analysis, histology, ancient DNA analysis, and robust statistical approaches have greatly augmented research. New imaging technology and close cooperation between archaeologists and biological anthropologists have been important as well. Investigations into topics of earlier interest, such as craniometrics, artificial deformation, and trephination have continued, but these fields of enquiry have been strengthened by technological advances and more holistic approaches.

The evolution of the field has been directional but with some intellectual distractions. In chapter 6 on osteological research development in Mexico, Lourdes Márquez Morfín and Patricia Olga Hernández Espinoza note the development of Marxist philosophy in the 1960s and 1970s, but with minimal impact on skeletal studies. Political developments in each country also have affected research activities through funding levels, decisions on academic hiring policies, and general academic support.

Key factors in the development of bioarchaeology and human skeletal biology in Latin America relate to close collaboration between archaeologists and physical anthropologists, as well as proper documentation, curation, and dating of samples of human remains. The exciting research currently taking place is possible only because of the availability of large skeletal samples that can be properly placed in time and space. Most chapters also note the increase in resources for support within Latin America, interdisciplinary studies, the growing ease of contact, and sharing information and perspectives with global colleagues.

## PALEOPATHOLOGY

Early descriptions of disease conditions in indigenous populations were related in the writings of European visitors dating back to the sixteenth century. In this volume, such presentations are especially noted in the Caribbean Archipelago with ethnohistorical descriptions of treponematosi, smallpox, bone fractures, body modification, congenital conditions, and associated therapeutic practices. Throughout Latin America, similar early accounts offer useful historical perspectives but also present challenges of related to language interpretation and understanding the terms used in diagnoses. By definition, ethnohistorical accounts reflect observations during the early European contact period and do not necessarily represent conditions present prior to the colonial period.

Developments in the field of paleopathology within Latin America largely parallel global trends. Academic roots extend to the scholarly mix of local specialists, largely drawn from the medical field coupled with foreigners with interests in the region. Prominent international scholars who worked in Latin America include Sir William Henry Flower, Adelaide Kendal Bullen, Alš Hrdlička, Marvin Allison, Enrique Gerszten, Arthur Aufderheide, A. F. Bandelier, José Pérez de Barradas, Rudolf Virchow, Roy Moodie, T. D. Stewart, M. T. Newman, G. G. MacCurdy, and Juan Comas Camps. Early local specialists were Felipe Poey, Manuel Rivero de la Calle, Nicolás León, Eusebio Dávalos Hurtado, and E. Silva Celis.

The pioneers listed above began to build research collections and followed the interests of the time. Primary topics of early research included general craniometry, cultural modifications, evidence of therapeutic intervention (primarily trephination), and specific disease conditions. Pathological conditions of interest during the nineteenth and early twentieth centuries related to dental disease, periostitis, treponematosi, osteomyelitis, osteoarthritis, and bone trauma.

Interest in the areas of research discussed above has been maintained throughout the history of Latin American paleopathology but has been supplemented more recently with research directed at conditions using a joint population and epidemiological perspective. Recent research also has become more interdisciplinary, especially in the integration of data from paleopathology with archeological information. This strengthened focus has

allowed interpretations of ecological adaptation and environmental influences on health conditions. Research has shifted toward evaluations of the impacts of diet and settlement patterns on health, using stress indicators documented on skeletal remains. Interpretations of hematological disorders have not only been documented but also related to environmental and cultural factors. Additional topics of recent interest have been enthesial alterations, degenerative joint disease, evidence of infectious disease, porotic hyperostosis, Schmörl nodules, scurvy, auditory exostoses, health influences on stature, life expectancy. Other research foci include Chagas disease, dental hypoplasia, hydrocephaly, scaphocephaly, hydatid cysts, leishmaniasis, pulmonary disease, parasites, arsenic poisoning (northern Chile), neoplastic and neurological disease, Harris lines, dwarfism, and mummies.

The research outlined above has been possible due to the availability of documented collections of human remains from archeological contexts. Such collections stem not only from quality archeological excavations but also from close collaboration between archaeologists and biological anthropologists. Since documentation and dating are key to analysis, quality record maintenance and carbon dating of samples are essential. Proper curation is also needed and has become increasingly available throughout Latin America. The environmental control of collections and regulated access ensure specimen availability for new developments and scientific interest.

Clearly the creation of key associations and meetings has contributed in major ways to the development of paleopathology in Latin America. In 2005, the Paleopathology Association Meetings in South America (PAMinSA) met for the first time in Rio de Janeiro, Brazil. Subsequent meetings in Colombia, Chile, and Argentina have brought many Latin American paleopathologists together to share research results and new ideas. The Congress of the Latin American Association of Biological Anthropology (ALAB) has gained recognition as well.

Also noteworthy in this regard are the contributions of the Mexican Association of Biological Anthropology and the Juan Comas Physical Anthropology Colloquium. These initiatives have supported research and presentations on paleopathology topics for many years. The Mexico chapter notes that radiological studies in paleopathology in that country can be traced back to a 1953 conference in Mexico City in which paleopathological specimens were presented, along with their radiographs. Similar conferences and workshops throughout Latin America have made substantial contributions to progress.

Momentum in the field of Latin American paleopathology is also closely associated with advancement in training and research centers. These developments have been gradual and highly variable in different regions. Clearly, the field of paleopathology in Latin America has evolved dramatically since its early stages in the nineteenth century. Impressive growth has been facilitated by the acquisition and curation of well-documented samples of human remains from archeological contexts, increased communication among practitioners, more quality publication outlets, enhanced opportunities for training, and improved equipment

for analysis. Technological advancement relates closely with radiocarbon analysis for dating purposes, radiography, microscopy, and computer access as well as chemical and molecular analysis. Most importantly, the field continues to attract dedicated and intelligent students with new ideas and enthusiasm for research.

## FORENSIC ANTHROPOLOGY

Aleš Hrdlička (1869–1943) pioneered the discipline of physical anthropology in the Americas through his position as the first curator of physical anthropology at the Smithsonian Institution in Washington, D.C. In addition to many other contributions to the field, he served as the first Smithsonian consultant to the Federal Bureau of Investigation on matters relating to forensic anthropology. Archival sources indicate that his very first consultation on a skeletal forensic case occurred in Argentina in 1910. While travelling through the town of Viedma in the valley of the Rio Negro, he was consulted by local law enforcement. A skeleton had been found and was thought to be that of a missing local rancher. Following his examination of the skeleton, Hrdlička concluded that it did not represent the missing person, but rather, an individual of great antiquity (Ubelaker, 1999). This investigation not only inaugurated Hrdlička's case-work career but also likely represents one of the first forensic anthropology analyses in Latin America.

The chapters in this volume relating to forensic anthropology (chapters 4, 8, 20, 26) document the tremendous advancement and evolution of the field of forensic anthropology in Latin America since Hrdlička's 1910 report (unpublished report cited and described in Ubelaker, 1999). For much of the period prior to the 1980s, consultation remained sporadic with minimal input from the anthropological community. This situation changed dramatically with the political unrest and armed conflicts that erupted in many Latin American countries in the 1970s and 1980s. These developments led to thousands of missing persons and concerned families. A tremendous need was created for systematic search and recovery efforts, as well as sound identification procedures. The nature of this need, as well as resources to meet it, varied throughout Latin America. In general, however, the problems called for anthropological expertise, especially experts with training in archaeological recovery, skeletal analysis, and cultural anthropology. Since then, many anthropologists

have answered the call to become involved, and their work has served as the impetus for the creation of various institutes and organizations. Key developments include the formation of the Argentine Forensic Anthropology Team (EAAF) in 1984, as well as the Fundación de Antropología Forense de Guatemala (FAFG; Flavel and Barker, 2009) and many others. Collectively these efforts have provided leadership, direction and training for scores of forensic anthropologists working in Latin America. They also have led to the discovery, recovery, and identification of many of the individuals who disappeared during the periods of political conflict. Support from the families of the missing has been instrumental in this process. In 2003, the Latin American Association of Forensic Anthropology (ALAF) was formed offering forensic anthropologists a forum for the discussion of developments in this rapidly growing field. More recently, ALAF has inaugurated a certification program for qualified individuals. Certification requirements include demonstrated experience as well as successful passing of an examination given during ALAF meetings. The remarkable advancements in forensic anthropology in Latin America have fueled new demands for training and methodology targeted specifically to the populations and regions under investigation. This new research necessity gradually is producing the needed reference collections and documentation. New population-specific techniques of analysis, enhanced communication, new training centers, and increasing international exposure pave the way for additional progress in Latin American forensic anthropology.

## ACKNOWLEDGMENTS

The authors thank Cassandra M. DeGaglia and Christian R. Thomas of the Smithsonian Institution for their assistance in the compilation of this manuscript.

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and human biodiversity. She has contributed to more than 80 publications in national and international journals. Dr. Aréchiga coordinated the undergraduate programs in industrial design at the Universidad Nacional Autónoma de México (2008–2012). She is an anthropometry instructor of the International Society for the Advancement of Kinanthropometry. She has been a member of the Asociación Mexicana de Antropología Biológica since its foundation. She is a professor of anthropometry in the graduate program of industrial design at the School of Architecture, Universidad Nacional Autónoma de México, and for the international diploma in physical activity, nutrition, and sports, organized by the Universidad del Valle de Toluca and the Centro de Estudios Olímpicos of the Universidad Europea Miguel de Cervantes de Valladolid, Spain. She has been coordinator of the seminar of research in sports. She has served on undergraduate and graduate program committees at various universities and is a member of Sistema Nacional de Investigadores, level II.

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**Norberto Baldi** (chapter 11) is a researcher and lecturer at the University of Costa Rica, where he has worked since receiving his Ph.D. from the University of Kansas in 2013. His areas of interest are the interaction of culture and genetics and the coevolution of dietary practices and the microbiome. A trained archaeologist, Dr. Baldi has carried out archaeological excavations focusing on the initial peopling of the Central American isthmus and societal transitions from hunter-gatherer to agricultural lifestyles. Currently, Dr. Baldi is investigating the population dynamics and epidemiology of indigenous and Afro-Caribbean populations in the Caribbean region of Central America through inquiry into microbiomes and the microevolutionary factors affecting these populations. Dr. Baldi has published work in internationally recognized journals and was recently awarded a grant by the Geographic Project of the National Geographic Society for conducting fieldwork in Central America. In 2015, he served as



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**Ramiro Barrantes** (chapter 11) is a human geneticist who has developed an extensive database of modern DNA patterns from indigenous groups in Costa Rica and other Central American regions. As a researcher, he has executed projects in several areas such as basic sciences, health, and anthropological genetics. The overall objective of his research programs is to investigate the history and genetic structure of these Central American indigenous populations. More specifically, he looks at the association of the genetic structure to some hereditary diseases (epidemiology genetics), as well as the mtDNA, Y chromosome, and nuclear DNA distribution in these populations. Concomitantly, he analyzes their population structure and ancestry. More recently, he has been looking at the ancient DNA of Amerindian groups. He has authored and coauthored more than 120 papers and three books on these topics. Currently, Dr. Barrantes is an active emeritus full professor at the University of Costa Rica, a member of the Academy of Sciences of Costa Rica, and president of the National Council for Science and Technology of Costa Rica (CONICIT).

**Isabel Barreto Messano** (chapter 27) is an associate professor (full time) at the University of the Republic (Uruguay) and a member of the National System of Researchers of the National Research and Innovation Agency (Uruguay). She has a degree in anthropology (University of the Republic), a doctor of biological sciences (National University of Córdoba), and has a postdoctoral degree in social sciences from the University of Valladolid (Spain). She works at the Faculty of Humanities and Education Science at the University Center of Tacuarembó of the University of the Republic, where she teaches graduate and undergraduate biological anthropology and directs various research projects. Dr. Barreto's main field of research is biodemography, which developed over several years and has consolidated both in university-level research groups and in the direction of graduate theses. Her main job is to rebuild the population of small towns with particular historical and demographic paths. Since 2014, she has coordinated her research from Polo University Development in the Department of Tacuarembó, where she focuses on biodemographic studies in rural areas.

Since 2013, she has been developing specific studies in applied anthropology, combining the participation of various institutions in its implementation: colleges, business, civil institutions, and social actors; likewise, she directs the Laboratory of Applied Anthropology at the University of the Republic. She is the author of two books and author and coauthor of numerous publications in peer-reviewed journals and outreach. She has lectured at national and international levels, as well as organized thematic symposia and academic activities. She is a member of numerous academic associations: the Demographics Historical Network and History of the Latin American Population, the Uruguayan Association of Population Studies, the Latin American

Population Association, the Structures Research Group Family of Yesterday and Today (Center for Advanced Studies, National University of Córdoba, Argentina), the Biological Anthropology Association of Argentina, and the Latin American Association of Biological Anthropology.

**Dinorah Castro de Guerra** (chapter 17) is an anthropologist who graduated from the Central University of Venezuela. She completed a master's degree and doctorate in genetics at the Venezuelan Institute for Scientific Research, where she has made a career of research for 25 years. She is currently a senior researcher and serves as the head of the Laboratory of Human Genetics and the coordinator of the graduate program in human genetics at the Venezuelan Institute for Scientific Research. She also teaches at the School of Anthropology at the Central University of Venezuela. Dr. Castro de Guerra has published widely on the origin and genetic composition of the Venezuelan and Latin American populations: on consanguinity and isonomy, admixture, the origin of mitochondrial DNA, and Y chromosome lineages and, most recently, on population pharmacogenetics. She has been president of the Venezuelan Society of Genetics (2000–2005) and the Latin American Association of Biological Anthropology (2010–2012). Currently, she is the secretary of the Board of the Latin American Network of Human Genetics (RELAGH).

**Yadira Chinique de Armas** (chapter 14) is a bioarchaeologist with expertise in skeletal biology, paleobotany, and stable isotope analysis of human remains. Her research interests are focused on the interaction between people and the environment among Caribbean indigenous populations with emphasis in their dietary practices. Her academic background includes a bachelor's degree in biology (graduating with honors from the University of Havana, 2007), a master's degree in physical anthropology (University of Havana, 2009), and a Ph.D. in biological sciences (graduating with honors, the University of Havana, 2014). She is currently working at the Department of Anthropology, University of Winnipeg, where she teaches subjects related to biological anthropology, human osteology, and bioarchaeology. Currently, she is codirector of excavations in the burial sites of Canimar Abajo (Matanzas) and Playa del Mango (Granma) in Cuba. Her research on early plant management and biological and cultural variations in Caribbean "Archaic" Age groups has been published in numerous specialized peer-reviewed journals and books. Her results have been presented at 42 international conferences. Her research work has received several prizes and awards, including the prize of the Cuban Society of Biological Anthropological (2006), the National Award of the Academy of Sciences of Cuba (2009), the award for most outstanding Ph.D. thesis of 2014 (Academic Committee of Natural Sciences, University of Havana) and the University of Winnipeg award for excellence in teaching, research, and service (2018). In 2016, Dr. Chinique de Armas received an award from the Social Sciences and Humanities Research Council of Canada (SSHRC

2016 postdoctoral competition) that funded her research in breastfeeding and weaning practices of Caribbean indigenous populations.

**José A. Cocilovo** (chapter 24) graduated with the title of biologist, and then he obtained a doctorate degree in biological sciences from the Faculty of Exact, Physical and Natural Sciences, National University of Córdoba, Argentina. He was a professor in the Faculty of Humanities of the National University of Córdoba and the Faculty of Exact, Physical, Chemical and Natural Sciences of the National University of Río Cuarto. For 40 years he has taught courses on prehistory and archaeology, anthropology and evolution, population genetics, and research methodology.

Dr. Cocilovo has worked for 30 years as a researcher of the National Scientific and Technical Research Council of Argentina (CONICET). He has participated in project evaluation commissions, scholarships, and researcher admission. He has collaborated on the development of research on ancient and current populations of Argentina, Chile, and Brazil. He has published numerous papers with an emphasis on the study of the physical characteristics of populations and the factors that determined human evolution in the south central Andean area. He has collaborated on studies on sexual dimorphism, age variation, artificial deformation of the skull, spatial distribution metric and nonmetric traits, paleodemography, analysis of genetic and environmental components of the phenotype, kinship, and evaluation of evolutionary models based on the action of genetic drift and migration. Dr. Cocilovo has also collaborated on binational research projects as a member or consultant in Argentina (CONICET, Fondo para la Investigación Científica y Tecnológica, and national universities), Brazil (National Council for Scientific and Technological Development) and Chile (Comisión Nacional de Investigación Científica y Tecnológica, Fondo Nacional de Desarrollo Científico y Tecnológico). He has cooperated with editorial boards of scientific publications such as *Latin American Antiquity*, *Current Anthropology*, *International Journal of Osteoarchaeology*, *Atacameños Studies* (Catholic University of the North, Chile), *Chungara* (University of Tarapacá, Chile), *Revista Argentina de Antropología Biológica*, Magazine Relations Society of Argentina Anthropology, *Folia Historic Northeast*, *International Journal of Anthropology*, etc. He has participated in the training of fellows, undergraduate thesis students, and Ph.D. candidates in biological sciences.

**Edwin F. Crespo-Torres** (chapter 15) is an associate professor of anthropology and the director of the Forensic Anthropology and Bioarchaeology Laboratory at the University of Puerto Rico—Río Piedras. His research interests include forensic anthropology, bioarchaeology, mortuary practices, paleopathology, and dental anthropology (Caribbean and Mesoamerica). Dr. Crespo-Torres received a B.A. in anthropology from the University of Puerto Rico (1983), Licenciatura en Antropología Física from Escuela Nacional de Antropología e Historia in Mexico (1989), a M.A.

in anthropology from Arizona State University (1994), and a Ph.D. in anthropology from Universidad Nacional Autónoma de México (2000; high honor). Since 1991, he has served as a consultant in the area of forensic anthropology at the Institute of Forensic Sciences of Puerto Rico. During this period of time he assisted a number of state (Criminal Investigation Unit, Puerto Rico Police Department), federal (FBI and DEA), and international (Interpol) law enforcement agencies. He has served as an expert witness, reporting at least 450 cases, and has testified in court on numerous occasions. In 1997, he was invited by the Center for Legal Action in Human Rights (CALDH) in Guatemala to participate in the exhumation of several clandestine graves located in the municipality of San Martín Jilotepeque. Recently, he collaborated with ICITAP-MÉXICO CSI Team (U.S. Department of Justice). In addition, since 1989, he has participated as a bioarchaeologist in the excavations of at least 634 human skeletal remains from archaeological projects on the island of Puerto Rico. At present he is an editorial board member of the *Journal of Caribbean Archaeology* (University of Florida, Gainesville). In his 25 years of professional experience in the field of bioarchaeology and forensic anthropology, Dr. Crespo-Torres has to his credit several published articles and book chapters, as well as hundreds of scientific reports on the analysis of human remains from archaeological and forensic contexts. He has been a member of the American Association of Physical Anthropologists, Dental Anthropology Association, Asociación Mexicana de Antropología Biológica, Puerto Rico Forensic Sciences Association (current president, 2015–2018), Asociación Latinoamericana de Antropología Forense, and Puerto Rico Academy of Arts and Sciences. Finally, he was awarded two distinctions, honorary rank of colonel by the Puerto Rico Police Department (2013) and forensic scientist of the year by the Puerto Rico Forensic Sciences Association (2014).

**Pedro Da-Gloria** (chapter 2) graduated in biology and earned his master's thesis in genetics and evolutionary biology at the Institute of Biosciences of the University of São Paulo. His Ph.D. was obtained in the Department of Anthropology of The Ohio State University. He is currently a professor in the Graduate Program in Anthropology at the Federal University of Pará. He has studied health and lifestyle of human past populations from northern Chile and eastern central Brazil, focused mostly on the early inhabitants of Lagoa Santa. He is also working with rural populations from Amazon, aiming to create health models to be applied to living and past populations. His main interests are bioarchaeology, bioanthropology, health, and human evolution. Dr. Da-Gloria's research has been supported by the São Paulo Research Foundation through a four-year grant named "Health and Lifestyle of the Paleoamericans of Lagoa Santa: An Ethnobiological Approach."

**Silvia L. Dahinten** (chapter 28) is a researcher at the National Scientific and Technical Research Council of Argentina (CONICET). She graduated with a bachelor's in anthropology

and a doctorate in natural sciences from the National University of La Plata, where she worked until 1994. She is currently working at the Instituto de Diversidad y Evolución Austral (CONICET) in Chubut province, where she is also a regular teacher in the Faculty of Natural Sciences, National University of Patagonia San Juan Bosco. Dr. Dahinten has worked in experimental biological anthropology by studying the influence of nutrition on craniofacial development in rodent models. Since 1996, her main interests have been related to the analysis of phenotypic plasticity of past and urban and rural populations of Patagonia. She has published research papers about experimental anthropology, human growth, and bioanthropology in international and national journals. She was president of the Argentine Association of Biological Anthropology (2001–2003) and a member of the organizing committee of several national meetings on biological anthropology and related disciplines. Currently, she is associate editor of the *Revista Argentina de Antropología Biológica*.

**Gonzalo Figueiro** (chapter 23) works at the Department of Biological Anthropology of the Universidad de la República in Montevideo (Uruguay). He received a bachelor of arts degree in anthropology (2001), a master's degree in genetics (2006) and a doctor of philosophy degree in biology (2013) from the Universidad de la República. His graduate studies focused on ancient DNA analysis of pre-Hispanic populations from Argentina and Uruguay. Dr. Figueiro's main research interests are genetics of ancient and modern populations, focusing on the reconstruction of population movements and admixture through the analysis of mitochondrial DNA and bioarchaeology of the prehistoric populations of Uruguay. He has published papers dealing with various issues in both fields. He is currently a member of the Argentinean Association of Biological Anthropology (Asociación de Antropología Biológica Argentina), the Latin American Biological Anthropology Association (Asociación Latinoamericana de Antropología Biológica), and the Genetics Society of Uruguay (Sociedad Uruguaya de Genética).

**Lígia A. Filgueiras** (chapter 5) is a biologist who graduated from the Federal University of Pará (UFPA) in Brazil (1998); she earned her master's degree in freshwater biology and interior fishery from the National Institute for Amazonian Research (INPA) in 2002 and a doctoral degree in anthropology/bioanthropology from the Graduate Program in Anthropology at UFPA in 2016. She is currently a professor of biology in the Graduate Programs of Natural Sciences and of Biology of the State University of Pará (UEPA), Brazil. She has been studying the bioanthropology and social determinants of health of Amazonian riverine and quilombola populations. She leads the Research Group in Bioanthropology for the State University of Pará (GP/GEB-UEPA).

**Sara Flores-Gutierrez** (chapter 17) is a junior anthropologist who graduated from the Central University of Venezuela. She is currently on the research staff of the Laboratory of Human

Genetics in the field of population genetics. Her young career has been focused on population pharmacogenetics.

**Luis Fondebrider** (chapter 26) is an Argentine forensic anthropologist, cofounder and current president of the Argentine Forensic Anthropology Team (EAAF), a nonprofit, scientific organization created in 1984 with offices in Buenos Aires, New York, Mexico, and South Africa. Through the application of forensic sciences, mainly forensic anthropology, archaeology, and genetics, and in collaboration with victims' relatives and investigative bodies, EAAF aims to shed light on the investigation of human rights violations.

Founded in Argentina in 1984, EAAF has worked in nearly 50 countries in the Americas, Africa, Europe, and Asia. Through its innovative work, the organization has helped make forensic sciences and the use of physical evidence a valuable component of human rights investigations and judicial proceedings, contributing to the search for truth, justice, reparation, and prevention of further violations. Dr. Fondebrider has worked as an expert witness and/or forensic adviser in the following countries: Argentina, Uruguay, Chile, Brazil, Bolivia, Peru, Paraguay, Colombia, Venezuela, Guatemala, El Salvador, Haiti, Croatia, Bosnia, Kosovo, Romania, Ukraine, Iraq, Lebanon, the Philippines, Indonesia, Cyprus, Georgia, South Africa, Zimbabwe, Ethiopia, Morocco, Libya, Vietnam, Thailand, Solomon Islands, Sri Lanka, Sudan, Kenya, and Namibia.

Dr. Fondebrider has worked as forensic expert for the following bodies: Truth Commissions of Argentina, El Salvador, Haiti, Uruguay, Peru, South Africa, and Solomon Islands; International Criminal Tribunal for the Former Yugoslavia; Committee of Missing Persons of Cyprus; Organization of American States Forensic Team case of 11 missing persons from Colombia; International Commission of Experts on the investigation of the cause of death of President Salvador Allende, Chile; United Nations (UN) Secretary-General Investigation Team for Democratic Republic of Congo; UN Commission of Inquiry on Darfur, Sudan; Presidential commission to search for and identify Che Guevara's remains; Presidential Panel of Forensic Experts for Chile; Victorian Institute of Forensic Medicine, Australia, Ned Kelly case; Special Prosecutor's Office of the Transitional Government of Ethiopia; National Prosecuting Authority of South Africa; Prosecutor's Office of Colombia; International Committee of the Red Cross (ICRC) project The Missing; consultant for Colombia, Sri Lanka, Iraq, Georgia, Cyprus, Libya, and Ukraine; Medico Legal Institute of Colombia; Medico Legal Institute of Vietnam; Federación Latinoamericana de Asociaciones de Familiares de Detenidos-Desaparecidos; Asian Federation Against Involuntary Disappearances; Amnesty International; Human Rights Watch; and International Center for Transitional Justice.

Dr. Fondebrider is part of the Forensic International Team leading the creation of the Manual on Genetics and Human Rights under the government of Argentina and the ICRC. Dr. Fondebrider is part of the UN Forensic Working Group to review the United Nations Manual on the Effective Prevention and

Investigation of Extra-Legal, Arbitrary and Summary Executions (Minnesota Protocol). Dr. Fondebrider teaches forensic anthropology at the annual course on legal medicine of the Faculty of Medicine of the University of Buenos Aires.

**Florencia Gordón** (chapter 23) got her undergraduate degree in anthropology (2005) and Ph.D. in natural sciences (2011) from the National University of La Plata (UNLP), Buenos Aires, Argentina. Her doctoral research focused on the bioarchaeological patterns of interpersonal violence and conflict in hunter-gatherer populations from Patagonia during the late Holocene. She is a researcher at Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET). She also teaches classes on anthropology at UNLP. She has published scientific articles in different national (*Revista Argentina de Antropología Biológica*, *Intersecciones en Antropología*, *Runa: Archivos para las Ciencias del Hombre*, *Revista del Museo de Antropología*) and international (*Magallania*, *Werken*, *Journal of Archaeological Science*, *International Journal of Osteoarchaeology*, *HOMO: Journal of Comparative Biology*, *Current Anthropology*) journals. She is currently extending her investigations to the influence that environmental factors may have on the evolution of human populations through the paleodiets of groups who lived in northern Patagonia during the Holocene.

**Patricia Olga Hernández Espinoza** (chapter 6) is a senior scientist at the Instituto Nacional de Antropología e Historia, where she has been employed for nearly four decades. Since 1995, she has been part of the professional group that leads the Physical Anthropology Postgraduate Program at the Escuela Nacional de Antropología e Historia. Her research focuses on the bioarchaeology of pre-Hispanic and post-Hispanic period populations. Dr. Hernández has published extensively in the general field of human skeletal biology with an emphasis on paleodemographic applications. She has served on the editorial boards of some Latin American scientific publications, including *Estudios de Antropología Biológica*. Dr. Hernández received a bachelor of arts (honors) degree and a doctor of philosophy from the Escuela Nacional de Antropología e Historia. She also received a master's degree on demography from El Colegio de México. She has been a member of Asociación Mexicana de Antropología Biológica (AMAB) since 1989, Sociedad Mexicana de Demografía since 1995, International Union for the Scientific Study of Population since 2000, Asociación Latinoamericana de Antropología Biológica since 2002, Society for American Archaeology since 2002, American Association of Physical Anthropologists since 2002, and the Society for the Study of Childhood in the Past since 2010. She served as the 2003–2005 president of AMAB. Dr. Hernández has received numerous honors, including the Premio INAH Javier Romero for 2003 best Ph.D. thesis.

**Edwin Francisco Herrera-Paz** (chapter 12) is a Honduran medical doctor with a degree from Universidad Nacional Autónoma de Honduras; he also has a master's in human genetics from

Universidad Nacional de Colombia and is a former fellow of the Instituto Nacional de Medicina Legal y Ciencias Forenses de Colombia. He has worked as a professor of genetics, physiology, and immunology at Universidad Católica de Honduras (campus San Pedro y San Pablo) since 2004, where he is also a scientific research consultant. He is also an international consultant to the Consortium on Asthma Among African-ancestry Populations in the Americas, a project led by Johns Hopkins University in Baltimore, and he practices privately as a medical geneticist. His areas of expertise include medical, forensic, and anthropological genetics. In 2004 Dr. Herrera-Paz won the Honduran National Science and Technology Contest for his anthropological genetics research on the Garifuna people. He has worked together with various research teams from the University of Ferrara (Italy) and the University of Santiago de Compostela (Spain) and currently works as a research associate on international projects with diverse academic institutions such as the University of Kansas, University of Western Australia, and University of Costa Rica. His interests are varied and include medical and forensic anthropology, population genetics, asthma genetics, isonymy studies, and the human microbiome. He has recently made efforts to unify the evolution of life toward higher levels of complexity in a single coherent theory in his book *Evolution to Complexity. From Unanimated Matter to the Universal Superorganism*. Dr. Herrera-Paz has published his studies in different peer-reviewed journals (and has also served as a reviewer for some of them) and has been a project reviewer for the Agence Nationale de la Recherche (French National Research Agency). At present, he is an activist against governmental corruption and impunity in his home country, Honduras.

**Pedro C. Hidalgo** (chapter 13), Ph.D., Dr.Sc. (humangenetik), is a tenured associate professor of human genetics at Centro Universitario de Tacuarembó, Universidad de la República, in Uruguay. He is a human and medical genetics recognized expert in research in biomedicine. He has authored papers in the area of human genetics and complex diseases for over 40 years, has over 60 publications in peer-reviewed journals, and has published chapters in several books. For many years he has researched the genetic structure of the Cuban population.

**Mercedes López-Blanco** (chapter 21) is a member of the board and vice president of the Bengoa Foundation in Caracas, Venezuela, and is also the coordinator of the study group on nutritional transition at this foundation. She is a member of the Advisory Board of the Centro de Atención Nutricional Infantil de Antimano in Caracas, a well-recognized nutritional care and research center. She has been a professor at Universidad Simón Bolívar for more than 40 years and was one of the principal researchers in the national growth surveys in the country.

She received her medical degree from the Central University of Venezuela with highest honors and a diploma of child health from the University of London as well as a doctoral degree in medical science from the University of Zulia. Dr. López-Blanco

has been a member of the executive committee of the International Association for the Study of Human Growth and Clinical Auxology for several years and currently coordinates the Sub-regional Latin American Working Group on Child Growth and Development. Dr. López-Blanco has published extensively in the field of human growth and development with an emphasis on the importance of growth references and on the growing problem of the “double burden” of nutrition, undernutrition and obesity, particularly in Latin America.

**María Antonia Luis** (chapter 28) is a professor of human biology at the School of Psychology, National University of La Plata. She is a licentiate in anthropology, biological orientation (1975), from the Faculty of Natural Sciences and Museum, National University of La Plata (FCNyM-UNLP). She served as academic secretary of the FCNyM-UNLP (1986–2007); vice-dean of the School of Psychology, UNLP (2008–2014); secretary of the Biological Anthropology Association of Argentina (1993–1996); and vice-president of the Biological Anthropology Association of Argentina (1999–2001). She participated as a member of numerous research projects whose object of study was to integrate, using descriptive-comparative methodology, biological and socioenvironmental dimensions of human growth in relation to different conditions of residence in the Argentine Republic. The results of these studies have been published in many journals and book chapters and presented at international and national congresses.

**Leandro H. Luna** (chapter 25) is an Argentinian bioarchaeologist with a Ph.D. in archaeology from the University of Buenos Aires and post-Ph.D. research at the University of Coimbra, Portugal. He has been a researcher at the National Scientific and Technical Research Council (CONICET) since 2009 and a member of the J. B. Ambrosetti Ethnographic Museum (Faculty of Philosophy and Letters, University of Buenos Aires, Argentina). He teaches in the course “Old World Prehistory” of the B.A. in anthropology at the University of Buenos Aires. He also coordinates a human identified collection team for the Chacarita Cemetery of Buenos Aires.

Dr. Luna’s research focuses on the analysis of human skeletal remains, especially on issues such as paleopathology, paleodemography, and biological distances of pre-Hispanic societies, mainly hunter-gatherers, that lived in the present territory of Argentina. His most important contributions are related to the characterization of biological dynamics and disease processes and also the identification of the first cases of pre-Columbian cancer in the country.

In the recent past, he collaborated with the Argentine Forensic Anthropology Team (Equipo Argentino de Antropología Forense) on the bioanthropological identification of skeletal remains of individuals assassinated during the military government in Argentina. His papers have been published in national and international high-impact journals, such as the *International Journal of Osteoarchaeology*, *HOMO: Journal of Comparative Human Biology*, *Journal of Archaeological Science*,

*Anthropologischer Anzeiger*, *Anthropological Science*, *Childhood in the Past*, *Antropologia Portuguesa*, *Revista Española de Antropología Física*, *Revista Argentina de Antropología Biológica*, *Intersecciones en Antropología*, and *Relaciones de la Sociedad Argentina de Antropología*.

**Robert M. Malina** (chapter 10) is professor emeritus in the Department of Kinesiology and Health Education of the University of Texas at Austin. His teaching and research career has spanned biological anthropology and kinesiology and includes more than 800 publications to date. He has earned doctoral degrees in physical education (University of Wisconsin–Madison, 1963) and anthropology (University of Pennsylvania, Philadelphia, 1968), and honorary degrees (doctor honoris causa) from the Catholic University of Leuven, Belgium (1989); the Bronislaw Czech Academy of Physical Education, Krakow, Poland (2001); the University School of Physical Education, Warsaw, Poland (2006); and the University of Coimbra, Portugal (2008). A primary area of interest is the human biology of indigenous populations in Oaxaca, southern Mexico. This research has included studies of the growth, nutritional status, performance, and physical activity of school-age children, as well as secular changes and physical activity in adults. The research in Mexico began in 1968 and continues at present. Another primary area of interest is the biological growth and maturation of children and adolescents in general and, specifically, in the context of motor development and performance, youth sports and young athletes, and the potential influence(s) of physical activity and training for sport. Professor Malina was editor of the *Yearbook of Physical Anthropology* (1980–1986), editor in chief of the *American Journal of Human Biology* (1990–2002), and section editor for growth and development for the *Exercise and Sport Sciences Reviews* (1981–1999) and the *Research Quarterly for Exercise and Sport* (1981–1993). He cochaired the expert panel on youth physical activity for the Centers for Disease Control and Prevention (2003–2004), which developed physical activity recommendation for American children and adolescents of school age. He also served on the Youth Health Subcommittee of the Physical Activity Guidelines Advisory Committee (2007–2008) and the Committee on Fitness Measures and Health Outcomes in Youth of the Institute of Medicine of the National Academies (2011–2012).

Professor Malina was the recipient of the Franz Boas Distinguished Achievement Award of the Human Biology Association (2006) and the Honor Award (2013) from the American College of Sports Medicine for contributions to sports medicine and exercise science. He was also the recipient of the Honor Award from the North American Society for Pediatric Exercise Medicine (2002), the Clark Hetherington Award of the National Academy of Kinesiology (2007), and the Distinguished Scholar Award of the North American Society for the Psychology of Sport and Physical Activity (2009). He is a foreign member of the Polish Academy of Sciences, section in biological sciences (physical anthropology), and a Fellow of the Human Biology

Association, the American College of Sports Medicine, and the American Association for the Advancement of Science, and the National Academy of Kinesiology. He also was named recipient of the 2015 Science Board Honor Award of the President's Council on Fitness, Sports and Nutrition.

**Lourdes Márquez Morfín** (chapters 6, 8) is senior scientist at the Instituto Nacional de Antropología e Historia (INAH), Mexico City, where she has been working since 1977 as bioarchaeologist. She received a bachelor of physical anthropology at the National School of Anthropology and History (ENAH) in 1979. She received a degree in Mexican history from El Colegio de México. She was the head of the Dirección de Antropología Física del INAH (1992–1995). Dr. Márquez has published extensively in the general field of human skeletal biology with an emphasis on health and nutrition evaluation of pre-Hispanic Mesoamerican populations. She developed, in collaboration of Patricia Hernández, the first paleodemographic studies for ancient groups of Mexico, especially from the Maya area, the Zapotec area, and the Valley of Mexico. Her contributions on demographic epidemiological historical studies about typhus and cholera have been recognized as pioneering works. She has been teaching in the postgraduate program of physical anthropology at ENAH from 1996 to the present, acting as the head of bioarchaeology and forensic anthropology studies. She has served on the editorial boards of numerous leading scientific publications, such as *Dimensión Antropológica*, *Estudios de Antropología Biológica*, *Ergo-Sum*, *Cuicuilco*, *Cuadernos del Sur*, and *Oaxaca*. She has been a member of the advisory council of the Wenner-Gren Foundation for anthropological research (1998–2000) and a member of the Sociedad Mexicana de Demografía and Asociación Latinoamericana de Antropología Biológica. She served as the vice president of the Asociación Mexicana de Antropología Biológica. In collaboration with Dr. José Pablo Baraybar from the Equipo Peruano de Antropología Forense and Dr. Alejandra Jimenez from the Comité Internacional de la Cruz Roja in Mexico since 2010, Dr. Márquez has conducted workshops related to forensic anthropology and human identification at the National School of Anthropology for colleges in several institutions in Mexico.

**Betty Méndez-Pérez** (chapter 21) was born and grew up in Caracas, Venezuela. She currently holds research and teaching positions at the Central University of Venezuela, where she has been employed for nearly five decades. She obtained a bachelor's in anthropology and doctorate degree in science (anthropology) at the Central University of Venezuela. From 1966 to 1968 she accomplished a two-year stay as a scholar at the University of Michigan, Ann Arbor, where she obtained her master's degree in arts (anthropology). Dr. Méndez-Pérez's research has focused on epidemiological auxology, growth and development, body composition, kinanthropometry, somatic maturation, and physical activity in both athletes and nonathlete populations. She acted as a member of the executive committee of International

Society for the Advancement of Kinanthropometry from 2002 to 2005 and 2006 to 2009 and has served on the editorial boards of several scientific journals. She is currently the head of the Unit of Bioanthropology, Physical Activity and Health of the Central University of Venezuela. She has published about 70 articles, chapters, and monographs, in addition to authoring or editing several books in her areas of knowledge. In addition, she has given invited presentations and workshops on the fields mentioned in several countries.

**Abigail Meza Peñaloza** (chapter 7) received a bachelor's of physical anthropology from the Escuela Nacional de Antropología e Historia. She has a master's degree in anthropology and received her doctorate in Mesoamerican studies from the Universidad Nacional Autónoma de México (UNAM). Since 2004, she has been a researcher and professor at Instituto de Investigaciones Antropológicas (IIA) at UNAM, specializing in the study of ancient populations; she applies general knowledge of human skeletal biology, focusing on taphonomy and paleopathology. She is currently a researcher at and head of the Osteology Laboratory of IIA-UNAM. She is also a member of the working group FOROST (<http://www.forost.org/>). Dr. Meza has published in different scientific journals, such as *Latin American Antiquity*, *Journal of Forensic Sciences*, *Estudios de Antropología Biológica*, and *Anales de Antropología*.

**Sergio F. S. Monteiro da Silva** (chapter 4) is an adjunct professor with the Departamento de Arqueologia, Universidade Federal de Pernambuco (UFPE), Recife, Brazil. He is a professorial lecturer with the Departamento de Anatomia, Centro de Ciências Biológicas, UFPE, and in the specialization course in forensic sciences, Faculdades Oswaldo Cruz, Sao Paulo, Brazil. He is coordinator of the Laboratório de Arqueologia Biológica e Forense and the Reserva Técnica de Arqueologia (organic materials), Departamento de Arqueologia, UFPE, and develops research on archaeological human remains in Fundação Museu do Homem Americano, Piauí, Brazil. Between 2005 and 2011, Dr. Silva served as an official professor of forensic archaeology and scientific methodology with the Campus I e II da Academia de Polícia Civil de São Paulo, Brazil. At this academy he taught simulated forensic archaeological excavation and introductory classes on forensic archaeology and forensic anthropology in the perspective of human rights for legal professionals such as police investigators, forensic experts, medical examiners, and forensic photographers at Brazilian federal and state forensic institutions. During that period, he served as a consultant in forensic sciences, archaeology, to the state police institution and the Ministério Público of Brazil for the Guerrilha do Araguaia. In 1990, he received a B.A. in fine arts from the Centro Universitário Belas Artes de São Paulo, and a second B.A. in History from the Faculdade de Filosofia, Letras e Ciências Humanas, Universidade de São Paulo. He did postgraduate studies in archaeology at the Museu de Arqueologia e Etnologia da Universidade de São Paulo (1995–2005) and participated in

archaeological excavation and lab studies on the coast of São Paulo in Araguaia (Tocantins), Custódia (Pernambuco), Pilar, Bairro do Recife antigo, Recife (Pernambuco), Baturité (Ceará), and Xingó (Sergipe) from the perspective of funerary archaeology and forensic archaeology (1990–2010). In 2002 he was a student in the forensic anthropology course taught by Dr. Douglas Ubelaker at the National Museum of Rio de Janeiro. He has published on topics related to the archaeology of death, forensic archaeology, osteoarchaeology, and historic archaeology in Brazil.

**Walter Alves Neves** (chapter 2) graduated with a degree in biology in 1981 from the Bioscience Institute of the University of São Paulo, where he also obtained his Ph.D. He has collaborated with many international universities throughout his career, including Stanford University; University of California, Berkeley; Center for American Archeology, Northwestern University; Universidad Nacional de Río Cuarto, Argentina; Universidad Nacional de La Plata, Argentina; and Universidad Católica del Norte, Chile. He worked for six years at the Museu Paraense Emílio Goeldi, where he founded the first program on ecological anthropology in Brazil. For 25 years he was the coordinator of the Laboratório de Estudos Evolutivos Humanos in the Biosciences Institute of the University of São Paulo, which was the first laboratory for human evolution in Latin America. His main interests are biological anthropology, prehistoric archaeology, human evolution, human ecology, and evolutionary theory. Throughout his career he has authored more than 120 articles, 12 books, and 22 book chapters, and he has advised 20 master's and seven Ph.D. students. He coordinated a large project in the Lagoa Santa region, east-central Brazil, named "Origins and Microevolution of Man in the America: A Paleoanthropological Approach," supported by the São Paulo Research Foundation. Moreover, he has been very active in science outreach, mostly through the organization of museum expositions and the publication of texts for the lay public. Dr. Neves coordinated the first overseas Brazilian mission of human evolution, "Hominin Biocultural Evolution in the Valley of Zarqa River, Jordan: A Paleoanthropological Approach." Currently he is a Visiting Scholar in the Institute of Advanced Studies at the University of São Paulo.

**Hadaluz Osorio Restrepo** (chapter 20) is an anthropologist at the University of Caldas, Colombia. His field of discipline is focused on issues such as the forced disappearance of persons, search for and exhumation of bodies buried in clandestine graves, and analysis and identification of the same. He currently works as a forensic anthropologist at the National Institute of Legal Medicine and Forensic Sciences in Pereira, Colombia, and is also a candidate for a master's degree in forensic science. He has served as a researcher on projects for the creation of national standards that allow the recognition of demographic information of a corpse from bone and dental tissue in the Colombian population. He has written chapters and articles of anthropological interest, covering topics such as conflict and

postconflict Colombia, the identification of corpses, and the forced disappearance of persons in the Peru.

**Evelia Edith Oyhenart**, Ph.D., (chapter 28) is a professor of biological anthropology at the Faculty of Natural Sciences and Museum, National University of La Plata (FCNyM-UNLP), and principal researcher at the National Scientific and Technical Research Council (CONICET). Dr. Oyhenart received her Ph.D. in natural sciences from the National University of La Plata in 1988. She was president of the Biological Anthropology Association of Argentina (1997–1999), secretary of the Research and Transference Department, FCNyM-UNLP (1998–2007), secretary (2006–2008) and president (2008–2010) of the Latin American Association of Biological Anthropology, and dean (2007–2010) and vice dean (2010–2014) of FCNyM-UNLP. Dr. Oyhenart has received the following honors: Best Experimental Study Award, Istanbul, 1998; Award for Scientific, Technological and Artistic Labor of the National University of La Plata, in the biological anthropology area, 2010; and Dr. Eduardo Usunoff Science and Community Award, Scientific Research Commission of the Province of Buenos Aires.

Dr. Oyhenart has been a professor of biological anthropology since 1986, focusing on different subjects: physiological, cultural, and developmental adaptations to extreme environments such as high altitude, cold, and heat as well as to nutritional stress. She was a visiting professor at the Center for Human Growth and Development, University of Michigan, Ann Arbor. Dr. Oyhenart has expertise in human physical growth and nutrition in relation to the environment. She currently develops two lines of research. One is devoted to the complex concept of human growth and quality of life. It includes the study of human growth in Argentinean cities with different socioenvironmental complexity, particularly nutritional status and body composition of children according to environment. The other line of research is concerned with experimental biological anthropology, mainly the study of pre- and postnatal growth in relation to factors such as those derived from maternal-fetus insufficiency and/or decreased quantity and/or quality of the food consumed. The results of these studies have been published in more than 90 articles and book chapters and have been presented at 93 international and 118 national congresses. Dr. Oyhenart has been an advisor to researchers, research assistants, teacher-researchers, postgraduate and postdoctoral fellows, and Ph.D. lecturers. She has delivered numerous lectures and courses on growth and nutrition. She has also been chair of doctoral committees, a member of the editorial board of the *Revista Argentina de Antropología Biológica*, and an external reviewer for the *American Journal of Physical Anthropology*, *American Journal of Human Biology*, *Annals of Human Biology*, *Revista Panamericana de Salud Pública*, and *Acta Trópica*, among others.

**María Eugenia Peña Reyes** (chapter 10) is a professor in the Graduate Program of Physical Anthropology at Escuela Nacional de Antropología e Historia in Mexico. She contributed

with other colleagues to the foundation of the graduate program of physical anthropology in Mexico, where she has worked since 1996. She studied physical anthropology (Escuela Nacional de Antropología e Historia, Mexico, 1980) and then continued with graduate studies in anthropology to earn a master of arts (University of Texas at Austin, 1990) and a doctoral degree in kinesiology (Michigan State University at East Lansing, 2002). Her main area of interest is growth and development, with an emphasis on maturation, and she has worked on several projects on the application of skeletal assessments of the hand, wrist, cervical vertebrae, and dental calcification. She has published more than 40 articles in national and international journals.

She has participated in the human biology project directed by Robert Malina since 1999, with a focus on growth and physical activity in schoolchildren and adults. Another area of interest is related to physical activity and health, she has developed some research in collaboration with physical education professors at elementary, middle, and high schools pursuing improvements in programs. Professor Peña Reyes has served on the editorial boards of journals in anthropology, *Cuicuilco* (2004–2008) and *Dimensión Antropológica* (2004 to the present). She has been a member of the Asociación Mexicana de Antropología Biológica since its foundation, a member of the Human Biology Association (since 1989), and a member of the American College of Sports Medicine (since 1999). She was the coordinator of undergraduate programs (1996–1997) and the Graduate Program of Physical Anthropology (2006–2008) at Escuela Nacional de Antropología e Historia.

**Edith Yesenia Peña Sánchez** (chapter 9) has been a professor-researcher in the Department of Physical Anthropology of the National Institute of Anthropology and History (INAH) since 1997 and a member of the National Research System of the National Council of Science and Technology in Mexico since 2010. She teaches sociomedicine in the online postgraduate program in the discipline of anthropology of health at the Faculty of Medicine at the National Autonomous University of Mexico. She has been an expert witness in anthropology in cases of sex-gender identity expression, sexual customs and uses in indigenous populations, and commercial sexual exploitation.

She is the author and coauthor of nine books, among which the following are most prominent: *Mortality Profiles in a Subadult Population: Parochial Jurisdiction of Santa María Cardonal, Hidalgo* (Scientific Collection, National Council of Culture and Arts [CONACULTA], INAH, Mexico, 2005); *The Environments and Sexualities of Handicapped People* (EDUFAM/CONACULTA-INAH, Mexico, 2003); and *The Biocultural Approach in Anthropology, Biocultural Processes: Diet-Nutrition and Health-Disease in Santiago de Anaya, Hidalgo* (CONACULTA-INAH, Mexico, 2012).

She has published several books in collaboration with Lilia Hernández Albarrán: *Aromas and Flavors of the Cuisine of the Hñāhñū of the Mezquital Valley, Hidalgo* (CONACULTA-INAH, Mexico, 2009); *Between Traditional Wisdom and Contemporary*

*Knowledge, Curative Practices and Representations in Suchitlán, Comala, Colima* (CONACULTA-INAH, Mexico, 2013); *Curative Resources and Biocultural Patrimony in Suchitlán, Comala, Colima* (CONACULTA-INAH, Mexico, 2014); *Traditions of the Hñāhñū Cuisine of the Mezquital Valley, Hidalgo* (Indigenous and Popular Cuisine Collection, No. 63, CONACULTA, Directorate-General of Popular Cultures, Mexico, 2014); and *Between Bodies and Pleasures, Sexual Practices and Representations in People with Acquired Disabilities* (Tendencias Collection, Autonomous University of Nuevo León, Mexico, 2015). In collaboration with Eduardo Javier Hernández, she coauthored *The Measurement of Adaptive Behavior in the Adapted Athlete* (National Council of Sports-Public Education Secretary, Mexico, first edition, 1998, second edition, 2000).

She is the coordinator of the collection of diversity at the Instituto Nacional de Antropología e Historia: *Memoires of the Second Cultural Week of Diversity* (CONACULTA-INAH, Mexico, 2005); *The Sexed Subject: Between Stereotypes and Rights* (CONACULTA-INAH, Mexico, 2009); *Sexuality as a Sociocultural Construction* (CONACULTA-INAH, Mexico, 2009); *Body, Sexuality and Vulnerability* (CONACULTA-INAH, Mexico, 2010); *Sexual Diversity: Justice Education and Health* (CONACULTA-INAH, Mexico, 2011); *Equal, but Different: Sexual Diversity in Context* (CONACULTA-INAH, Mexico, 2011); *Discrimination and Violence: Sexuality in Vulnerable Groups* (CONACULTA-INAH, Mexico, 2013); *Sexual Diversity, Religion and Health: The Emergence of Denouncing Voices* (CONACULTA-INAH, Mexico, 2013); and *Sexual Diversity and Human Rights, Boys, Girls and Adolescents* (CONACULTA-INAH, Mexico, 2014). She is also an editor of *Studies in Sexual Anthropology Magazine*, financed by INAH since 2005.

Dr. Peña has received prizes and honorable mentions for her work on medical sciences applied to sports awarded by the CONADE-SEP in Mexico City, 1998, on the subject of “Adaptive Behaviour in the Handicapped Athlete”; the Javier Romero Molina Award in 1998 with an honorable mention for her work titled “Mortality Analysis in Minors under 16 in Cardonal, Hidalgo,” awarded by the CONACULTA-INAH-SEP in 1999; and the Noemí Quezada Award, 2008, Universidad Nacional Autónoma de México, awarded for her work “Health, Nutrition and Growth in Preschoolers of Santiago de Anaya: Health Care Systems, Sociocultural Perception and Strategies for Domestic Survival,” which also received an honorable mention from the Javier Romero Molina Award of INAH.

**Javier Rivera-Sandoval** (chapter 19) is a professor and researcher with the Department of History and Social Science at the Universidad del Norte, Barranquilla, Colombia. He has worked on numerous projects related to archaeology, historical archaeology, and bioarchaeology in Colombia, Panama, and Cuba. His research in bioarchaeology has an emphasis on historical contexts with topics like paleopathology, paleoepidemiology, and paleodemography. In the forensic context, his interest is in methods of human identification. Dr. Rivera-Sandoval received



an anthropology degree from the Universidad Nacional de Colombia; a master's in bioarchaeology, paleopathology, and forensic anthropology from the University of Bologna, Italy; and a doctor of archaeology from the Universidad Nacional del Centro de la Provincia de Buenos Aires, Argentina. He is member of the Asociación Latinoamericana de Antropología Biológica.

**Claudia Rodrigues-Carvalho** (chapter 3) is a professor at the National Museum (Anthropology Department/Archaeology Graduate Program), an institution of the Federal University of Rio de Janeiro (UFRJ), Brazil. An archaeologist studying bioanthropology and bioarchaeology, Dr. Rodrigues-Carvalho graduated with degrees in public health, with a focus on past populations (master's, 1997, and doctor of science, 2004), from the Sergio Arouca National School of Public Health, Oswaldo Cruz Foundation. Her current teaching activities include undergraduate classes in bioanthropology and forensic anthropology and graduate classes in human evolution, archaeology, bioarchaeology, and associated subjects. Dr. Rodrigues-Carvalho has been working on the study of health, lifestyle, and mortuary practices of past people, especially the prehistoric coastal groups of Brazil. Parallel themes of investigation also in development are the history of bioarchaeology and paleopathology and the study of skeletal markers of stress and activity. Studies regarding mummified tissues, forensic anthropology, cultural heritage, and scientific collections are also topics of interest. Dr. Rodrigues-Carvalho is the curator of the human osteological collection at National Museum. From 2010 to 2013 she was director of the National Museum and was reelected for the 2014–2017 period. Since 2013, she has coordinated a work group for the creation of UFRJ's System of Museums, Cultural Heritage, and Collections. Dr. Rodrigues-Carvalho has published research papers and book chapters regarding paleopathology, bioarchaeology, and related topics. She is also the leader of the science diffusion project "Science until the Bones," which has been active since 2009.

**Carlos David Rodríguez Flórez** (chapter 18) is a researcher (junior scientist, A2 category) at the National Council of Science and Technology of Colombia (COLCIENCIAS). He is a licentiate in anthropology from the University of Cauca, Colombia (Honors in 2002) and a doctor of biological sciences from the National University of Córdoba, Argentina (honors in 2012). He is currently working at the Anthropological Research Institute of the Universidad Nacional Autónoma de México, Mexico City, through the Postdoctoral Program in Anthropology. He was also a teacher of anatomy, anthropology, and dentistry courses at the Graduate Program of Anthropology and Graduate Program of Dentistry at the University of Caldas and Antonio Nariño University (Colombia). Dr. Rodríguez Flórez has worked on the study of skeletal and dental variation patterns of human past populations from Mexico, Venezuela, Colombia, Ecuador, Argentina, and Uruguay since 2002. His main interests are related to the analyses of dental and skeletal data in preconquest populations of South and Central America and the association

with the process of settlement of the Americas. He has published some research papers about archaeology, osteology, dental paleopathology, dental nonmetric traits, and forensic dentistry methods in international and national journals. In 2015 he published an article about the dental variation of the earliest Americans (Naharon 1 sample from Mexico = 13,721 CYBP) in the *Bulletin of the International Association for Paleodontology*. Dr. Rodríguez Flórez is also the author of the book *La Sinodontia y su aporte en la comprensión del poblamiento prehispánico de Centroamérica y las Islas del Caribe*, published by Editorial UNAM, Mexico. Dr. Rodríguez Flórez reviewed grant projects for the COLCIENCIAS (Colombia), Consejo Nacional de Ciencia y Tecnología (Mexico), and Comisión Nacional de Investigación Científica y Tecnológica (Chile) and reports and papers from other researchers for regional bulletins and journals of archaeology, anthropology, and dentistry.

**Claudia Mercedes Rojas-Sepúlveda** (chapter 19) performs research mainly in the physical and biocultural anthropology fields, and she has been particularly interested in life conditions of past populations of northern South America. She has been working on bioarchaeology, paleopathology, and paleoepidemiology. Dr. Rojas-Sepúlveda has published several papers in leading scientific publications, including the *American Journal of Physical Anthropology*, *Chungara: Revista de Antropología Chilena*, and *Bulletins et Mémoires de la Société d'Anthropologie de Paris*. She has been a professor of anthropology at Universidad Nacional de Colombia since 2014 and is a researcher in the Grupo de Investigación en Antropología Biológica. Previously, she was a professor at the Universidad del Magdalena (2010–2014). She organized the Paleopathology Association Meeting V in South America in 2013. She has edited special editions on her field in the journals *Jangwa Pana* (Universidad del Magdalena) and *Maguaré* (Universidad Nacional de Colombia). She has been a member of the Asociación Latinoamericana de Antropología Biológica and the Société d'Anthropologie de Paris. Between 2012 and 2013, she was vice president of the Paleopathology Association. Her doctorate degree (summa cum laude) was conferred by the Aix-Marseille Université, her master's degree is from the Université de la Méditerranée (France), and her bachelor's in anthropology from the Universidad Nacional de Colombia.

**Mirjana Roksandic** (chapter 14) is a professor at the University of Winnipeg and graduate faculty at the University of Manitoba. She obtained her B.A. in archaeology at the University of Belgrade, a D.E.A. in anthropology at the University of Bordeaux (Science), and a Ph.D. in archaeology at the Simon Fraser University (2000). She is currently the chair of the Anthropology Department and the coordinator of the Interdisciplinary Program in Bioarchaeology; she teaches upper-division courses in bioarchaeology and human evolution. Dr. Roksandic examines the intersection of biology and culture in two main topical areas: sedentary hunter-gatherers in littoral environments and early human evolution in Europe. It is informed by human evolutionary biology and life history

theory and benefits from expertise in archaeological practice and hunter-gatherer studies. She has conducted research in Cuba, Nicaragua, Portugal, and the Balkans. Combining diverse lines of biological evidence with a strong background in regional archaeologies enables her to maximize the potential of the fragmentary and truncated archaeological record to inform our understanding of past humans and their behavior. Her research in Cuba and the Caribbean is funded by the Social Sciences and Humanities Research Council of Canada, and her research in the Balkans is funded by the Natural Sciences and Engineering Research Council of Canada. Dr. Roksandic has edited and coedited three books: *Violent Interactions in the Mesolithic: Evidence and Meaning* (2004), *Cultural Dynamics of Shell-matrix Sites* (2014) and *Paleoanthropology of the Balkans and Anatolia* (2017). She has published her research in 23 papers in the relevant journals in the field of biological anthropology and 22 book chapters and has given 57 conference presentations. She has organized and chaired 11 conference sessions, most recently “Caribbean Archaeology in the Globalized World” (World Archaeology Congress 2016) and “Cuban Bioarchaeology” (American Association of Physical Anthropologists annual meeting, 2016).

**Francisco M. Salzano** (chapter 1) graduated in natural sciences from the Federal University of Rio Grande do Sul (UFRGS) in 1950, and he specialized in genetics at the University of São Paulo (USP) in 1951. Returning to Porto Alegre, he was admitted as a member of UFRGS’s staff in 1952 and in 1955 obtained his Ph.D. at USP. A one-year postdoctoral fellowship followed at the University of Michigan, Ann Arbor, during 1956–1957. Over the years, he developed his professional career at UFRGS, attaining professorship in 1981; in 1999 he was awarded the title of emeritus professor. His scientific investigations began with research on *Drosophila*; but after his U.S. fellowship, he turned to human genetics, in which he was engaged until his death in September 2018. In addition, he collaborated on investigations involving Brazilian native grasses, wheat, rodents, felines, cattle, chickens, and nonhuman primates. His studies in relation to *Homo sapiens* involved normal and pathological characteristics in a large number of populations of all major ethnic groups, with an emphasis on South Amerindians. He was author or coauthor of 1,511 contributions to the scientific literature, including 532 full scientific papers, 60 book chapters, and 21 books. A total of 46 Ph.D. and 48 M.Sc. students obtained their degrees under his supervision. He presided over or was on the governing board of many national and international associations and received many honors at those two levels, being a member of the Brazilian, U.S., Chilean, Latin American, and Third World academies of sciences. Additionally, he received honoris causa doctorates from the University of Toulouse and University of Costa Rica.

**César Sanabria-Medina** (chapter 20) received an undergraduate degree in anthropology, specializing in forensic anthropology, from the National University of Colombia, Bogotá. He was

accredited in criminal investigation by the Criminal Investigation Faculty of the Police School, Bogotá, Colombia. He has an M.Sc. in forensic anthropology and Ph.D. (cum laude) in human evolution, physical, and forensic anthropology from the Faculty of Medicine, University of Granada, Spain. Since 1999 he has worked as a forensic anthropologist at the National Institute of Legal Medicine and Forensic Sciences, Bogotá, Colombia. From 1999 to 2014 he served as an expert in forensic anthropology in the institute’s Anthropology Group, also serving as chief. Additional services were performed for the National Group of Forensic Pathology, examining and identifying human remains in various conditions of preservation. His work has supported the Office of the Attorney General of Colombia during excavations of mass and clandestine graves to recover victims killed by guerrillas and paramilitary groups. In 2009 he created the Human Bone Collection for the Colombian Population. The collection includes 600 individuals of known age and sex. It is the largest and most modern collection in Latin America. Since 2015 he has led the Research Group in Forensic Sciences of the National Institute of Legal Medicine and Forensic Sciences of Colombia. In 2012 he became an assistant professor at the Faculty of Medicine, Antonio Nariño University, Bogotá, where he combines teaching and scientific research in physical and forensic anthropology. He was formerly a professor at the National University of Colombia, Bogotá. He has been a professor of undergraduate and postgraduate courses at the Pontificia Universidad Javeriana, Universidad Militar Nueva Granada, Universidad Externado de Colombia, Universidad del Rosario, Universidad de los Andes, and Universidad Libre de Colombia. Dr. Sanabria has supervised four international doctoral students (Escuela Nacional de Antropología e Historia, Mexico; University of Barcelona, Spain; Complutense University of Madrid, Spain; and the University of Reading, United Kingdom) and several international master’s students. Dr. Sanabria has been invited to speak at international conferences and workshops at universities and nongovernmental organizations throughout Latin America, including Mexico, Costa Rica, Guatemala, Venezuela, Peru, and Bolivia. He is a member of the Latin American Association of Forensic Anthropology, Colombian Association of Forensic Anthropology, and Colombian Association of Legal Medicine and Forensic Science (ASOMEF). He has published books, book chapters, and peer-reviewed articles in Colombian and international journals. He is also certified as a forensic anthropologist by the Latin American Association of Forensic Anthropology (ALAF).

**Mónica Sans** (chapter 22) is a doctor of biological sciences, has a master’s degree in the same topic (1991), and has a bachelor’s in anthropological sciences (1985), all from the Universidad de la República. At present she is a full professor and director of the Department of Biological Anthropology and the chairwoman of the Institute of Anthropological Sciences of the College of Humanities and Sciences, Universidad de la República, Uruguay. She also was the director of human biology, interdisciplinary studies, at the Universidad de la República until this year and

continues to be a researcher in the Program for the Development of Basic Sciences (PEDECIBA) and the National System of Researchers (SNI). Dr. Sans has studied population genetics in Uruguay and Latin America for the last 30 years, including different origins and the admixture process, based on different genetic markers. Specifically, she has analyzed the contribution of Native people to the contemporary population of Uruguay because Natives had been considered to be extinct; these studies contributed to a new perception of Uruguayan national identity. Her studies also include classical analysis as well as mtDNA of past populations from Uruguay and their relations with other American populations. Her recent interests also include complex diseases (such as cancer) and ancestry. She has published more than 100 articles and book chapters and coedited several books, the more recent being *Racial Identities, Genetic Ancestry and Health in South America: Brazil, Argentina, Uruguay and Colombia*. Among her honors, she has been president of the Asociación Latinoamericana de Antropología Biológica, president of the Sociedad Uruguaya de Genética, vice-president of the Asociación Latinoamericana de Genética, and a member of editorial boards of prestigious international journals.

**Carlos Serrano Sánchez** (chapter 7) was first a researcher in the Departamento de Antropología of the Instituto Nacional de Antropología e Historia. He has since worked at the Universidad Nacional Autónoma de México (UNAM) at the Centro de Estudios Mayas and, since 1979, at the Instituto de Investigaciones Antropológicas, of which he was director in the period from 2004 to 2012. His teaching work has been carried out at the Escuela Nacional de Antropología e Historia (ENAH) at the undergraduate level and in postgraduate programs of anthropology and Mesoamerican studies at the UNAM. He has directed several research projects on the skeletal biology of ancient Mesoamerican populations and on the anthropological profile of the contemporary population of Mexico. His publications include *Archaeological Contexts and Osteology of the Neighborhood of La Ventilla, Teotihuacan*; *Funerary Practices in the City of the Gods: Human Burials in the Ancient Teotihuacan*; *Funeral Customs and Human Sacrifice in pre-Hispanic Cholula*; and *Taphonomy, Environment and Culture: Contributions to the Anthropology of Death*. Dr. Serrano obtained the title of physical anthropologist at the ENAH and a doctorate in biological anthropology from the University of Paris. He is a member of the Mexican Academy of Sciences and the National System of Researchers, Mexico. And he is also a member of several scientific associations in which he has held a variety of positions and commissions: founder and first president of the Asociación Mexicana de Antropología Biológica; vice president for the region of Mexico and Central America at the Asociación Latinoamericana de Antropología; president of the Asociación Latinoamericana de Antropología Biológica; and president of the Sociedad Mexicana de Antropología. Dr. Serrano has been honored with several awards from scientific societies and institutions for his academic career.

**Clara Scabuzzo** (chapter 23) got her degree in anthropology (2004) and Ph.D. in natural sciences (2010) from the Faculty of Natural Sciences of the National University of La Plata, Buenos Aires, Argentina. She is currently a researcher at the National Scientific and Technical Research Council (CONICET). From the beginning of her education, even during college, she has focused on the investigation of human remains recovered at several archaeological sites. Dr. Scabuzzo's research focuses on characterizing the lifestyle of indigenous populations of the Pampean region and the Paraná Delta through the development of analysis such as stable isotopes, occupational stress markers, and paleopathologies. Her work has been included in several academic publications, including book chapters, field guides, and papers in both national and international journals.

**Hilton P. Silva** (chapter 5) has biology and medical degrees from the Universidade Federal do Pará (UFPA) in Brazil (1990, 1991), a master's degree in anthropology from the Pennsylvania State University (1993), a master's in public health and a doctorate of philosophy in anthropology/bioanthropology from The Ohio State University (1998, 2001). He was a Fulbright Scholar between 1991 and 1993 and is currently an associate professor of anthropology at the Graduate Program in Anthropology of UFPA and at the Graduate Program in Health, Environment and Society in the Amazon (Public Health) of UFPA. He is also the director of the House of Studies Brazil-Africa, coordinator of the Laboratory of Bioanthropological Studies in Health and the Environment, and a research collaborator at the Research Centre for Anthropology and Health of the Department of Life Sciences of Coimbra University, Portugal. Dr. Silva was formerly a professor of the Biological Anthropology Division of the National Museum of Rio de Janeiro, Federal University of Rio de Janeiro, Brazil (1999–2009), having been curator of the Human Evolution Exhibit of that institution between 2005 and 2009 and chair of the Department of Anthropology between 2004 and 2006. Dr. Silva was a visiting professor of biological anthropology at the State University of New York–Binghamton, USA (2002); at Coimbra University, Portugal (2004 and 2010); and at Michigan State University, USA (2012). He was the first recipient of the Edward E. Hunt Jr. Award of the Human Biology Council (currently Human Biology Association) among other academic prizes and has been the principal investigator on several long-term projects about health, children's growth, nutrition transition, and the emergence of chronic diseases in rural, traditional populations living in protected areas of the Brazilian Amazon and in the Atlantic Forest. These projects have contributed to the development of public policies more appropriate for the lifestyle of many local populations. Dr. Silva has done consulting work in the areas of health, public policies, education, and the environment for public and private institutions in Brazil and abroad and conducted volunteer work in Brazil, the United States, Cuba, Guinea-Bissau, and Cape Verde. He has advised undergraduate and graduate students in the health and social sciences fields and authored and coauthored

a diverse array of scientific publications and presentations in Brazil and internationally.

**Jorge A. Suby** (chapter 25) is a researcher at the National Scientific and Technical Research Council of Argentina (CONICET). He is a licentiate (2002) and doctor (2007) in biological sciences from the National University of Mar del Plata. He is currently working at the Department of Archaeology of the National University of the Center of Buenos Aires Province, where he is also a teacher of bioarchaeology and paleopathology courses in the Ph.D. Program of Archaeology. He is also a technician in nuclear medicine, certified by the National Council of Atomic Energy (2002). Dr. Suby has worked in the study of health and disease patterns of past human populations from southern Patagonia since 2003. His main interests are related to the analysis of infectious, degenerative, and metabolic diseases in skeletal remains, their association with hunter-gatherer lifestyles, and their biocultural changes through time. He has published numerous research papers about paleopathology, bioarchaeology, and bioanthropology in international and national journals. In 2012, Dr. Suby published an introductory book about paleopathology, recently translated to Portuguese and published by Coimbra University Press. He has also coedited the book *Avances Recientes de la Bioarqueología Latinoamericana*. Dr. Suby reviewed grant projects for the National Agency of Science and Technology and also reports from other researchers for the National Council of Science. He was also a member of the organizing committees of the Paleopathology Association Meeting in South America (PAMinSA) III and VI, held in Necochea (2009) and Buenos Aires (2015), respectively. Moreover, he integrated the Scientific Committee of PAMinSA IV (Lima, 2011) and V (Santa Marta, 2013).

**Héctor Hugo Varela** (chapter 24) received the degree of licentiate and doctor in biological sciences at the National University of Río Cuarto (UNRC), Río Cuarto, Córdoba, Argentina. He has taught at this institution since 1987 and has participated in the courses of the anatomy of vertebrates, anthropology and evolution, animal biology, and population genetics. He currently is an associate professor (population genetics) in the Department of Natural Sciences, UNRC. He has been a researcher of the National Scientific and Technical Research Council of Argentina (CONICET) since 1999. Dr. Varela has been dedicated to the study of the biology of native populations of South America, particularly the prehistoric groups that inhabited the south central Andean area. He has worked on issues like settlement, kinship, phenotypic variation (genetic and environmental) within and between populations, demography, genetic divergence, migration, genetic drift, adaptation, sexual dimorphism, age variation, artificial deformation, and geographical and chronological variation. The results of this research have been presented at conferences and published in journals on biological anthropology, such as the *American Journal of Physical Anthropology*, *HOMO*, *Current Anthropology*, *Revista Española de Antropología Biológica*,

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