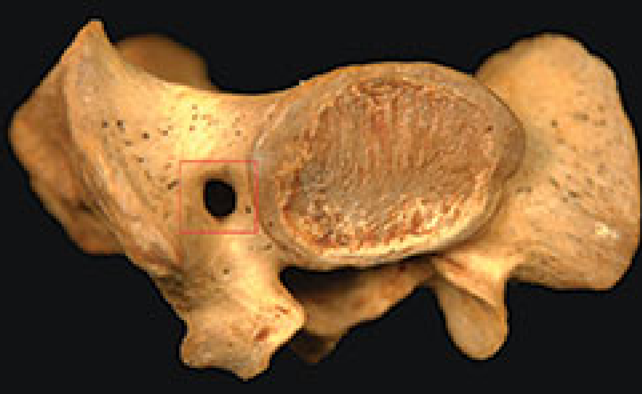
Photographic Regional Atlas of Non-Metric Traits and Anatomical Variants in the Human Skeleton



Robert W. Mann ~ David R. Hunt ~ Scott Lozanoff

PHOTOGRAPHIC REGIONAL ATLAS OF NON-METRIC TRAITS AND ANATOMICAL VARIANTS IN THE HUMAN SKELETON

PHOTOGRAPHIC REGIONAL ATLAS OF NON-METRIC TRAITS AND ANATOMICAL VARIANTS IN THE HUMAN SKELETON

By

ROBERT W. MANN, Ph.D.
DAVID R. HUNT, Ph.D.
SCOTT LOZANOFF, Ph.D.

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SPECIAL CONTRIBUTORS

Anna Dhody, MA. Curator of Collections, Mütter Museum, College of Physicians of Philadelphia, Philadelphia, Pennsylvania

Prof. Dr. Katerina Harvati, PhD, Director Paleoanthropology, University of Tübingen, Tübingen, Germany

Joseph T. Hefner, PhD, Forensic Anthropologist and Assistant Professor, Michigan State University (formerly at the Joint POW/MIA Accounting Command, Central Identification Laboratory, Joint Base Pearl Harbor-Hickam, Hawaii)

Pap I. Ildikó, PhD, Natural History Museum of Hungary (Magyar Termeszettudományi Múzeum), Budapest, Hungary

Ericka L'Abbe, PhD, Curator of the Bone Collection, Department of Anatomy, University of Pretoria, Pretoria, South Africa

Steven Labrash, Director Willed Body Program, Department of Anatomy, John A. Burns School of Medicine, University of Hawai`i, Hawai`i

Beth Lozanoff, Medical Illustrator, Department of Anatomy, John A. Burns School of Medicine, University of Hawai`i, Hawai`i

Pasuk Mahakkanukrauh, MD, Rehabilitation Medicine, Professor of Anatomy, Department of Anatomy, Chiang Mai University School of Medicine, Chiang Mai, Thailand

Janet Monge, PhD, Professor, Department of Anthropology, University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia, Pennsylvania

Cortland Sciotto, (Retired Master Chief Petty Office) Forensic Science Academy, Joint POW/MIA Accounting Command, Hawaii

Professor Dr. Dr. Michael Schultz, Department of Anatomy, (Universitätsmedizin Göttingen), School of Medicine University of Göttingen, Göttingen, Germany

Barbara Straßmann, M.A., Curator for the Berliner Gesellschaft für Anthropologie, Ethnologie and Urgenschichte (BGAEU), Berlin, Germany

Panya Tuamsuk, MD, Professor of Anatomy, Curator Osteology Collection, Department of Anatomy, Khon Kaen University School of Medicine, Khon Kaen, Thailand

Hugh H. Tuller, MA, Anthropologist, Joint POW/MIA Accounting Command (JPAC), Central Identification Laboratory (CIL), Hawaii

This book is dedicated to my wife Vara. My best friend and love of my life.

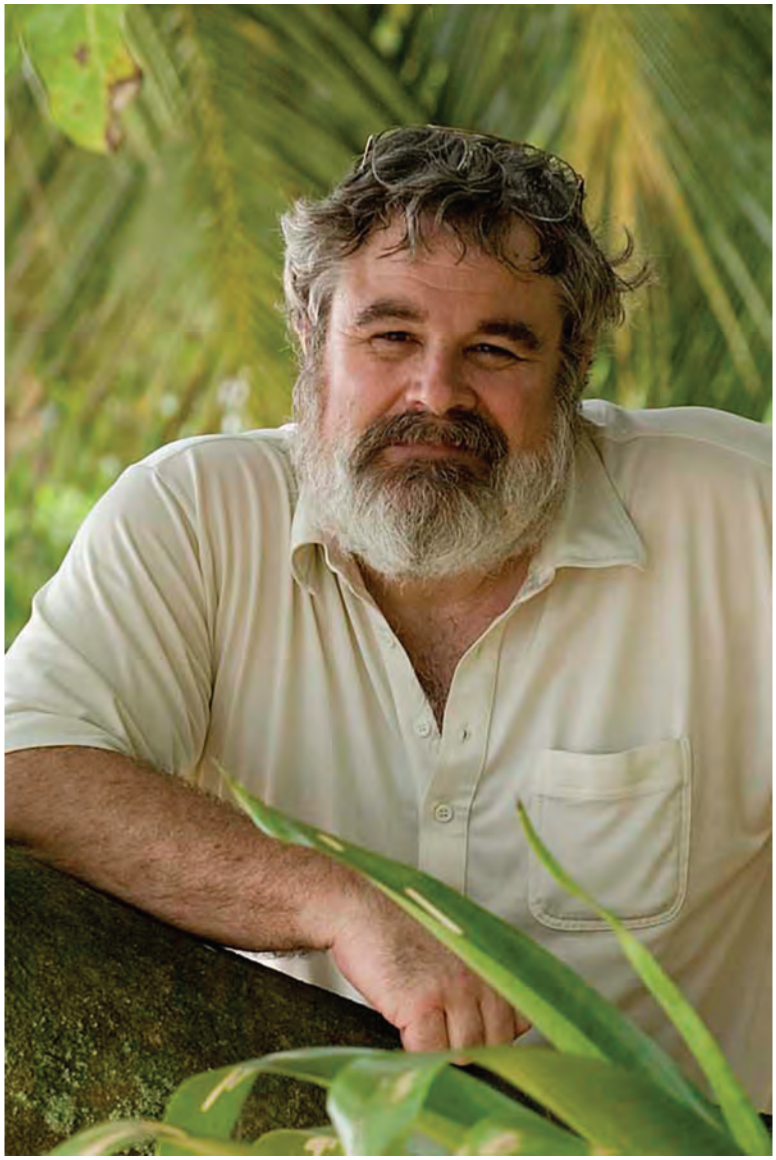
RWM

To my lovely wife Kim and my daughter Hannah, and the continuous love and support of my parents.

DRH

To Alexandra, Natasha, Nicholas, and most of all, Beth.

SL



In memory of Chip Clark . . . friend, colleague and photographer extraordinaire.

INTRODUCTION

The impetus for this book was the first author's interest in skeletons, libraries and vintage textbooks. This passion led him down a sometimes poorly lit path searching the medical and anatomical literature going back to the 1700s in order to learn more about the human skeleton and, more precisely, to gain a better understanding of our past, through the eyes of our anatomical, anthropological and medical predecessors. It was this personal journey and revival of bringing what had been found, often in obscure and mostly forgotten articles, to the present, and to incorporate them into a teaching regimen for students. This book is a result of that journey, one that incorporates physical anthropology with medicine, anatomy, biomechanics, chemistry, and biology in one text.

It was based on this endeavor that the book took roots and the authors combined their experience, skills and knowledge as anthropologists and anatomists. Wherever possible, the authors have sought to cover these skeletal traits as best they can and to show the range of variation of traits along a continuum from small to large, single and multiple, divided and undivided, left and right, and so forth. The goal in compiling this book was not to show only the most unusual expression of a trait, its smallest or largest form, or its most unusual shape, but to show its typical ("expected") and rare ("unexpected") expressions. Showing only the most extreme examples of traits and variants, they believe, ignores the range of variation and can lead to a bias in reported frequencies, geographical distributions and appearance of traits. These differences in trait expression in this book, therefore, reflect significant variation in size, shape, location and frequencies of many, perhaps even most, traits that an observer may encounter in examining one or a thousand skeletons.

To better understand how scientists perceive, classify and categorize anatomical variants of the human skeleton, the authors reviewed the literature and noted nearly 300 features that scientists have identified or classified as non-metric traits, discrete traits and dichotomous traits, among others, in the human skeleton (see Table 1). Interestingly, when considered more closely, many of these features appear to suffer from misidentification or interpretation. For example, some "non-metric" traits are the result of abnormal or pathological growth leading to pathological symptoms while many have yet to be shown to have a genetic basis. Other variant features, such as nasal and chin shape, are shared by all of us and might more accurately be classified as morphoscopic characteristics.

The question, therefore, one that is not easily answered, is how do we define normal from pathological, non-metric traits, typical and atypical? For example, a parietal foramen, commonly classified as a non-metric trait or anatomical variant is a normal and occasionally occurring feature that transmits an emissary vessel (Santorini's vein) connecting veins of the scalp with the superior sagittal sinus. This hypostotic feature is the result of a normal developmental process where an emissary vessel penetrates the outer table into the diploe or through the inner table. The formation of this vein is typical, as is the concomitant formation of a foramen housing it in the vault; not having this foramen, however, is clearly a "normal" condition that is present in many people.

An enlarged parietal foramen, in comparison, is an atypical or pathological feature resulting in faulty ossification in the region of Obelion that may or may not transmit an emissary vessel. A small, normally occurring parietal foramen and an enlarged parietal foramen are not merely features that differ in size along a continuum of "normal," but by the developmental processes that produce them. A parietal foramen, therefore, is a feature that may or may not be present in one or both parietal bones, may be double or triple on one side, or may be considered pathological if larger than 5 mm in maximum diameter. Here we see a feature or anatomical variant that can be viewed as normal or pathological, based on size alone. Other "normal" variants and non-metric traits include the supraorbital notch and foramen, nasal bone foramen, accessory frontal grooves, occipital foramen exsutural (the expressed non-metric trait), and rhomboid fossa for attachment of the costoclavicular ligament, to name a few. Surprisingly, it is difficult to discern whether it is the presence or absence of some traits that represents the "norm." One feature that most non-metric traits share, however, is that they seem to be "unexpectedly" present.

There are, of course, variants and features included in some non-metric trait lists that reflect abnormal or pathological development. Examples of what the authors would call "abnormal" non-metric traits and anatomical variants include the external auditory exostosis, tertiary occipital condyle, bone spur, exostosis in the trochanteric fossa and palatal exostosis (torus palatinus), the latter, if large enough, becomes symptomatic. Still other variants, such as a bipartite parietal bone that is formed by an accessory (subsagittal) suture, is such a rare feature that it is sometimes viewed as pathological in comparison to the normally and commonly occurring ossicles often present along the lambdoidal and sagittal sutures. While both conditions develop through the same process, one is common (lambdoidal ossicle) while the other is exceedingly rare (subsagittal suture). When discussing the bipartite parietal bone, the rarity of the trait makes it a significant finding, one worthy of reporting in the literature. Researchers have, of course, been aware that some non-metric traits are pathological in origin, but they often include these features in their parameter trait lists of normal or non-metric traits. Still other traits fall within a gray area where their origin and development is either unknown or debated. Some "gray area" examples include the ossified trochlear pulley, vastus notch and bipartite patella, distal femoral cortical excavation, cervical fossa of Allen, Walmsley's facet, third trochanter, os trigonum and calcaneus secundarius, to name a few.

Considering the extensive research and many thousands of human skeletons and cadavers that have been dissected and studied long before the days of Albinus and Vesalius, it is perhaps surprising that variation of the human skeleton has not been better documented and more easily available in a single reference book. This compartmentalization of non-metric traits and anatomical variants of the skeleton in books, scientific articles, poster presentations, abstracts, and public discussions is evident when one attempts to find an example of a trait, variant, or unusual osseous or dental feature. Searching the literature to identify a skeletal feature can take weeks or months and, at the end of a search, one may still remain confused regarding its name, frequency and rarity, etiology, range of expression and whether anyone has published a description. Exacerbating this issue is the fact that many traits and features that some view as anecdotal and not "worthy of mention" would likely help explain human diversity and development, if described and reported. Unfortunately, many subtle traits and variants go unreported and, as a result, so do their existence, frequency and range of variation. This book is intended to alleviate some of these mysteries, although it cannot address or answer all of them.

As previously mentioned, non-metric traits and anatomical variants are often identified based on their frequency of expression/presence in an osteology collection or a geographical group. Typically, the most common expression of a trait is viewed as typical or normal while unusual, uncommon, atypical, or rare traits are viewed as variants along a size and shape continuum. While some researchers choose to view non-metric traits merely as features that are either present or absent, these traits actually vary in size, shape, number and location, and not merely their presence or absence.

Choosing the appropriate terms to identify or describe a non-metric trait or anatomical variant, therefore, can sometimes be alleviated or, at the very least, reconsidered, by the choice of terms. For example, dichotomous terms such as normal or abnormal lead us to believe there are only two states for a particular feature – one is the result of normal developmental processes, while the other is pathological in origin, expression, or symptoms. The dilemma of how to view and interpret variability of the human body and which terms to use, however, is one of antiquity and in fact, was a topic of great concern to Andreas Vesalius (1514-1564), the Father of Anatomy (Straus and Temkin 1943). To avoid having to identify or label anatomical traits as normal or abnormal, Vesalius referred to them based on their frequency as "always," "usually," "frequently," "more frequently," "most frequently," "sometimes," "not always," rarely," relatively rarely," much more rarely," and "very rarely." What Vesalius did was remove the "finality" and "diagnosis" of normal or abnormal by using qualitative terms to quantify features according to how often he found them in his own research. While contemporary statisticians and researchers typically rely more on quantitative methods such as frequencies, intra- and inter-observer variability and multivariate statistics to report frequencies of traits and anatomical variants, steadfast qualitative terms such as "rare" and "common" maintain their place in scientific research and reporting. The current authors utilized quantitative, semi-quantitative and qualitative frequencies when reporting traits and anatomical variants in this book.

This atlas is the culmination of more than 75 combined years' of skeletal research and analysis by the authors and is intended to:

1) Utilize large, color photographs and a regional skeletal approach, to provide as many examples as we could of anatomical variants and non-metric traits in the human skeleton.
2) Identify and describe the widest possible range of anatomical variants and non-metric traits in the human skeleton in a single source.

3) Impart information on anatomical variants and non-metric traits spanning diverse temporal and geographical regions.
4) Provide clarity or, at the very least, stimulate discussion on the difference between an anatomical variant, non-metric trait, anomaly and morphoscopic trait.
5) Provide descriptions, relative frequencies, and references for anatomical variants and non-metric traits in the human skeleton.
6) Increase our knowledge of the intra- and inter-variability of the human skeleton.

Some recommended anatomy and skeletal reference texts and databases that the authors have found especially helpful include, but are not restricted to the following:

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CONTENTS

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Abbreviations and Names of Skeletal Collections Used in This Book

CIL = Central Identification Laboratory, Hickam Air Force Base, Hawaii.

CSC = CIL Study Collection, Central Identification Laboratory, Joint POW/MIA Accounting Command, Joint Base Pearl Harbor-Hickam, Hawaii.

CMU = Chiang Mai University, Department of Anatomy, Faculty of Medicine, Chiang Mai, Thailand.

CU = Chiba University, Chiba, Japan.

FSA = Forensic Science Academy, Central Identification Laboratory, Joint POW/MIA Accounting Command, Joint Base Pearl Harbor-Hickam, Hawaii.

Freiburg University, Freiburg, Germany.

GU = Göttingen University, Georg-August University of Göttingen, Göttingen, Germany.

HNHM = Hungarian Natural History Museum (Magyar Termeszettudományi Múzeum), Budapest, Hungary.

JABSOM = John A. Burns School of Medicine, University of Hawaii School of Medicine, Hawaii.

KKU = Khon Kaen University, Department of Anatomy, Faculty of Medicine, Khon Kaen University Medical School, Khon Kaen, Thailand.

LABANOF = Laboratorio di Antropologia e Odontologia Forense, University of Milano.

MM = Mütter Museum, College of Physicians of Philadelphia, Pennsylvania.

PAVN = Peoples Army of Vietnam Forensic Institute, Vietnam.

RV = Rudolf Virchow Skull Collection, Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte (BGAEU), Berlin, Germany.

SI = Smithsonian Institution, National Museum of Natural History, Washington, DC.

UPenn = University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia, Pennsylvania.

University of Pretoria, Department of Anatomy, Pretoria, South Africa.

UTK = University of Tennessee, William M. Bass Osteology Collection, Knoxville.

University of Tübingen (Eberhard Karls Universität Tübingen), Institute for Archaeological Sciences, Tübingen, Germany.

Chapter 1

FRONTAL VIEW OF THE SKULL

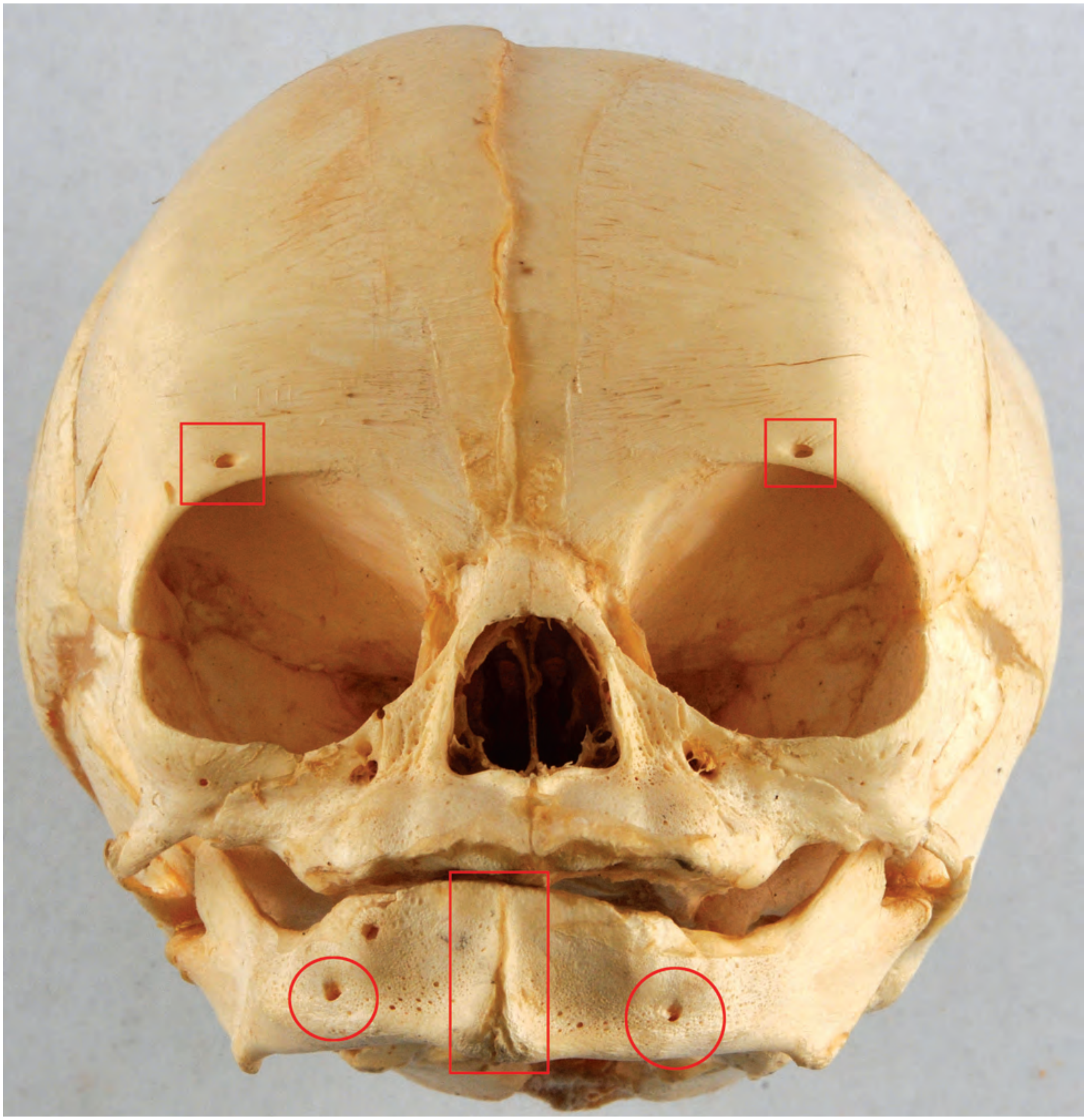

Figure 1. Anatomy of a newborn skull showing bilateral supraorbital foramina (squares), patent/open metopic (frontal, interfrontal, median frontal) suture, partially fused mental symphysis (rectangle) and mental foramina (circles). Note the horizontal growth lines (striae) in the frontal bone (CSC). The metopic, in comparison to other sutures, contributes little to growth of the cranium (Massler and Schour 1951). The approximately 110 centers of ossification typically result in 45 bones in the neonate and 22 in the adult skull (Sperber et al. 2010). See Apinhasmit et al. (2006); Berge and Bergman (2001); Chung et al. (1995); Dutton (2011); Hauser and DeStefano (1989); Schaefer et al. (2009); Scheuer and Black (2000, 2004).

Figure 2. Normal morphology of a fetal skull. Note the wide metopic/interfrontal/frontal/median frontal suture that widens as it approaches the coronal suture, "sunburst" growth lines in the frontal bones, presence of a bony nasal septum and nasal bones, and "V" or "kite-shaped" anterior fontanelle covered by thin but tough membrane (dura mater) that later becomes replaced by bone (cf. Basmajian 1964). The anterior fontanelle usually closes between 10 and 18 months, but as early as 3 months or as late as 28 months (Segall et al. 1973). Although the cranial bones of a newborn and infant are eggshell thin, they are pliable, flexible, and can withstand considerable force. The heraldic shape of the anterior fontanelle and sagittal suture when viewed from above gives the sagittal suture its name: sagitta = an arrow (Brash 1953). Cf. Schaefer et al. (2009); Scheuer and Black (2000, 2004). The ectocranial surface of sutures is predominately under tension, resulting in bone deposition, while the endocranial surface is predominately under compression, resulting in bone resorption.

a

b

Figure 3a-b. Comparison of the anterior fontanelle in two fetuses. (a) The dura mater, a translucent membrane (dura mater or "tough mother") spanning the bones. (b) Close-up of the irregular, scalloped margins forming the metopic suture in one of the fetuses.