Second Edition

Forensic Anthropology

A Comprehensive Introduction

Edited by
Natalie R. Langley
MariaTeresa A. Tersigni-Tarrant

CRC Press
Taylor & Francis Group

Forensic Anthropology

Forensic Anthropology

A Comprehensive Introduction

Second Edition

Edited by

Natalie R. Langley

MariaTeresa A. Tersigni-Tarrant

CRC Press

Taylor & Francis Group

Boca Raton London New York

CRC Press is an imprint of the

Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed on acid-free paper
Version Date: 20170119

International Standard Book Number-13: 978-1-4987-3612-1 (Hardback)

Contents

Preface

The discipline of forensic anthropology has grown considerably since the founding of the Physical Anthropology Section of the American Academy of Forensic Sciences in 1972. Forensic anthropologists have gone from being expert consultants working primarily in academia to full-time board-certified employees in the medico-legal system (although a number of forensic anthropologists still hold dual appointments as professors and consultants). The formal organization of the field spurred the formation of academic programs for educating and training researchers and practitioners. Proper training in the theory, methods, and best practices of forensic anthropology begins at the undergraduate level and continues into graduate education, preferably at the PhD level. An undergraduate anthropology education is typically broad-based and establishes familiarity with three or four of the subdisciplines in the field (physical anthropology, cultural anthropology, archaeology, and linguistic anthropology). Specialization in applied areas such as forensic anthropology usually does not begin until the graduate level; however, more and more programs are offering undergraduate courses in forensic anthropology.

As researchers, practitioners, and educators, the editors of this volume found it challenging to develop introductory courses in forensic anthropology because educational texts in forensic anthropology tend to be targeted at more advanced audiences. Hence, the motivating force behind the development of the first edition of this text was to provide a book designed primarily for an introductory course that would prepare the next generation of forensic anthropologists to face the important issues of best practice being addressed currently by the Scientific Working Group for Forensic Anthropology (SWGANTH) and the issues brought forward in the National Academy of Sciences report *Strengthening Forensic Science in the United States: A Path Forward* (2009). To this end, these chapters are written by content experts in the field who have done novel research in forensic anthropology and helped to provide the foundations for best practice.

The second edition, *Forensic Anthropology: A Comprehensive Introduction*, has been reorganized considerably to provide a cohesive and user-friendly text for a semester course in forensic anthropology. The authors incorporated book reviews, feedback from users, and anonymous peer reviews of the first edition into the design of the second edition and anticipate that the new product will serve the educational community more effectively. Each chapter has learning objectives, review questions aligned with these objectives, a chapter summary, and glossary definitions for advanced terms or jargon that are not defined in the chapter text. The second edition has been condensed from 22 chapters to 18 chapters with more specialized and advanced topics added as appendices. The text is organized into four main sections plus two appendices: I. Forensic Anthropology and the Crime Scene, II. The Skeleton and Skeletal Documentation, III. Skeletal Individuation and Forensic Anthropological Analyses, and IV. Human Identification and Advanced Forensic Anthropology Applications.

The first section, Forensic Anthropology and the Crime Scene, contains Chapters 1 through 4. Chapter 1 provides an overview of forensic anthropology in the United States, including a history of the discipline from the earliest application of physical anthropology in a medico-legal setting to the issues faced by forensic anthropologists today. Chapter 2 is new to this edition and addresses how anthropologists handle skeletal remains as evidence. Chapter 3 discusses how archaeological methods are used to recover and document crime scenes. Chapter 4 discusses how taphonomic processes affect the formation, recovery, and interpretation of crime scenes and skeletal remains.

The second section, The Skeleton and Skeletal Documentation, contains Chapters 5 through 7 and covers human osteology, odontology, and the first and last steps of doing a forensic anthropology case (processing and the case report). Chapter 5 presents basic human osteology that will be helpful for understanding the content in the remaining chapters in this book. This chapter is not meant to replace a human osteology class, but simply to provide a quick reference for less experienced readers; advanced reading and reference suggestions are provided for those requiring more in-depth osteology. Chapter 6 provides an overview of the human dentition and dental numbering systems used in forensic case reports. Chapter 7 details how to process remains and prepare a forensic case report and includes sample case reports for reference.

The third section, Skeletal Individuation and Analyses, consists of Chapters 8 through 14 and covers how forensic anthropologists develop a biological profile from skeletal remains (sex, age, ancestry, and stature) and analyze skeletal pathology and trauma. The importance of choosing proper methods and understanding the advantages and limitations of available methods is highlighted throughout these chapters. In addition, the authors call attention to areas of burgeoning research and areas where additional research is needed. Chapters 8 through 11 deal with the primary elements of the biological profile. Chapter 12 is new to this edition and provides an overview of individualistic skeletal features and skeletal responses to pathology and trauma. Chapter 13 discusses the biomechanics and interpretation of low- and high-velocity skeletal trauma and nascent research in the field of skeletal trauma interpretation. Chapter 14 provides a detailed explanation of the Fordisc program used by forensic anthropologists in the United States to estimate sex, ancestry, and stature from metric data, including a brief history of the software development, its limitations, and common criticisms.

Chapters 15 through 18 comprise the fourth section, Human Identification and Advanced Forensic Anthropology Applications. Chapter 15 provides a comprehensive discussion of time since death (TSD) and the many processes that are factored into determining the postmortem interval (environmental/meteorological, individual, and cultural/case-specific factors), the variety of methods available for TSD estimation (entomology, botany, soil chemistry, and morphoscopic techniques), and decomposition research (past, present, and future directions). Chapter 16 details acceptable techniques for tentative, circumstantial, and positive personal identification and their implications for forensic practice, research, and the investigative process. Chapter 17 deals with forensic anthropology in large-scale situations, namely human rights violations and mass disasters, and provides considerations for handling these unique and sensitive situations. Chapter 18 explicates the effects of fire on the human body and details how to approach fire scenes, thermal trauma, and situations in which remains are commingled.

This book concludes with two appendices. Appendix A, Application of Dentition in Forensic Anthropology, discusses the use of the dentition in forensic anthropology, including age, ancestry, and sex determination and assessing dental anomalies and pathologies. Appendix B, Age Estimation in Modern Forensic Anthropology, provides an advanced look at the topic of age estimation, including an examination of statistical methods, bias, and the problems with age-at-death estimation.

Although the chapters are written so that less experienced readers can understand the content, the editors feel that readers from a wide variety of experience levels will find the material both interesting and useful. As the chapters are thoroughly referenced and give special attention to current research and best practice, the text can serve as a useful addition to any forensic anthropology laboratory or library. We encourage its use as part of a forensic anthropology curriculum, as a reference for the laboratory, and as a review of the many complex subject areas that have come to encompass forensic anthropology. Thank you for choosing to purchase this text, and we look forward to receiving input from our reading audience on this revised edition.

Natalie R. Langley and MariaTeresa A. Tersigni-Tarrant

Acknowledgments

The editors thank the contributing authors for their time, patience, and effort to make the needed improvements to this second edition. We also thank Mark Listewnik at Taylor & Francis Group for his invaluable suggestions, efficient responses to all matters, and undivided attention during the preparation of this text. We acknowledge the support of our respective employers (Saint Louis University, Missouri, LMU-DeBusk College of Osteopathic Medicine, Tennessee, and Mayo Clinic School of Medicine, Arizona Campus) during this time-consuming endeavor and the patience of our friends, families, and colleagues as we worked many nights and weekends. Finally, we are thankful for the friendship we have in one another that makes a task such as this possible and all the more pleasant.

Editors

Natalie R. Langley, PhD, D-ABFA, is a faculty member in the Department of Anatomy at the Mayo Clinic College of Medicine and Science. She is an adjunct faculty member in the University of Tennessee Anthropology Department and the DeBusk College of Osteopathic Medicine Anatomy Department (previous name: Natalie R. Shirley). She received her BA (1998) and MA (2001) in anthropology from Louisiana State University and her PhD (2009) from the University of Tennessee, Knoxville. Dr. Langley is a diplomate of the American Board of Forensic Anthropology (#110) and consults for the Georgia Bureau of Investigation. She is a fellow of the American Academy of Forensic Sciences, and a member of the American Association of Anatomists, American Association of Clinical Anatomists, and American Association of Physical Anthropologists. In 2007, the AAFS Forensic Science Foundation awarded her the Emerging Forensic Scientist Award for her research in skeletal maturation. Dr. Langley has published articles in the *Journal of Forensic Sciences, American Journal of Physical Anthropology, Forensic Science International, International Journal of Legal Medicine, Anatomical Sciences Education*, and *Clinical Anatomy,* and has written numerous book chapters. Her research interests include skeletal maturation in modern populations, age and sex estimation from the human skeleton, secular changes in skeletal biology, currency of forensic standards, skeletal trauma, and anatomy education. During the spring of 2012, she was the forensic anthropologist on an eight-episode television series airing on the National Geographic Channel titled *The Great American Manhunt.*

MariaTeresa A. Tersigni-Tarrant, PhD, D-ABFA, is an associate professor in the Department of Surgery's Center for Anatomical Science and Education (CASE) at the Saint Louis University School of Medicine (SLU SOM), Missouri, where she serves as the director of Gross Anatomy Laboratory and Morgue Operations. Dr. Tersigni-Tarrant teaches gross anatomy, embryology, and histology to medical students, graduate students, and allied health students at SLU SOM. Dr. Tersigni-Tarrant is also an adjunct associate professor in the SLU SOM Department of Pathology where she serves as the director of forensic education, organizing, developing, and implementing curriculum for basic and advanced medico-legal death investigator training courses that are offered multiple times per year. She received both her BS degrees (microbiology and anthropology) from Michigan State University (2000). She received her MA (2002) and PhD (2005) in physical anthropology from the University of Tennessee, Knoxville. She completed a postdoctoral fellowship at the laboratory formally known as JPAC-CIL (2005–2006), where she helped to create the standard operating procedures for histological analysis of osseous remains. Dr. Tersigni-Tarrant is a diplomate of the American Board of Forensic Anthropology (#98), and she provides anthropological consulting services for the city of St. Louis (Missouri), the Missouri Disaster Response System, and the Georgia Bureau of Investigation. Dr. Tersigni-Tarrant is a fellow of the American Academy of Forensic Sciences and is a member of the American Association of Physical Anthropologists and American Association of Clinical Anatomists. She serves on the Missouri State Anatomical Board, Missouri Disaster Response Team, and the St. Louis Area Regional Response System. Her research interests include human and nonhuman histology, child abuse: patterned fractures and timing of healing, long bone fracture patterning, bone pathology, and developmental anatomy.

Contributors

Bridget F. B. Algee-Hewitt, PhD, is a biological anthropologist in the Department of Biology at Stanford University, California. Dr. Algee-Hewitt was awarded her PhD in anthropology at the University of Tennessee, Knoxville and her master's degree from Bryn Mawr College, Pennsylvania, in classical and near eastern archaeology. She has completed postdoctoral work in both skeletal biology and human genetics, as the Haslam Post-Doctoral Fellowship for Research in Forensics at the University of Tennessee, and is a fellow in the Stanford Center for Computational, Evolutionary and Human Genomics. She has also served as an assistant professor in biomedical sciences, teaching clinically oriented anatomy, physiology, and advanced human dissection. Dr. Algee-Hewitt's current research program includes developing novel computational approaches to biological data analysis, addressing, in particular, population inference from a dual skeletal and genetic perspective. The breadth of her interests in skeletal biology, population genetics, and biostatistics has allowed her to contribute to research that has theoretical implications for the larger study of human variation, evolution, and population history in anthropology while also making practical contributions to the applied fields of human identification in the forensic sciences. Dr. Algee-Hewitt has recently received a National Institute of Justice grant in support of newly developed computational methods for age-at-death estimation from skeletal indicators using laser scan data.

Bruce E. Anderson, PhD, D-ABFA, is a forensic anthropologist with the Pima County Office of the Medical Examiner (PCOME), in Tucson, Arizona. Dr. Anderson received his PhD degree in 1998 from the University of Arizona, where he is currently an adjunct assistant professor of anthropology. Prior to his hiring by the PCOME in 2000, he served as a senior anthropologist for the U.S. Army's Central Identification Laboratory in Hawaii (CILHI) where his principal duties were the field recovery and laboratory analyses leading toward identification of human remains associated with past U.S. military conflicts. Dr. Anderson currently mentors anthropology students in the Forensic Anthropology Internship Program at the PCOME and works with postdoctoral fellows as part of the PCOME's Forensic Anthropology Fellowship Program. He is a fellow in the American Academy of Forensic Sciences (AAFS), is certified as a diplomate by the American Board of Forensic Anthropology (ABFA), was a founding member of the Scientific Working Group in Forensic Anthropology (SWGANTH), and served as a forensic anthropologist during the development and initial launch of the National Missing and Unidentified Persons System (NamUs).

Gregory E. Berg, PhD, D-ABFA, is a laboratory manager and forensic anthropologist at the Defense POW/MIA Accounting Agency Central Identification Laboratory in Hawaii, where he works on the recovery and identification of missing U.S. service personnel. He earned his BA in anthropology at the University of Arizona in 1993, his MA in the bioarchaeology program at Arizona State University in 1999, and his PhD at the University of Tennessee, Knoxville, in 2008. He has more than 25 years of field experience in archaeology and physical anthropology and has presented or published numerous articles and papers in the *Journal of Forensic Sciences, Journal of Archaeological Science, Optometry*, and at various annual meetings. His recent research has concentrated on ancestry and sex determination, trauma analysis, aging techniques, human identification and eyewear, and intra- and interobserver error studies, which have been particularly focused on aging and population determination methods used in human identification. Dr. Berg is a member of the American Academy of Forensic Sciences, and is a diplomate of the American Board of Forensic Anthropology (#93).

Angi M. Christensen, PhD, D-ABFA, attended the University of Washington, earning a BA in anthropology, and received her MA and PhD in anthropology from the University of Tennessee, Knoxville. She currently works as a forensic anthropologist for the Federal Bureau of Investigation (FBI) Laboratory in Quantico, Virginia. She assisted with the development of the FBI's Forensic Anthropology Program, whose mission is to provide casework services, operational assistance, consultation, research, training, and outreach to law enforcement at federal, state, and local

levels. Her research interests have included methods and issues related to personal identification, error and error rates in forensic contexts, scientific admissibility issues, human remains in aquatic forensic contexts, and the interpretation of skeletal blast trauma. She also serves as an active member of the Anthropology Subcommittee of NIST's Organization of Scientific Area Committees, assisting to develop standards and best practices for the discipline of forensic anthropology.

Derek Congram, PhD (Simon Fraser University, Canada), teaches and conducts research at the Munk School of Global Affairs, University of Toronto, Canada, and also consults as an archaeologist/biological anthropologist in medico-legal and humanitarian contexts. He has worked for governments, universities, nongovernmental, and international organizations in 20 countries. His principal research interests are spatial analysis and GIS-modeling of unmarked burials in conflict contexts, bioarchaeology of the Spanish Civil War, professional ethics, and public (bio) archaeology. He is the editor of and a contributor to the publication *Missing Persons; Multidisciplinary Perspectives on the Disappeared* (Canadian Scholars' Press), 2016.

Kate M. Crowley, DMD, D-ABFO, is a board certified forensic odontologist on staff with the Office of the Chief Medical Examiner in Boston, Massachusetts. Dr. Crowley is also a periodontist working in private practice with offices located in Weymouth and Fall River, Massachusetts.

Joanne Bennett Devlin, PhD, D-ABFA, is a faculty member in the Anthropology Department at the University of Tennessee, Knoxville. She previously worked as an archaeologist in the Great Basin, the mid-Atlantic, and the Southeast. Currently, as an assistant director of the Forensic Anthropology Center (FAC), she oversees graduate student training, and conducts casework while also engaging in teaching in FAC sponsored short training courses. Dr. Devlin is a certified firefighter in Knox County, where she has served for more than 10 years. She is also a diplomate of the American Board of Forensic Anthropology and a consulting forensic anthropologist with the Hamilton County Cold Case Task Force. Dr. Devlin also works with the National Center for Missing and Exploited Children (NCMEC) on cases of unidentified subadults. Her research interests include taphonomic signatures of fire and geophysical methods of clandestine grave discovery.

Angela M. Dautartas, MA, received her BS in anthropology from Radford University, Virginia, in 2005 and her MA in anthropology from the University of Tennessee, Knoxville, in 2009. She is currently a doctoral candidate in the Anthropology Department and research assistant with the Forensic Anthropology Center at the University of Tennessee, Knoxville. Her current research explores the use of animal models in taphonomic studies. Her research interests include human decomposition, time since death, and paleopathology. She is also an adjunct instructor in the Natural and Behavioral Sciences Department at Pellissippi State Technical and Community College and in the Division of Social Sciences at Maryville College, Tennessee.

Alice F. Gooding, MS, is an assistant professor of anthropology at Kennesaw State University (KSU). She received her MS from the University of Georgia (UGA) in 2011. Her research at UGA tested age-at-death estimation methods on a modern sample and explored the application of these methods on cold cases from the Georgia Bureau of Investigation. She is finishing her PhD at the University of Tennessee, Knoxville, in biological anthropology. Her dissertation examines the relationships between skeletal senescence and biomechanical loading in the adult limbs. Gooding is also a clinical instructor with the Philaphelphia College of Osteopathic Medicine. Her current research tests the biomechanical response of bone to blast force trauma. She is a member of the FBI Atlanta Regional Forensic Specialist Working Group and works closely with local high schools to develop curriculum for forensic courses and teacher training.

Pierre Guyomarc'h, PhD, received his BA in archaeology from Paris Sorbonne and Besancon Universities in France, and his MSc and PhD in biological anthropology from the University of Bordeaux, France, in 2011. After working for two years as a forensic anthropologist at the Joint POW/MIA Accounting Command Central Identification Laboratory (JPAC-CIL, HI), he started to work as a forensic adviser with the International Committee of the Red Cross (ICRC) in Burundi, Ukraine, and Lebanon. His research interests include the development of identification methodologies through morphometrics and medical imaging. Within the ICRC, he focuses on forensic humanitarian action, promoting a proper management of the dead and best practices for the identification of missing persons after armed conflicts or disasters.

Nicholas P. Herrmann, PhD, is an associate professor of anthropology at Texas State University in the Department of Anthropology and the Forensic Anthropology Center at Texas State (FACTS). Dr. Herrmann works extensively with human skeletal remains from archaeological, forensic, and anatomical contexts. His research focuses on the biological variation of human populations both past and present. His research is based on prehistoric, historic, and modern populations from Greece, Cyprus, Honduras, and across the United States. He has directed or codirected projects examining stature estimation, geophysical prospection, commingled human remains, geospatial mapping applications, archaeological surveys, historic cemeteries, and stable isotope and trace element variation in modern U.S. populations.

David R. Hunt, PhD, D-ABFA, is the collections manager in the Physical Anthropology Division of the Smithsonian's National Museum of Natural History, Washington, DC. He received two BA degrees in 1980 from University of Illinois, Urbana, in physical anthropology and classical archaeology, and earned his MA in 1983 and PhD in 1989 at University of Tennessee, Knoxville, in skeletal biology and forensic anthropology. He is a diplomate of the American Board of Forensic Anthropologists. His areas of research include human skeletal biology/variation, paleopathology, forensic anthropology, and nondestructive investigation using computer-assisted tomography and mummies of the world. He has a professorial position at George Washington University and is a physical/forensic anthropology consultant for the Office of Chief Medical Examiner, Northern Virginia Region, and is a consultant for Project Alert and the Forensic Imaging Unit at the National Center for Missing and Exploited Children. Hunt is involved in U.S. archeological excavations as well as international archeological excavations and skeletal biological research in Mongolia, Egypt, and Rwanda. He consults on human remains curation in museum and institutional settings.

Richard L. Jantz, PhD, was educated at the University of Kansas, Lawrence, and has been a faculty member at the University of Tennessee, Knoxville, since 1971. His research interests mainly include quantitative human variation with an emphasis on American populations, both early and recent. In the mid-1980s, he established the forensic anthropology data bank, which serves as a resource to study skeletal variation among modern Americans. He, along with Steve Ousley, developed Fordisc, software that automates estimation of sex, ancestry, and height from skeletal measurements. His primary research activity in forensic anthropology deals with improving estimates of sex, ancestry, and height, and documenting the changes occurring in the American population during the twentieth century. He retired from his active faculty position in 2009 and as the director of the Forensic Anthropology Center in 2011, a position he had held since 2000. He is now an emeritus professor and is enjoying not going to meetings and working on research that has been put off for decades.

Kerriann (Kay) Marden, **PhD**, is currently an assistant professor of anthropology and the director of the Forensic Science Program at Eastern New Mexico University, and regularly consults on forensic anthropology cases for the New Mexico Office of the Medical Investigator. Her research has spanned topics ranging from bioarchaeology to forensic anthropology. She was granted three Smithsonian Institution Fellowships, where she conducted paleopathological research of Ancestral Puebloan remains under Don Ortner and David R. Hunt. Kay served as an assistant to Marcella Sorg, a forensic anthropology consultant for the Offices of the Chief Medical Examiner of Maine, New Hampshire, and Rhode Island. Kay continues to collaborate with Dr. Sorg on taphonomic research projects and on a forthcoming edited volume. Kay holds doctoral and master's degrees in anthropology from Tulane University, Louisiana, and a master's degree in applied sociology from the University of Maryland at Baltimore County. She was previously certified by the American Board of Medico-legal Death Investigators, and she is an active member of D-MORT.

Lee Meadows Jantz, PhD, received her BA, MA, and PhD in anthropology from the University of Tennessee, Knoxville. As associate director of the Forensic Anthropology Center, Dr. Meadows Jantz is responsible for the body donation program and curation of the William M. Bass Donated and Forensic Skeletal Collections. She is a senior lecturer and adjunct associate professor in the Department of Anthropology at University of Tennessee, Knoxville, and serves as instructor for the outdoor recovery, taphonomy, and human identification courses offered through the Forensic Anthropology Center. Dr. Meadows Jantz is a founding member of the SWGANTH board and serves as a forensic anthropologist on the federal DMORT-WMD team. She consults with federal, state, and local law enforcement agencies on human identification cases. Her research interests include skeletal biology (past and recent populations), forensic anthropology, and human growth and development.

Stephen D. Ousley, PhD, attended the University of Tennessee, Knoxville. As a graduate research assistant, he worked as database administrator and data collector for the Forensic Data Bank, a repository of skeletal data from modern Americans. His master's thesis evaluated theories of the peopling of the New World using Native American anthropometrics, and his dissertation was a quantitative genetics analysis of fingerprints. For nine years, he was the director of the Repatriation Osteology Laboratory in the Repatriation Office of the National Museum of Natural History at the Smithsonian Institution. In 2007, he started teaching at Mercyhurst College, Pennsylvania. He is best known for coauthoring Fordisc, a computer program that aids in the identification of unknown human remains using various statistical methods. His research interests focus on forensic anthropology, human growth and development, human variation, geometric morphometrics, and dermatoglyphics.

Marin A. Pilloud, PhD, D-ABFA, RPA, is currently an assistant professor of anthropology at the University of Nevada, Reno. Dr. Pilloud's research is broadly focused on the application of dental morphology and metrics to answering research questions in both bioarchaeology and forensic anthropology. She has been active in bioarchaeological research programs in Neolithic Anatolia and prehistoric California, and, within forensic anthropology, she is primarily interested in the use of teeth in the estimation of ancestry.

James T. Pokines, PhD, D-ABFA, is an assistant professor in the Forensic Anthropology Program, Department of Anatomy and Neurobiology, Boston University, Massachusetts, and is the forensic anthropologist for the Office of the Chief Medical Examiner, Commonwealth of Massachusetts, in Boston. He served for more than a decade as a forensic anthropologist and laboratory manager at the Joint POW/MIA Accounting Command, Central Identification Laboratory, in Hawaii, after completing a postdoctoral fellowship there in forensic anthropology administered by the Oak Ridge Institute for Science and Education. Dr. Pokines received his BA in anthropology and archaeology from Cornell University, New York, his MA and PhD degrees in anthropology from the University of Chicago, and ABFA Board certification in forensic anthropology. His research also includes comparative vertebrate osteology, zooarchaeology, taphonomy, and paleoecology, and he has ongoing archaeological projects in the Bolivian Andes (Tiwanaku and related sites), South Africa (taphonomy), and northern Jordan (including a natural faunal trap and multiple Paleolithic sites). He has also conducted research in the Upper Paleolithic of Cantabrian Spain, modern predator taphonomy in Kenya, and zooarchaeology in the Nile Delta (Tell Timai).

M. Katherine Spradley, PhD, is an associate professor in the Department of Anthropology at Texas State University and faculty in the Forensic Anthropology Center at Texas State. Dr. Spradley is the Director of Operation Identification (OpID). OpID aims to facilitate the identification and repatriation of human remains found along or within close proximity of the South Texas border through community outreach, scientific analysis, and collaboration with governmental and nongovernmental organizations. Her current research focuses on metric data from human skeletons to address identification methods in forensic anthropology, to track population migrations when there is little or no historical documentation, and to explore the skeletal morphological changes associated with human migrations and changing environments (e.g. climate, nutrition, and health).

Denise To, PhD, D-ABFA, RPA, is a forensic anthropologist and forensic archaeologist with the Defense POW/MIA Accounting Agency where she currently serves as a laboratory manager. Dr. To received her master's degree in anthropology with an emphasis on bioarchaeology from Arizona State University and her PhD in physical anthropology from the same school in 2008. She has more than 22 years of experience as an archaeologist, which includes excavation of the Pyramid of the Moon at Teotihuacan. In addition to numerous sites in the United States, she has worked in Belgium, Bulgaria, France, Germany, Laos, Mexico, Palau, Papua New Guinea, Philippines, Saipan, Solomon Islands, South Africa, South Korea, Vanuatu, Vietnam, and Wake Island. Dr. To has taught human remains recovery courses in Hawaii for Chaminade University, Hawaii, as well as in Bogota, Colombia, for the U.S. Department of Justice's International Criminal Investigative Training Assistance Program. Dr. To received the U.S. Joint Civilian Service Achievement Award in 2011 for her efforts in Kathmandu, Nepal, in response to the crash of Agni Air 101, and was also deployed to Louisiana in response to Hurricane Katrina while as a member of the Disaster Mortuary Operational Response Team. She is certified as a diplomate by the American Board of Forensic Anthropology, is a member of the Register of Professional Archaeologists, and is a fellow of the American Academy of Forensic Sciences.

Katherine Weisensee, PhD, is currently an associate professor in the Department of Sociology and Anthropology at Clemson University, South Carolina. She received her BA in anthropology from Brandeis University, Massachusetts, and her MA and PhD in anthropology from the University of Tennessee, Knoxville. Dr. Weisensee teaches a variety of undergraduate courses, including forensic anthropology, human variation, biological anthropology, and introduction to anthropology. She acts as a forensic anthropology consultant for several counties in the upstate of South Carolina. Her research interests include geometric morphometrics, paleodemography, population genetics, and time since death.

Rebecca J. Wilson-Taylor, PhD, received her PhD in anthropology from the University of Tennessee, Knoxville, in 2013. Currently, she is a forensic anthropologist in the Central Identification Laboratory at the Defense POW/MIA Accounting Agency (DPAA), which seeks to fulfill the nation's promise to recover and identify unaccounted-for U.S. service members. Prior to joining DPAA, Dr. Wilson-Taylor worked as the assistant coordinator for the University of Tennessee's Forensic Anthropology Center where she conducted research at the Anthropology Research Facility, developed continuing education opportunities, and helped to manage the body donation program. She is also a member of the federal DMORT-WMD team. Her research interests include forensic taphonomy, human decomposition, sexual dimorphism, and paleopathology.

Debra Prince Zinni, PhD, D-ABFA, is the forensic anthropology laboratory manager at the Defense POW/MIA Accounting Agency, Joint Base Pearl Harbor-Hickam, Hawaii. Dr. Zinni received her BS in anthropology and psychology at James Madison University, Virginia, her MA in anthropology from The George Washington University, and her PhD from the University of Tennessee, Knoxville. Prior to her current position, she was an assistant professor at Boston University School of Medicine, Massachusetts, and the state forensic anthropologist for the Commonwealth of Massachusetts. Dr. Zinni is a fellow in the Anthropology Section of the American Academy of Forensic Sciences and is certified as a diplomate by the American Board of Forensic Anthropology (ABFA). Dr. Zinni serves as a treasurer on the Board of Directors of the ABFA.

Section I

Forensic Anthropology and the Crime Scene

Chapter 1

Forensic Anthropology in the United States *Past and Present*

MariaTeresa A. Tersigni-Tarrant and Natalie R. Langley

CONTENTS

LEARNING OBJECTIVES

1. Explain how forensic anthropology fits into the larger discipline of anthropology and define the major subdisciplines of anthropology.
2. Describe how training in each of the anthropology subfields contributes to a forensic anthropologist's understanding of human skeletal biology.
3. Recount the events that began and ended each of the three historical periods in forensic anthropology.
4. Explain the role of outdoor decomposition research facilities in forensic anthropology practice, research, and education.
5. Discuss the importance of documented modern skeletal collections for forensic anthropology research, practice, and education.
6. Explain the significance of the National Academy of Sciences (NAS) report to the forensic sciences and forensic anthropology. Name the organizations and committees that resulted from this report, and list their primary objectives.

The discipline of **anthropology** seeks to understand the many intricate aspects of what it means to be human. Derived from the Greek word *anthropos,* meaning "human," and *logia,* referring to the "study of," anthropology seeks to shed light on human behavior, biology, language, and culture in past and present contexts. Anthropology is a holistic discipline that encompasses multiple subdisciplines. The four most common subdisciplines are archaeology, sociocultural anthropology, linguistic anthropology, and physical/biological anthropology. These subdisciplines are not mutually exclusive, and each seeks to define and interpret various aspects of the human condition. Archaeology reconstructs the history of past populations through contextual analysis of the artifacts and structures (i.e., material culture) that these populations have left behind. Sociocultural anthropology uses observation and interviews of participants to understand cultural groups or subcultures. Linguistic anthropology investigates the origins and use of language, as well as language changes over time. Physical/biological anthropology studies human biological origins, adaptation, and variation in an evolutionary context, as well as the life histories of our nonhuman primate relatives. Each subdiscipline of anthropology is broken down further into smaller, more specialized subfields or applied areas of study that focus on specific aspects of what it means to be human. Figure 1.1 illustrates several common subfields of archaeology, cultural anthropology, linguistic anthropology, and physical/biological anthropology.

Forensic anthropology is an applied subdiscipline of physical/biological anthropology. Forensic anthropologists use their knowledge of modern human skeletal variation to help law enforcement identify unknown decedents and, if possible, provide information about the circumstances surrounding a death. The American Board of Forensic Anthropology defines forensic anthropology as "the application of the science of physical or biological anthropology to the legal process," adding that "[p]hysical or biological anthropologists who specialize in forensics primarily focus their studies on the human skeleton" (www.theabfa.org).

Forensic anthropologists employ the principles of skeletal growth, development, degeneration, and variation to ascertain biological information about an individual, such as age, sex, ancestry, and stature. These four components are collectively referred to as the **biological profile**. If the remains are human, modern, and of forensic significance, a forensic anthropologist constructs a biological profile to assist law enforcement in identifying the unknown decedent. Forensic anthropologists may also use their understanding of bone biomechanics (i.e., the way in which bone behaves under certain loads or forces) and/or bone healing to evaluate skeletal trauma. (The interpretation of skeletal trauma is discussed in detail in Chapter 13.) Furthermore, forensic anthropologists apply the principles of forensic taphonomy and bone weathering to determine what happened to the remains in a given depositional environment. Forensic taphonomy encompasses animal activity and bone weathering due to environmental factors such as sun, soil, plants, and humidity and is discussed further in Chapter 15.

Nationally, anthropology is recognized as one of the forensic sciences by the **American Academy of Forensic Sciences** (AAFS). The AAFS has 11 sections, each representing a different subdiscipline of forensic science. The AAFS has specific requirements for membership, as do each of the sections within the academy. Requirements have been developed for various levels of membership, from student and trainee affiliate members to associate and full members and fellows. Promotion from one level of membership to the next is contingent on completing the necessary requirements

Figure 1.1 Subfields within the four major subdisciplines of anthropology.

for promotion, which vary by section. Figure 1.2 presents the membership of each AAFS section as a percentage of the total AAFS membership. Figure 1.3 imparts the notion that, although anthropology is not the largest section, it is the section with the highest percentage of student or trainee affiliates. This may represent a significant trend for the future membership of the Anthropology Section of the AAFS.

Of the AAFS-recognized forensic science disciplines, anthropologists work most closely with forensic pathologists and forensic odontologists. Forensic pathologists are medical doctors with specialized training in pathology. Pathologists conduct forensic autopsies and determine cause of death. Forensic pathologists consult forensic anthropologists to examine skeletal, badly decomposed, severely burned, fragmentary, or commingled remains and submit a case report. Forensic odontologists are also referred to as forensic dentists. Forensic anthropologists rely on forensic odontologists to certify a positive identification of human remains by using the dentition. In these instances, the odontologist compares antemortem records (typically radiographs) with postmortem radiographs to make the identification.

Most forensic anthropologists are affiliated with the AAFS, as well as with the **International Association of Forensic Sciences (IAFS)**. Forensic anthropologists also disseminate research at the **American Association of Physical Anthropologists (AAPA's)** annual meetings. In addition, several regional forensic anthropology organizations exist

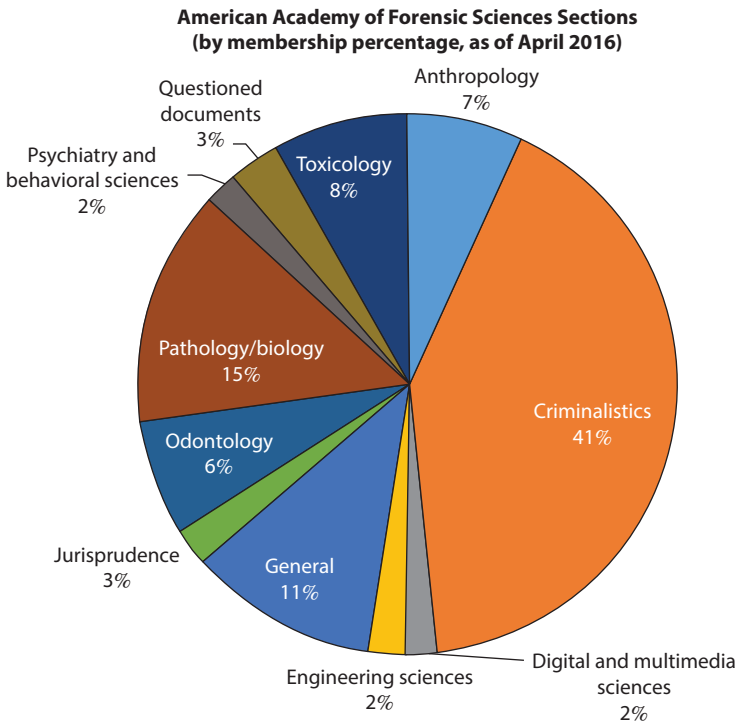

Figure 1.2 Membership in the sections of the American Academy of Forensic Sciences.

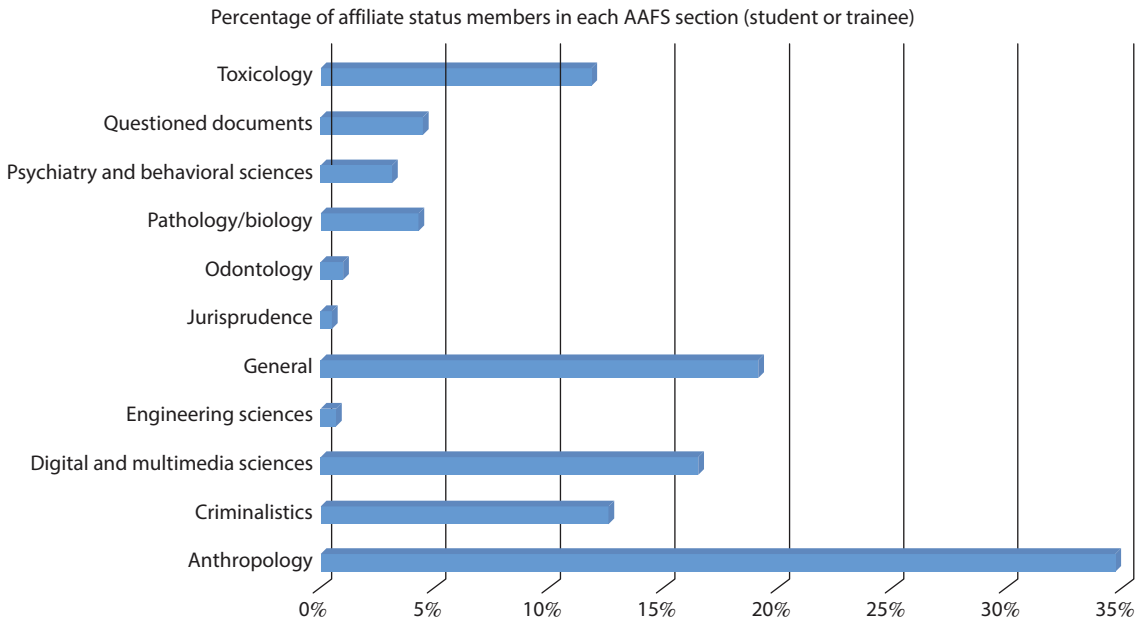

Figure 1.3 Percentage of student and trainee affiliate status members in each of the AAFS sections.

throughout the United States: Mountain, Swamp, and Beach Forensic Anthropologists (MS&B—Southeast United States); Mountain, Desert, and Coastal Forensic Anthropologists (MD&C—Southwest United States); Northeast Forensic Anthropology Association (NEFAA—Northeast United States); and Midwest Bioarchaeology and Forensic Anthropology Association (BARFAA—Midwest United States). The annual meetings of these organizations, though often a slightly less formal affair than the AAFS annual meetings, allow for the presentation of anthropological research and symposium discussions that facilitate the dissemination of research and scholarship in burgeoning areas of physical and forensic anthropology.

FORENSIC ANTHROPOLOGY IN THE PUBLIC EYE

The rising popularity of the forensic sciences as a result of popular crime novels and television (TV) dramas such as *CSI* and *Bones* has led to a misconception about the true nature of forensic anthropology. Forensic cases are not solved in a day, and, unfortunately, many cases go unsolved for years or even decades. Furthermore, although DNA is an excellent way to identify unknown persons, it is expensive and time-consuming, often taking six months or more to get results. Whenever possible, a forensic anthropologist seeks dental records or other radiographs to make a positive identification, because these methods are quick and inexpensive.* This also helps alleviate DNA laboratories of excessive backlogs, so that they can process other pertinent crime scene material. Nonetheless, there are some informative nonfiction texts and TV shows that give an accurate depiction of forensic anthropology. For a list of some of these resources, please see the Additional Information section of this chapter.

WHAT WE ARE "NOT": DEBUNKING HOLLYWOOD MYTHS

Some popular TV dramas give inaccurate depictions of the forensic sciences. In most crime scenes, multidisciplinary collaborations between various branches of the forensic sciences are necessary to solve a crime. For example, criminalists process scene evidence such as fingerprints and blood spatter, toxicologists process evidence from bodily fluids, pathologists conduct a forensic autopsy on the body, and anthropologists assist with skeletal trauma analysis. Each of these tasks is accomplished by trained professionals within each discipline and not by a single person with training in all areas of the forensic sciences. In other words, the forensic sciences are splintered into a number of highly specialized fields. This ensures that all aspects of a crime scene are analyzed by qualified experts and then assembled to give the most complete picture possible. Certainly, fictional TV dramas use their artistic license in order to present a case in a one-hour time slot, using a limited number of actors. Nonetheless, a number of nonfiction programs give more accurate depictions of how forensic scientists work together to solve crimes (e.g., *Forensic Files*, *The New Detectives*, and *FBI Files*).

Another misconception about forensic anthropology involves the educational requirements to practice forensic anthropology. There is no formal degree in "forensic anthropology" in the United States; instead, forensic anthropologists pursue a degree in anthropology, with a concentration in physical or biological anthropology and further specialization in forensic anthropology. Forensic anthropologists are proficient in skeletal biology, anatomy, and modern human variation. In addition, many forensic anthropologists are knowledgeable in bone injury biomechanics, pathology, and taphonomy, as well as statistics and archaeological recovery methods. Anthropologists emphasize a **four-field approach** and receive training in each subfield of anthropology. As a result of this multifaceted educational training, forensic anthropologists bring a unique perspective to understanding human variation in that they consider the biological and sociocultural determinants of human skeletal biology. For example, characteristic skeletal features indicate whether a skeleton is male or female, but other skeletal markers can reveal aspects of an individual's identity, such as socioeconomic status, health history, and occupation. These clues give law enforcement a more complete picture of an unidentified person and assist greatly in the search for identity.

Unfortunately, with the increasing number of TV dramas and movie plots based on the forensic sciences, the line between fiction and reality has become effectively blurred. This has resulted in general public being increasingly

* Methods of positive identification are discussed in Chapter 16.

aware of the forensic sciences but not necessarily well versed on what can actually be achieved through each type of analysis. Consequently, potential jurors and members of the public may have expectations of forensic analyses that are unattainable and unwarranted. Moreover, the fictionalization of forensic practitioners' ability to be able to analyze and report on multiple aspects of a crime (such as the fingerprint analysis, ballistics, and autopsy report) can cause confusion when the data are presented to families or in the courtroom. In sum, while these shows are intended to intrigue the audience and present a plausible (however unlikely) crime scene, it would behoove the curious viewer to perform a critical analysis of what is fact, what is fiction, and what is a stretch with regard to the forensic sciences, or for that matter, any discipline that is represented in a TV drama or movie.

EDUCATIONAL AND EMPLOYMENT OPPORTUNITIES

In order to practice forensic anthropology, a master's or doctorate in physical or biological anthropology with additional training and experience in forensic anthropology methods is recommended. Students interested in this career path should consult the website of **American Board of Forensic Anthropology** (http://www.theabfa.org/) for additional information. The website of **Scientific Working Group for Forensic Anthropology** also offers a list of journal articles and publications concerning forensic anthropology practice and theory that was created by the Society of Forensic Anthropologists (SOFA); this resource can be found at http://www.swganth.org/news–resources.html. Although universities do not offer a formal "forensic anthropology" degree, a number of anthropology programs offer a focus in forensic anthropology. In addition to an anthropology curriculum, students may benefit from coursework in genetics and biomechanics. According to a 2009 survey of the AAFS's Anthropology* section members, nearly half of practicing forensic anthropologists (44.5%) are employed at an academic institution and do forensic casework on a consulting basis (Agostini and Gomez 2009). Within academia, forensic anthropologists are typically employed as physical anthropologists, anatomists, osteologists, and/or skeletal biologists. Other common employment agencies are medical examiner and coroner's offices (19.1%), federal agencies (12.7%), private consulting firms (i.e., self-employed consultants) (5.5%), museums (2.7%), and nonprofit organizations (2.7%). The remaining 12.7% of the members surveyed were retired or students. The survey by (Agostini and Gomez 2009) also revealed that the majority of forensic anthropologists report an annual income of $50,000–$100,000.

It is highly recommended that students interested in pursuing a career in forensic anthropology or any of the forensic sciences, whether applied or research-oriented, read the recent National Academy of Sciences (NAS) report entitled "Strengthening Forensic Science in the United States: A Path Forward" (2009), as this report will likely affect training, policy, and practice in the forensic sciences for years to come (see section on the NAS report later in this chapter).

BRIEF HISTORY OF FORENSIC ANTHROPOLOGY

Forensic anthropology is a relatively young subfield within biological anthropology. The development of forensic anthropology is divided into three periods that are divided by events that arguably changed the path of the field: the formative period (early 1800s–1938), the consolidation period (1939–1971), and the modern period (1972–present).

FORMATIVE PERIOD (EARLY 1800s–1938)

The origin of forensic anthropology is said to lie within the twisted tale of the Parkman murder in 1849. Dr. George Parkman was a physician who donated the land to Harvard, on which the medical school was built. Dr. Parkman was murdered by Harvard's Chemistry Professor John Webster in the medical building. Dr. Webster had purportedly borrowed money from Parkman and killed him to avoid paying back the debt. The local newspapers reported the salacious details of the case, suggesting that Webster mutilated Dr. Parkman's body, put parts of it in the anatomy laboratory and in a septic tank, and burned the head in the furnace. Harvard's anatomy professors Oliver Wendell Holmes and Jeffries Wyman were asked to aid in the investigation of Dr. Parkman's death. Wyman and Holmes were able to put the pieces back together and to suggest that the skeleton belonged to a person whose description was consistent with George Parkman. Webster was eventually convicted of the murder when dentures found in the furnace were shown to match a mold of Parkman's teeth that his dentist had used to make the dentures.

* When the study was published, the Anthropology Section of the AAFS was known as the Physical Anthropology section.

The first avid practitioner of the applied study of forensic anthropology was Thomas Dwight (1843–1911). Dwight was considered the father of forensic anthropology in the United States (Stewart 1979), because he was one of the first Americans to discuss how to identify remains using information obtained from the human skeleton. In 1878, Dwight submitted an essay to the Massachusetts Medical Society entitled, "The Identification of the Human Skeleton. A Medico-Legal Study" (Dwight 1878). Dwight succeeded Oliver Wendell Holmes in the Parkman Professorship of Anatomy position at Harvard. As a trained anatomist, Dwight recognized the need for research on methods to determine age, sex, and stature from the skeleton.

George Dorsey (1839–1931) learned from Dwight's research at Harvard. Dorsey received his doctorate from Harvard in anthropology in 1894 and became curator of the Field Museum of Natural History in Chicago. It was at this museum that Dorsey tested his theory that the articular surfaces of long bones could be used as an indicator of sex; he concluded that humeral head diameter was a better diagnostic tool for sex estimation than the femoral head diameter, a point later confirmed by (Dwight 1905). Dorsey was asked to consult on the case of the Leutgert murder, in which the Chicago sausage maker Adolph Leutgert was accused of killing his wife by placing her in a vat of potash, which effectively dissolved most of the body, except four small pieces of bone and the ring that she normally wore. Dorsey was able to say that the fragments came from a human rib, hand, and foot. Leutgert was later convicted, but Dorsey faced harsh criticism from other anatomists of the time for his testimony and conclusions in this case. This criticism is said to have caused Dorsey to abandon further pursuit of forensics, although (Stewart 1979) believes that Dorsey's assertions about the skeletal remains were correct. At the beginning of World War I, Dorsey removed himself from academe and joined the U.S. Navy.

Harris H. Wilder (1864–1928) was a contemporary of George Dorsey, whose most notable contribution to forensic anthropology dealt with personal identification. Wilder was a European-trained zoologist, who became interested in physical anthropology while teaching at Smith College late in his career. Wilder's physical anthropological focus was on dermatoglyphics (fingerprint analysis) and facial reconstruction by using skulls. Wilder and Bert Wentworth published a book in 1918 entitled *Personal Identification: Methods for the Identification of Individuals, Living or Dead* (Wilder and Wentworth 1918). However, (Stewart 1979) points out that this text has no mention of Dwight's previous research on identification, suggesting that at that point, Dwight's research may not have found its way to other scholars within and outside of the field.

Another American anatomist whose work had implications for forensic anthropology was Paul Stevenson (1890–1971). Stevenson spent a good deal of his career studying in China. He contributed two important publications dealing with age determination based on epiphyseal union (Stevenson 1924) and stature estimation by using long bones in a Chinese population (Stevenson 1929). However, it is unclear if Stevenson was aware of the impact of these contributions on forensic anthropology.

According to (W.M. Krogman 1976), Aleš Hrdlička (1869–1943) was the "founding father of American Physical Anthropology." Hrdlička was born in Bohemia in 1869 and came to New York in 1882, at the age of 13 years, where he worked as a cigar maker and went to school at night. After a bout with typhoid at the age of 19 years, Hrdlička began to study medicine at the Eclectic Medical College of New York City, where he graduated in 1892. He went on to study at the New York Homeopathic College for two years, and he took an internship at the New York Homeopathic Hospital for the Insane, where he published on the somatometry of adult patients with various types of insanity. In 1896, Hrdlička received his training in physical anthropology in Paris under Manouvrier, where he learned how to measure the skeleton quantitatively. In 1897, Hrdlička began to study human skeletons at the College of Physicians and Surgeons in New York City. In 1899, Hrdlička embarked on a series of trips to study the American Indians of the southwestern United States and northern Mexico for the American Museum of Natural History. In 1903, he became a part of the Division of Physical Anthropology at the U.S. National Museum in Washington, DC (now known as the Smithsonian), and became curator in 1910. Hrdlička was a giant in the field of physical anthropology. He founded the *American Journal of Physical Anthropology* (AJPA) in 1918 and the American Association of Physical Anthropologists (AAPA) in 1928, two contributions for which he is often remembered most. Hrdlička was the editor of AJPA from 1918 until 1942.

Another physical anthropologist whose work on human variation shaped the theoretical foundations of biological and forensic anthropology was Earnest A. Hooton (1887–1954). Hooton received his doctorate in liberal arts at the University of Wisconsin in 1911. In 1912, he received his diploma in anthropology from Oxford University, and the following year, he joined the anthropology department at Harvard. Hooton's research focused on human variation

with respect to human origins and adaptation. Under his direction, Harvard became an important center for training physical anthropologists, and his students became prominent practitioners in the field.

T. Wingate Todd (1885–1938) was also a prolific researcher in anatomy and physical anthropology during the latter part of the formative period. Todd's work influences forensic anthropology even today. Todd was interested in skeletal aging methods and growth and development. He was trained in England as an anatomist and moved to the United States in 1912 to take Dr. Carl Hamann's vacated teaching position at Western Reserve University (Dr. Hamann had become Dean of the medical school). A recent change in Ohio state law permitted professors to retain cadavers that the medical students dissected, and Drs. Todd and Hamann had the foresight to begin an anatomical collection that would soon surpass any other in existence in terms of number of specimens and level of documentation (i.e., age, sex, ancestry, stature, weight, cause of death, and case history). In addition, Todd took anthropometric measurements and photographs of most of the cadavers. By the time of his death in 1938, Todd had managed to build a skeletal research collection containing over 3000 documented individuals. He used the specimens in the collection for numerous anatomical and anthropological studies, and the Hamann–Todd Collection continues to be an important resource for skeletal biology research today.

Todd's contributions to anthropology are numerous and include documentation of differences in limb proportions between American Blacks and Whites; establishment of the usefulness of endo- and ectocranial suture closure for age estimation; development of an age estimation method based on the pubic symphysis; establishment of principles of epiphyseal union; and extensive documentation of human postcranial and craniofacial growth, development, and maturation. During his career, Todd authored nearly 200 publications in anatomy and physical anthropology, many of which have significant implications for forensic anthropology. In addition, two of his students, Wilton Krogman and Montague Cobb, went on to make important contributions to physical anthropology. We discuss Krogman in the following sections, but his legacy includes the landmark bulletin *Guide to the Identification of Human Skeletal Material* (Krogman 1939), as well as the close mentoring of William M. Bass. Cobb was the first African-American to earn a Ph.D. in physical anthropology and left behind a legacy reminiscent of his mentor. The W. Montague Cobb Human Skeletal Collection at Howard University contains approximately 700 skeletons and serves many of the same research purposes as the Hamann–Todd Collection in Cleveland.

Robert J. Terry (1871–1966) was also an anatomist who had the foresight to curate a research collection of skeletal remains. Dr. Terry was an anatomy professor and department head at Washington University Medical School in St. Louis, Missouri. In the same manner as Todd, Terry began collecting skeletal remains from medical school cadavers during the 1920s. Terry Collection cadavers have associated morgue records with the individual's name, sex, age, ancestry, date, and cause of death. Terry also took photographs and anthropometric measurements of most of the cadavers, as well as skin and hair samples; however, only the hair samples remain today. In addition, plaster death masks were made of 836 of the cadavers. Terry retired in 1941, and Dr. Mildred Trotter (1899–1991) assumed his anatomy teaching position and continued to build the collection, until she retired 26 years later. Today, the nearly 2000 skeletons of the Terry Anatomical Collection are housed in the Smithsonian Institution in Washington, DC.

CONSOLIDATION PERIOD (1939–1971)

It has long been posited that the end of the initial period of forensic anthropology (here termed the formative period) and the beginning of the consolidation period were marked by the publishing of Wilton Marion Krogman's *Guide to the Identification of Human Skeletal Material* in the Federal Bureau of Investigation's (FBI's) Law Enforcement Bulletin in 1939. This publication summarized all that had been discovered about the identification of skeletal remains until that time. The significance of this publication is that, for the first time, an article pertaining to forensic identification had been written by an anthropologist and was included in a journal focused on forensics, as opposed to anatomy or the broader discipline of physical anthropology.

Wilton Marion Krogman's prestigious career began in the spring of 1925, where he first lectured in physical anthropology at the University of Chicago. Krogman insisted that it was this experience, coupled with a term paper assignment on the anthropology of teeth given by his professor Dr. Fay-Cooper Cole, that focused his entire professional career:

> That did it! Teeth lead to jaws, jaws to face, face to head, head to body: in other words a coordinated whole. But more than that, it led from statics to the dynamics of age progress. Thus launched my life-work in growth and development, comparative and human anatomy (Krogman 1976).

The term paper introduced Krogman to paleontology, orthodontia, and the work of T. Wingate Todd. Krogman submitted a reworked version of this term paper to the First District Dental Society of New York City's Morris L. Chaim Prize, where T. Wingate Todd was one of the judges. Krogman won the prize, and Todd saw promise in the paper and in Krogman. On a stopover in Chicago, Todd sought out Krogman, who indicated that he would like to do graduate work with Todd. In 1928, Krogman was awarded the Cleveland Foundation Fellowship in anatomy, thanks to Todd's arrangements. Krogman wrote his dissertation under Todd's direction. In 1929, Krogman instructed at the University of Chicago, and in 1930, he took a fellowship at the Hunterian Museum at the Royal College of Surgeons in London. In 1931, Krogman became an associate professor of anatomy and physical anthropology at Western Reserve University. Krogman's appointment at his mentor's department put him in contact with the foremost physical anthropologists of the time. As Krogman (1976) explained, "Todd's department was a magnet for the physical anthropologists of the 1930s."

Krogman expanded upon his article in the FBI bulletin and produced the first textbook in Forensic Anthropology, entitled *The Human Skeleton in Forensic Medicine* (Krogman 1962). The textbook focused on the practical application of human osteology to forensics. Krogman's text became the primary reference for physical anthropologists practicing forensic anthropology, much like his 1939 article had been at the time of its publication. The theme of the book was human variation. Krogman emphasized that the methods identified within the text did not present hard and fast rules; instead, they were meant to be guidelines for assessing remains, with the understanding that humans represented a wide range of morphological variability. Krogman's dedication to research helped push forensic anthropology forward. He imparted a great deal of his wisdom on his graduate students. One of these students, William M. Bass, undoubtedly had the greatest impact on the modern era of forensic anthropology. We discuss the influence and legacy of Bass in greater detail in the following sections.

MODERN PERIOD (1972–PRESENT)

The founding of the Physical Anthropology Section of the American Academy of Forensic Sciences (AAFS) in 1972 is often referred to as the beginning of the modern period in forensic anthropology. At this time, the term "forensic anthropologist" began to be used on a regular basis to refer to practitioners in the field. The section founding was thanks in a large part to Ellis R. Kerley (1924–1998). Kerley had joined AAFS in 1968 as part of the pathology/biology section. Through his encouragement, other physical anthropologists also joined the AAFS. By 1972, with 14 anthropologists as members of the academy, Kerley and colleagues had exceeded the minimum number of members required to establish a new section. Thus, the Physical Anthropology Section of AAFS was born, and this formal organization of the field provided an appropriate stage for the presentation of new ideas. In addition, the academy's flagship journal, *Journal of Forensic Sciences*, was well suited for research concerning new methods in the identification of skeletal remains.

Ellis Kerley was also instrumental in establishing the American Board of Forensic Anthropologists (ABFA) in 1977. This board certifies forensic anthropologists in a similar manner to the certification of physicians by their various boards, using a rigorous application and examination process to ensure that each diplomate of the board is qualified and competent to undertake forensic anthropology casework. In 1987, Kerley became the forensic anthropology consultant and scientific director of the United States Army Central Identification Laboratory in Hawaii, where he oversaw the identification of repatriated war remains. He also served as president of the AAFS from 1990 to 1991. In 2000, the Ellis R. Kerley Forensic Sciences Foundation was established in his memory. The foundation is dedicated to furthering the development of forensic anthropology by assisting students in the field of anthropology and continuing the research in forensic identification of the skeleton (http://www.kerleyfoundation.org/). Each year, the foundation issues at least one scholarship to a graduate student who is enrolled in a physical or forensic anthropology program and who is involved with the AAFS or the ABFA. In addition, the foundation hosts a reception at the AAFS annual meetings, where it presents an award to recognize innovative efforts to continue research in human identification.

As mentioned earlier, William M. Bass was Kerley's student who went on to have the most significant impact on forensic anthropology. In the 1960s, Bass established a graduate program in physical anthropology at the University of Kansas and recruited Ellis Kerley and Thomas McKern to be a part of the department. This graduate program produced some of the foremost physical/forensic anthropologists, including Douglas Ubelaker, Walter Birkby, Judy Suchey, Linda Klepinger, and Richard Jantz.

In 1971, Dr. Bass moved from Kansas to Tennessee, and in doing so, he began an anthropology program in the eastern United States that has produced more forensic anthropologists than any other program to date. By the time Dr. Bass retired in 1994, he had trained over 20 practitioners, including Bill Rodriguez, Anthony Falsetti, Hugh Berryman, Steve Symes, Murray Marks, Doug Owsley, Stephen Ousley, Emily Craig, and Walter Birkby (Rhine 1998). In fact, nearly 40% of practicing forensic anthropologists can trace some element of their academic lineage through Bass (Marks 1995). Many of this new generation of graduates went on to change the face of forensic anthropology by taking it from a strictly academic discipline, in which practitioners acted as consultants, to an applied field that became incorporated into the medical examiner setting. Hugh Berryman was the first forensic anthropologist to be employed full-time outside of academia. In 1980, he was hired as morgue director of the Shelby County Medical Examiner and University of Tennessee Hospital Morgue in Memphis. Over three decades, that single position grew to over 20 full-time positions nationwide and continues to grow today (Berryman 2009) (Figure 1.4). While the majority of these positions are filled by PhDs, a little more than one-third of these employees have master's degrees only. Several factors that contributed to the increase in full-time medical examiner/coroner positions over the last 30 years include a favorable economy, the realization that forensic anthropologists' skills include more than just skeletal analysis, and a number of mass disasters that required anthropological expertise (i.e., the Oklahoma City bombing, the 9/11 attacks on the Pentagon and World Trade Center, and the Tri-State Crematorium situation in Noble, Georgia) (Berryman 2009).

Although a number of forensic anthropologists attained full-time positions in coroner's and medical examiner's offices, many maintained academic appointments and continued to train new practitioners. For example, one of Bass' students, Richard Jantz, has mentored a number of forensic anthropologists, including Stephen Ousley, with whom he created the Fordisc program. Fordisc stands for "forensic discrimination" and is currently in its third version. The Fordisc program has made it possible for forensic anthropologists to determine the sex, ancestry, and stature of unknown remains from cranial and/or postcranial measurements with the click of a button. We discuss this program in detail in Chapter 14.

ANTHROPOLOGY RESEARCH FACILITIES

Perhaps, Bass' most notorious accomplishment is the establishment of the first outdoor research facility devoted to the study of human decomposition. The Anthropology Research Facility (ARF) was founded in 1980 in response to Dr. Bass' realization that the forensic community needed information about the postmortem interval that was based on controlled scientific research on human cadavers. The need for this type of research became evident to Dr. Bass in 1977, when he was asked to inspect decomposing remains that were discovered in a disturbed burial (Bass 1984; Bass and Jefferson 2003). Based on his field observations of the state of decomposition, Dr. Bass estimated that the remains had been in the grave for approximately 1 year. However, after exhuming the remains and bringing them back to his laboratory for closer inspection, he noticed aspects of the clothing that indicated that they belonged to a Civil War colonel. To his dismay, Bass had underestimated the time since death (TSD) by 113 years! To Bass' credit, Colonel Shy's remains had been uncharacteristically well preserved for that era owing to embalming and a high-quality iron casket. Nonetheless, a survey of the literature exposed a dearth of research on decomposition changes, so Dr. Bass resolved to remedy the situation. Fortunately, he had the full support of an open-minded UT administration and an available plot of land on which to establish the unconventional research facility.

The first ARF consisted of a 16-square-foot concrete slab enclosed on all sides and above by a chain-link fence. The first donation arrived in 1981, and three more followed that year. Many of the early donations were unclaimed bodies from the State of Tennessee Medical Examiner, but as the donation program grew in popularity with increasing publicity, the donor population also grew in diversity. In 2009, the ARF received its 1000th donation and has received nearly 1800 donations since inception. Over 3500 individuals have filed paperwork to donate their bodies to the ARF for scientific research. The pre-registered donor paperwork requests information about donors, such as birth date, sex, ancestry, height, weight, number of children, medical and dental history, occupation, habitual activities, handedness, shoe size, education level, childhood socioeconomic status, and photographs. In addition, hair and blood samples are taken as donations arrive, and fingerprints and laser scans are soon to be added to that protocol. As a result of the increase in body donations, the ARF has expanded its initial 16-foot plot to a 1.3-acre tract of land. Today, the ARF is part of a larger establishment within the UT Anthropology Department—the Forensic Anthropology Center (FAC). The FAC oversees all activities at the ARF, including donor relations, law

1980s

- 1980 Hugh Berryman, PhD, D-ABFA — Shelby County ME & UT Chattanooga, Morgue Director
- 1981 Donna Fontana, MS — New Jersey State Police, Forensic Anthropologist
- 1982 David Wolf, PhD — Kentucky ME (first State Forensic Anthropologist)
- 1983 Craig Lahren, MA — Shelby County ME, Assistant Morgue Director
- 1984 William Rodriguez, PhD, D-ABFA — Caddo & Bossier Parish, LA, Deputy Chief Coroner
- 1986 William Rodriguez, PhD, D-ABFA — Onondaga, NY ME , Forensic Anthropologist & Chief of Operations
- 1986 Craig Lahren, MA — Hamilton County, TN ME, Coordinator of Forensic Services
- 1986 Robert Mann, PhD, D-AFBA — Shelby County ME, Assistant Morgue Director
- 1987 Steve Symes, PhD, D-AFBA — Shelby County ME, Assistant Morgue Director
- 1988 William Haglund, PhD — King County, WA ME , Chief Medical Investigator
- 1989 William Rodriguez, PhD, D-ABFA — Office of the Armed Forces Medical Examiner, Chief Forensic Anthropologist and Deputy Chief ME

1990s

- 1994 Emily Craig, PhD, D-AFBA — Kentucky State Forensic Anthropologist
- 1994 Gwen Haugen, MA — St. Louis County MEO, Forensic Investigator/Forensic Anthropologist (1994-97; 2007-present)
- 1990s Deborah Gray — Riverside County, CA Sheriff's Department, Forensic Anthropologist/Archaeologist/CoronerSergeant
- 1995 Charles Cecil, PhD — San Francisco OCME, Medical Inverstigator II/Forensic Anthropologist
- 1995 Nici Vance, PhD — Oregon State Police Forensic Laboratory, Forensic Anthropologist; OSME, State Forensic Anthropologist (since 2006)
- 1996 Dana Austin, PhD, D-AFBA — Tarrant County, TX ME, Forensic Anthropologist
- 1996 Ann Marie Mires , PhD — Massachusetts State OCME, Forensic Anthropologist
- 1997 Craig Lahren, MA — North Dakota State Forensic Examiner's Office, Administrator and Forensic Anthropologist
- 1997 Tom Bodkin, MA — Hamilton County, TN ME, Coordinator of Forensic Services
- 1997 Laura Fulginiti, PhD, D-ABFA — Maricopa County, AZ ME, Forensic Anthropologist
- 1997 Fran Wheatley, MA — Metropolitan Nashville/Davidson County ME, Death Investigator/Forensic Anthropologist
- 1998 Clyde Gibbs, BS, AS — North Carolina OCME, Chapel Hill, Medical Examiner Specialist
- 1999 Amy Mundorff, PhD — New York City OCME, Forensic Anthropologist

2000-2010

- 2001 Jennifer Love, PhD, D-ABFA — Regional Forensic Center, Memphis
- 2001 Alexis Gray, PhD — San Bernadino County Sheriff's Department, Coroner's Division, Forensic Anthropologist
- 2002 Robert Karinen, MA — Ada County Coroner's Office, Boise, ID, Forensic Supervisor
- 2002 Rick Snow, PhD — Georgia Bureau of Investigation, Forensic Anthropologist
- 2002 Gina Hart, MA — Newark Regional ME, Forensic Anthropologist/Death Investigator
- 2002 Brian Spatola, MA — Washington D.C. OCME, Mortuary Supervisor and Anthropologist
- 2004 Katherine Taylor , PhD — King County, WA ME, Forensic Anthropologist
- 2004 Brad Adams, PhD, D-ABFA — New York City OCME, Director of Forensic Anthropology
- 2005 Jeanette Fridie, MA — New York City OCME, Forensic Anthropologist
- 2005 Pamela Steger, MS — Travis County Medical Examiner's Office, Medicolegal Death Investigator
- 2005 Daniel Jackson, MA — Travis County Medical Examiner's Office, Forensic Anthropologist/Death Investigator
- 2006 Christian Crowder, PhD, D-ABFA — New York City OCME, Deputy Director of Forensic Anthropology
- 2006 Benjamin Figura, MA — New York City OCME, Forensic Anthropologist/Director of Identification
- 2006 Fran Wheatley, MA — Shelby County ME, Administrator and Anthropologist
- 2006 Brian Spatola, MA — Central Virginia OCME, Morgue Supervisor and Anthropologist
- 2006 Sharon Derrick, PhD, D-ABFA — Harris County, TX ME, Agency Coordinator and Anthropologist
- 2006 Jennifer Love, PhD, D-ABFA — Harris County, TX ME, Forensic Anthropology Director
- 2006 Jason Wiersema, PhD, D-ABFA — Harris County, TX ME, Mass Disaster Coordinator
- 2006 Bruce Anderson, PhD, D-ABFA — Tuscon, AZ Forensic Science Center, Forensic Anthropologist
- 2006 Laura Regan, PhD, Lt. Col. — Armed Forces Medical Examiner System, Director of Operations and Deputy Chief Forensic Anthropologist
- 2006 Lisa Leone, MA — Greenville North Carolina Regional ME, Pathologist Assistant/Forensic Anthropologist/Death Investigator
- 2007 Chris Rainwater, MS — New York City OCME, Forensic Anthropologist/Director of Photography
- 2007 Kristen Hartnett, PhD — New York City OCME, Forensic Anthropologist/Assistant Director of Forensic Anthropology
- 2007 Dominique Semeraro, MS — Rhode Island OSME, Senior Medical Examiner Agent, RI State Forensic Anthropologist
- 2008 Murray Marks, PhD, D-ABFA — UT Regional Forensic Center, Forensic Anthropologist
- 2008 Lauren Zephro, PhD — Santa Cruz County Sheriff's Department, Latent Print Examiner, Forensic Anthropologist
- 2008 Hilary Sheaves, MA — North Carolina OCME, Chapel Hill, Autopsy Technician
- 2008 Olivia Alley, MA — Travis County Medical Examiner's Office, Forensic Anthropologist/Death Investigator
- 2009 Debra Prince Zinni, PhD, D-ABFA — Commonwealth of Massachusetts OCME, State Forensic Anthropologis

Figure 1.4 Forensic anthropologists working in the medical examiner's setting between 1980 and 2010.

enforcement training and education, public outreach, and human identification services. The FAC offers hands-on training in forensic taphonomy, human identification, and human remains recovery to a variety of professionals, including the FBI's Emergency Response Teams, the National Forensic Academy, and participants in the FAC's regular short courses.

Since its inception 30 years ago, the ARF has fulfilled Bass' initial goal. Anthropologists now understand the various stages of human decomposition and the variables affecting the rate at which the decomposition process occurs.* This understanding has enabled forensic anthropologists to give more accurate TSD estimates. While much of the early research focused on general decomposition changes at the macroscopic level, some of the more recent projects have begun to explore decomposition at the microscopic level. For instance, Dr. Arpad Vass isolated chemical signatures produced by volatile fatty acids during the decomposition process; he used this information to predict TSD with a high degree of accuracy (Vass et al. 1992, 2002). Vass also developed a Decompositional Odor Analysis (DOA) Database for surface and buried remains; this database can be used for training cadaver dogs as well as in the development of portable analytical instruments to locate human remains in shallow burial sites (Vass et al. 2004, 2008). Other researchers have studied DNA recovery from various parts of decomposing remains (i.e., bone, hair, and fingernails) in different environmental conditions (i.e., open ground, shaded ground, buried, and aqueous) (Opel et al. 2006). In addition, projects have explored the effects of factors such as clothing and covers, indoor versus outdoor environments, insect and animal activity, and aqueous environments. One could say that for every question answered by research at the ARF, several more have surfaced. Many of these questions are related to the effects of different geographic locations and climates on the decomposition process (i.e., desert versus woodland). As a result, outdoor research facilities have been established at other geographic locations, and their research is helping forensic anthropologists obtain a more complete picture of the human decomposition process in various environments.

The first of the new generation of decomposition research facilities was opened in 2006 at Western Carolina University (WCU) in Cullowhee, North Carolina, as part of the Western Carolina Human Identification Laboratory. The WCU facility is smaller than the ARF, but it allows for the study of decomposition in a mountain environment. In 2008, Dr. Jerry Melbye at Texas State University in San Marcos obtained funding and land for the Forensic Anthropology Research Facility (FARF). The FARF is under the direction of Dr. Daniel Wescott, a former student of Dr. Richard Jantz, and employs other faculty, including Dr. Michelle Hamilton, a former student of Dr. Bass; Drs. Kate Spradley and Ashley McKeown, former students of Dr. Richard Jantz; and Dr. Nicholas Herrmann, a former student of Dr. Lyle Konigsberg. The facility sits on a 26-acre section of the 4200-acre Freeman Ranch in Texas Hill Country and has an adjoining laboratory to help with facility operations and processing. The ranch has already proven a valuable location to study vulture scavenging—a previously unaddressed topic in the literature (Reeves 2009; Spradley et al. 2012). Much like the ARF, the FARF serves as a resource for forensic anthropology students and law enforcement agencies. Furthermore, the FARF is contributing much-needed data about decomposition in warm, arid climates.

A nearby facility has also opened recently at Sam Houston State University. The Southeast Texas Applied Forensic Science Facility (STAFS) is an outdoor research and training facility located on a 247-acre parcel of land near the Sam Houston National Forest. The research facility proper is a 1-acre plot surrounded by security fencing and an adjoining 8 acres of minimum security reserved for training activities. The STAFS has a variety of simulated environmental conditions, including a fluvial environment, and webcams are located to monitor the facility from computers. In addition, the STAFS has a morgue building with coolers, freezers, digital radiograph, and microscope capabilities (http://www.cjcenter.org/stafs/). Human decomposition outdoor research facilities have been proposed in Illinois, Nevada, and even India, and decomposition research on pigs has begun in Montana, as well.

DOCUMENTED DONATED SKELETAL COLLECTIONS

Research facilities have made it possible to assemble modern skeletal collections, as well. While the Hamann-Todd, Terry, and Montague Cobb Collections are invaluable contributions to physical anthropology in the United States, the demographic profile of these collections is primarily of European American and African American individuals

* Chapter 15 provides a detailed discussion of the decomposition process and the variables affecting decomposition rates.

from the early to mid-twentieth century. The human skeletal form is in a constant state of flux owing to the changing demographics of the American population and changes in diet and healthcare (to name a few factors). In order for forensic anthropologists to develop methods and standards to use in modern forensic casework, we need modern skeletal samples, and the selfless individuals who donate their remains to forensic anthropology research facilities have made this possible.

For example, after bodies are used for research at the University of Tennessee's ARF, the skeletal remains are collected carefully, cleaned, and curated in the William M. Bass Donated Skeletal Collection, where they are used for teaching and research purposes. Since record keeping began in 1994, researchers ranging from universities to biomedical research companies to law enforcement agencies such as the FBI have visited the Bass Collection (Shirley et al. 2011). The Bass Collection is the largest collection of modern human skeletal remains in the country, and it has given researchers an unparalleled opportunity to gain an understanding of modern human skeletal variation. Researchers have documented differences between twentieth and twenty-first century Americans and their nineteenth century predecessors, including increases in stature and changes in cranial form (Jantz 2001, 1999, 2000; Meadows and Jantz 1995; Ousley and Jantz 1997). These studies have demonstrated the importance of using modern skeletal samples to establish criteria for estimating age, sex, ancestry, and stature from skeletal remains. The Bass Collection is predominantly of American White males, but the demographic profile is increasing in diversity each year. Presently, the collection contains Americans of European, African, Hispanic, Native American, and Japanese ancestries. It comprises ~70% males and 30% females, with ages ranging from fetal to 101 years. To date, 800 of the skeletons have been scanned using computed tomography (CT) scanning, and these scans have been used in a variety of research projects in anthropology as well as biomedical engineering, including the development of a female knee implant design by Dr. Mohamed Mahfouz and colleagues in the UT Department of Mechanical, Aerospace, and Biomedical Engineering (Shirley et al. 2011). The Forensic Anthropology Research Facility (FARF) at Texas State University follows the ARF model and accessions donor skeletal remains into the Texas State Donated Skeletal Collection for scientific research and education purposes.

Another important collection of modern human skeletal remains is the Maxwell Museum Documented Skeletal Collection at the University of New Mexico. This collection was established in 1984, and it contains over 200 individuals with documented age, sex, ancestry, and cause of death. In addition, health and occupational data are available for donations dating 1995 and later. The Maxwell Donated Collection is housed in the Osteology Repository directly above the Maxwell Museum Laboratory of Human Osteology and serves as a resource for training, education, and research. During his tenure at University of New Mexico (UNM), Dr. Stan Rhine often consulted the collection to answer questions about forensic cases that he consulted on for the New Mexico Office of the Medical Investigator (Rhine 1998). In addition, the collection has been used for instructional seminars in forensic anthropology and for research concerning bone response to repetitive motions, skeletal manifestations of disease, skeletal trauma, identification of handedness, and modern human variation.

Finally, a number of forensic anthropology laboratories curate remains from unsolved cases, as well as remains donated by the families of victims. The Louisiana State University FACES Laboratory is one such laboratory. Although these collections do not have the extensive documentation that is associated with the donated collections at the University of Tennessee and the University of New Mexico, they serve as valuable research resources.

ETHICS IN PRACTICE AND RESEARCH

Unfortunately, when judged by today's ethical standards, physical anthropology has a tainted past when it comes to handling skeletal remains. Some of the existing skeletal collections (particularly collections of Native American remains) were obtained in an opportunistic manner that would be considered unethical today. However, at the time that the collections were amassed, there were no laws or regulations governing the collection and handling of human skeletal remains. Laws such as the **Native American Graves Protection and Repatriation Act** (NAGPRA, 1990) set a precedent for addressing ethical concerns that have spread beyond the handling of Native American skeletal material. Physical anthropologists have made great strides in correcting the misdoings of early practitioners, and in doing so, they have created an environment in which research and education are conducted with the utmost

respect and reverence. As researchers and curators of human skeletal material, physical anthropologists take their moral responsibility seriously. Indeed, a number of physical anthropologists have become involved in human rights organizations around the globe. Forensic anthropologist bring valuable skills to the table in dealing with human rights violations, including the ability to sort commingled remains in mass graves, establish a biological profile from unidentified skeletal remains, evaluate skeletal trauma, ascertain manner and/or cause of death, and handle the sociocultural factors affiliated with this type of work. Forensic anthropologists have done work in Bosnia, Kosovo, Rwanda, Argentina, Peru, Colombia, and Iraq, to name a few countries. This type of work and the organizations under which it is performed are discussed in Chapter 17.

BEST PRACTICE IN FORENSIC ANTHROPOLOGY: FROM SWGANTH TO OSAC

Germane to the topics covered in this chapter is a brief review of several important developments within the larger forensic science field. This includes the National Academy of Sciences (NAS) report entitled "Strengthening Forensic Science in the United States: A Path Forward" (2009) as well as the work of the Scientific Working Group for Forensic Anthropology (SWGANTH) and the Organization of Scientific Area Committees (OSAC).

The NAS report is a final grant report published by the U.S. Department of Justice and contains recommendations for improving research, practice, and training in the forensic sciences. (For more information on the NAS report, please go to https://www.ncjrs.gov/pdffiles1/nij/grants/228091.pdf.) The report proposed the creation of an independent federal entity, to be named the National Institute of Forensic Science, to serve as an administrator and advisory board to enforce best practice in the forensic sciences. Many predicted that the NAS report suggestions would restructure the way in which many forensic anthropologists operate, particularly with respect to mandated laboratory accreditation and individual certification. An initial response to this report was the independent creation of Scientific Working Groups (SWGs) by many of the forensic science disciplines. The working group for forensic anthropologists is the Scientific Working Group for Forensic Anthropology (SWGANTH).

Mirrored after similar scientific working groups in other disciplines, the SWGANTH was charged with identifying "best practices" in forensic anthropology. The SWGANTH was established by the Department of Defense Central Identification Laboratory (DoD CIL) and the Federal Bureau of Investigation (FBI) and consists of a 20-member board that comprises forensic anthropologists from various backgrounds and agencies. In an effort to remove the veil that often cloaks forensic anthropology methods and practice, the SWGANTH board established committees to review multiple aspects of forensic anthropology and to establish a "best practice model" for each of these areas. These committees drafted best practice suggestions in areas pertinent to the practice of forensic anthropology, including proficiency testing, ethics, qualifications, laboratory management, age estimation, sex assessment, stature estimation, commingled remains, and many other aspects of case analyses. (For a full listing of the guidelines established by the SWGANTH, go to www.swganth.org.) Despite the thorough nature of the guidelines, the SWGANTH does not have the ability to enforce these guidelines within the field or regulate forensic anthropology practitioners. Instead, the onus is on the practitioners to be certain that they are aware of these "best practices" and are striving to achieve these goals.

The NAS report's recommendation to create an independent federal entity that enforces best practice in the forensic sciences became a reality in 2013. The Department of Justice (DOJ) partnered with the National Institute of Standards and Technology (NIST) to create the **National Commission on Forensic Science**. The commission seeks to promote scientific validity, reduce fragmentation, and improve federal coordination of forensic science. The commission consists of federal, state, and local forensic science service providers, research scientists and academics, law enforcement officials, prosecutors, defense attorneys, and judges. The NIST, in coordination with the forensic science community and its practitioners, has created the **Organization of Scientific Area Committees** (OSAC), which will help develop or coordinate the development of guidelines and standards for the forensic sciences. The Scientific Area Committees will replace the independent SWGs and develop national standards for the forensic science disciplines.

These guidelines and standards, similar to those created by the SWGs, are intended to ensure that the highest-quality science is used in each of the forensic sciences and that conclusions are derived through research and testing and are based on rigorous scientific facts. Guidelines and standards are provided for research, testing, reporting and testimony for each of the recognized forensic disciplines. The OSAC has a governing board called the Forensic Science Standards Board, which comprises research representatives, professional association representatives,

Table 1.1 Current listing of the Scientific Area Committees and the Forensic Science Disciplines covered by each committee.

Scientific Area Committee	Forensic Science Disciplines covered by committee
Biology/DNA	Biological data interpretation and reporting Biological methods Wildlife forensics
Chemistry/Instrumental Analysis	Fire debris and explosives Geological materials Gunshot residue Materials (trace) Seized drugs Toxicology
Crime Scene/Death Investigation	Anthropology Disaster victim identification Dogs and sensors Fire and explosion investigation Medico-legal death investigation Odontology
Digital/Multimedia	Digital evidence Facial identification Speaker recognition Video/imaging technology and analysis
Physics/Pattern Interpretation	Blood stain pattern analysis Firearms and toolmarks Footwear and tire Forensic document examination Frictionridge

Scientific Area Committee (SAC) chairs, and an NIST ex officio member. This group of individuals is charged with overseeing all the committees and subcommittees of the OSAC, approving scientific standards, and facilitating communication among the OSAC committees and subcommittees and between OSAC and the forensic science community. Within the OSAC, the forensic science disciplines are separated into five SACs: Biology/DNA; Chemistry/Instrumental Analysis; Crime Scene/Death Investigation; Digital/Multimedia; and Physics/Pattern Interpretation. (See Table 1.1 for a complete listing of the forensic science disciplines encompassed by each SAC.) Anthropology falls under the Crime Scene/Death Investigation SAC. In practice, each SAC develops scientific standards for the forensic disciplines covered by that committee. Then, the OSAC Forensic Science Standards Board approves these standards. Once accepted, the guidelines are disseminated to practitioners in the forensic science disciplines affected by these guidelines. More information on the OSAC can be found at: http://www.nist.gov/forensics/osac/index.cfm.

FORENSIC ANTHROPOLOGY IN THE INTERNATIONAL ARENA

Although the primary focus of this chapter and much of this textbook is practice and research in forensic anthropology in the United States, the discipline has an international presence as well. Chapter 17 summarizes several important ways in which forensic anthropologists are employed in the global arena. The above-mentioned International Association of Forensic Sciences (IAFS) is a worldwide association of academics and practicing professionals from various disciplines in forensic science; it holds meetings every three years. *Forensic Science International* is an English journal that publishes original contributions in the forensic sciences and has an international audience. In addition, a number of non-English journals publish forensic research and case reports.

The Forensic Anthropology Society of Europe (FASE) also offers a certification process for forensic anthropologists. It is structured differently than that provided by the American Board of Forensic Anthropologists. The FASE certification has three levels: one for practitioners with a master's degree (level II); a more advanced certification for practitioners with more experience and an MD or PhD (level II), and the Honoris Causa certification for more experienced and established practitioners, who have been practicing for at least 15 years.

Skeletal collections (both modern and archaeological) are also available for research in various countries throughout the world, including South Africa, Colombia, Portugal, England, France, Germany, China, and Japan. However, to the knowledge of these editors, outdoor human decomposition research facilities are not known outside of the continental United States.

Readers interested in the practice of forensic anthropology outside of the United States are encouraged to consult Dr. Douglas Ubelaker's (2013) edited volume *Forensic Science: Current Issues, Future Directions.*

SUMMARY

In summary, forensic anthropology can be described as an applied subdiscipline of physical/biological anthropology. In practice, forensic anthropologists assist the medico-legal community in the identification of unknown remains by developing a biological profile by using information gleaned from a skeletal examination. They are often involved in trauma analysis of the skeleton, postmortem interval estimation, single and mass burial excavations, mass disasters, and human rights work. The unique multi-disciplinary training of forensic anthropologists enables them to bring a unique perspective to understanding human variation in that they consider the biological and sociocultural determinants of human skeletal biology.

Forensic anthropologists in the United States are affiliated with the American Academy of Forensic Sciences (AAFS), International Association of Forensic Sciences (IAFS), and American Association of Physical Anthropologists (AAPA). Many forensic anthropologists also attend regional conferences. The Anthropology Section of the AAFS was founded in 1972 and comprises 7% of the AAFS membership; it has the largest percentage of student members of any of the sections.

The history of forensic anthropology can be subdivided into three distinct periods, each initiated by an important publication or event. The Formative Period (early 1800s–1938) began with the earliest practitioners and researchers, most of whom were anatomists. The Consolidation Period (1939–1971) began with Krogman's 1939 publication in the Federal Bureau of Investigation's (FBI's) Law Enforcement Bulletin (*Guide to the Identification of Human Skeletal Material*). The Modern Period (1972–present) began with the founding of the Physical Anthropology Section of the American Academy of Forensic Sciences (AAFS) in 1972. Key events and influential figures in each of these periods helped shape forensic anthropology into the discipline that it is today.

Documented skeletal collections and outdoor research facilities serve as the laboratories for much of the research in forensic anthropology and as a data source for developing and validating methods. The University of Tennessee's Anthropology Research Facility (ARF) was established in 1981. It is the oldest of the human decomposition outdoor research facilities in the United States. Texas State University's Forensic Anthropology Research Facility (FARF) was founded in 2008. Other facilities exist (e.g., Sam Houston State University's Southeast Texas Applied Forensic Science Facility [STAFS] and a facility at Western Carolina University), and still others are proposed each year. These facilities contribute much-needed data about decomposition in various climates and geographic regions. They also offer training courses to law enforcement, educators, practitioners, and researchers, and they have made it possible to assemble modern skeletal collections to study modern skeletal variation.

The National Academy of Sciences (NAS) report "Strengthening Forensic Science in the United States: A Path Forward" (2009) forever changed the face of the forensic sciences. The initial response was the creation of Scientific Working Groups (SWGs) to make recommendations for best practice. The Scientific Working Group for Forensic Anthropology (SWGANTH) was established by the Department of Defense Central Identification Laboratory (DoD CIL) and the Federal Bureau of Investigation (FBI) and consists of a 20-member board that comprises forensic anthropologists from various backgrounds and agencies. SWGANTH committees have drafted best practice suggestions in areas pertinent to the practice of forensic anthropology, including proficiency testing, ethics, qualifications, laboratory management, age estimation, sex assessment, stature estimation, commingled remains, and other aspects of case analyses.

The NAS report's recommendation to create an independent federal entity that enforces best practice in the forensic sciences was instituted in 2013, when the Department of Justice (DOJ) partnered with the National Institute of Standards and Technology (NIST) to create the National Commission on Forensic Science. The commission seeks to promote scientific validity, reduce fragmentation, and improve federal coordination of forensic science. The NIST has created the Organization of Scientific Area Committees (OSAC), which will coordinate

the development of guidelines and standards for the forensic sciences. The Scientific Area Committees (SACs) will replace the independent SWGs and develop national standards for the forensic science disciplines. Within the OSAC, the forensic science disciplines are separated into five SACs: (1) Biology/DNA, (2) Chemistry/Instrumental Analysis, (3) Crime Scene/Death Investigation, (4) Digital/Multimedia, and (5) Physics/Pattern Interpretation. Anthropology falls under the Crime Scene/Death Investigation SAC. The OSAC has a governing board (Forensic Science Standards Board) that comprises research representatives, professional association representatives, Scientific Area Committee (SAC) chairs, and an NIST ex officio member. In practice, each SAC develops scientific standards for the forensic disciplines covered by that committee, and then, the OSAC Forensic Science Standards Board approves these standards. Once accepted, the guidelines are disseminated to practitioners in the forensic science disciplines affected by these guidelines.

Although this text takes a U.S.-centric approach to forensic anthropology practice and research, readers should be aware that the discipline has a global presence. Professional organizations, scientific journals, certification processes, and skeletal collections are present in many countries outside of the United States. Readers interested in the practice of forensic anthropology outside of the United States should consult Dr. Douglas Ubelaker's (2013) edited volume *Forensic Science: Current Issues, Future Directions*.

Review questions

1. List and define the subdisciplines of anthropology.
2. Describe the general principles used by forensic anthropologists to develop a biological profile.
3. Identify the AAFS and describe its structure.
4. Identify the three main historic periods of the history of forensic anthropology and describe the salient event that initiated each period.
5. Describe the contributions of T. Dwight, A. Hrdlička, and W. M. Krogman to physical/forensic anthropology.
6. What do anthropologists hope to learn from outdoor research facilities?
7. Name three documented modern skeletal collections. Why are these important to the discipline of forensic anthropology?
8. What is NAGPRA and why is it important to forensic anthropology?
9. What did the NAS report conclude regarding the state of forensic science in the United States? What has been done to address this?
10. Describe the SWGANTH and its purpose.
11. Define OSAC. What is the principle charge of this group? Where does forensic anthropology fit into the SACs?

Glossary

American Academy of Forensic Sciences (AAFS): the professional organization with which most forensic anthropologists are affiliated in the United States. The AAFS is comprised of 11 sections and publishes the *Journal of Forensic Sciences*.

American Association of Physical Anthropologists (AAPA): the leading professional organization for physical anthropologists consisting of paleoanthropologists, primatologists, and forensic anthropologists. The AAPA publishes the *American Journal of Physical Anthropology* and the *Yearbook of Physical Anthropology*.

American Board of Forensic Anthropology (ABFA): a nonprofit organization that provides a program of certification in forensic anthropology. Diplomates must demonstrate an ongoing record of practice and research in the field of forensic anthropology and engage in continuing education.

Anthropology: the discipline that studies all aspects of what it means to be human (culture, language, history and origins, and biology).

Biological profile: the four primary components of a person's physical identity (phenotype) that forensic anthropologists ascertain from the skeleton: age, sex, ancestry, and stature. The biological profile helps law enforcement in the search for missing persons.

Four-field approach: the study of the four subfields of anthropology in order to gain a more holistic understanding of humans and our ancestors (cultural anthropology, biological anthropology, linguistic anthropology, and archaeology).

International Association of Forensic Sciences (IAFS): the only worldwide association of academics and practicing professionals from various forensic science disciplines. The IAFS holds meetings every three years.

National Commission on Forensic Science: a commission created by the Department of Justice (DOJ) and the National Institute of Standards and Technology (NIST) upon the recommendation of the NAS report (2009). The commission seeks to promote scientific validity, reduce fragmentation, and improve federal coordination of forensic science.

Native American Graves Protection and Repatriation Act (NAGPRA): An Act enacted in 1990 that requires federal agencies and institutions that receive federal funding to return Native American remains and cultural items to lineal descendants and culturally affiliated Indian tribes. NAGPRA also establishes processes for the excavation or discovery of Native American cultural items and makes it a crime to traffic in Native American human remains without the right of possession.

Organization of Scientific Area Committees (OSAC): the overarching committee that consists of five scientific area committees (SACs). The OSAC coordinates development of standards and guidelines to improve quality and consistency of work in the forensic science community.

Scientific Working Group for Forensic Anthropology (SWGANTH): a scientific working group consisting of a number of committees that recommend and disseminate guidelines for best practice, quality assurance, and quality control in forensic anthropology.

References

Agostini GM and Gomez EJ. 2009. Forensic anthropology academic and employment trends. *Proceedings of the American Academy of Forensic Sciences Annual Meetings*, Denver, CO, February 16–21. Vol. 15, p. 346.

Bass WM. 1984. Time interval since death. In: TA Rathbun and JE Buikstra (Eds.), *Case Studies in Forensic Anthropology*. Springfield, IL: Charles C. Thomas, pp. 136–147.

Bass WM and Jefferson J. 2003. *Death's Acre: Inside the Legendary Forensic Lab "The Body Farm" Where the Dead Do Tell Tales*. New York: G.P. Putnam's Sons.

Berryman HE. 2009. Full time employment of forensic anthropologists in medical examiner's/coroner's offices in the United States—A history. *Proceedings of the American Academy of Forensic Sciences Annual Meeting*, Denver, CO, Vol. 15, p. 328.

Committee on Identifying the Needs of the Forensic Sciences Community, National Research Council. 2009. Strengthening forensic science in the United States: A path forward, A Report. Document No. 228091. NIJ Award No. 2006-DN-BX-0001.

Dwight T. 1878. The identification of the human skeleton: A medico-legal study. *Mass Med Soc* 12:165–218.

Dwight T. 1905. The size of the articular surfaces of long bones as characteristics of sex; an anthropological study. *Am J Anat* 4:19–32.

Jantz R. 2001. Cranial change in Americans. *J Forensic Sci* 46(4):784–787.

Jantz L and Jantz R. 1999. Secular change in long bone length and proportion in the United States, 1800–1970. *Am J Phys Anthropol* 110:57–67.

Jantz R and Jantz ML. 2000. Secular change in craniofacial morphology. *Am J Hum Biol* 12:327–338.

Krogman WM. 1939. A guide to the identification of human skeletal material. *FBI Law Enforcement Bulletin* 8(8):3–31.

Krogman WM. 1962. *The Human Skeleton in Forensic Medicine*. Springfield, IL: Charles C. Thomas.

Krogman WM. 1976. Fifty years of physical anthropology: The men, the material, the concepts, the method. *Annu Rev Anthropol* 5:1–14.

Marks MK. 1995. William M. Bass and the development of forensic anthropology in Tennessee. *J Forensic Sci* 40(5):741–750.

Meadows L and Jantz R. 1995. Allometric secular change in the long bones from the 1800s to the present. *J Forensic Sci* 40(5):762–767.

Native American Graves Protection and Repatriation Act (NAGPRA). 1990. PL 101–601, 104 Stat 3048, United States.

Opel KL, Chung DT, Drabek J, Tatarek NE, Jantz LM, and McCord BR. 2006. The application of miniplex primer sets in the analysis of degraded DNA from human skeletal remains. *J Forensic Sci* 51(2):351–356.

Ousley SD and Jantz RL. 1997. The forensic data bank: Documenting skeletal trends in the United States. InKJ Reichs(Ed.), *Forensic Osteology: Advances in the Identification of Human Remains*. Springfield, IL: Charles C. Thomas, pp. 442–458.

Reeves NM. 2009. Taphonomic effects of vulture scavenging. *J Forensic Sci* 54(3):523–528.

Rhine S. 1998. *Bone Voyage: A Journey in Forensic Anthropology*. Albuquerque, NM: University of New Mexico Press.

Shirley NR, Wilson RJ, and Jantz ML. 2011. Cadaver use at the University of Tennessee's Anthropological Research Facility. *Clin Anat Rev* 24(3):372–380.

Spradley MK, Hamilton MD, Giordano A. 2012. Spatial patterning of vulture scavenged human remains. *Forensic Sci Int* 219:57–63.

Stevenson PH. 1924. Age order of epiphyseal union in man. *Am J Phys Anthropol* 7:53–93.

Stevenson PH. 1929. On racial differences in stature long bone regression formulae for the Chinese (with editorial note by Karl Pearson). *Biometrika* 21:303–318.

Stewart TD. 1979. *Essentials of Forensic Anthropology, Especially as Developed in the United States*. Springfield, IL: Thomas, Vol. 17, p. 300.

Ubelaker DH(Ed.). 2013. *Forensic Science: Current Issues, Future Directions.* West Sussex, UK: Wiley Blackwell.

Vass AA, Barshick SA, Sega G, Caton J, Skeen JT, Love JC, and Synstelien JA. 2002. Decomposition chemistry of human remains: A new methodology for determining the postmortem interval. *J Forensic Sci* 47(3):542–553.

Vass AA, Bass WM, Wolt JD, Foss JE, and Ammons JT. 1992. Time since death determinations of human cadavers using soil solution. *J Forensic Sci* 37(5):1236–1253.

Vass AA, Smith RR, Thompson CV, Burnett MN, Dulgerian N, and Eckenrode BA. 2008. Odor analysis of decomposing buried human remains. *J Forensic Sci* 53(2):384–391.

Vass AA, Smith RR, Thompson CV, Burnett MN, Wolf DA, Synstelien JA, Dulgerian N, and Eckenrode BA. 2004. Decompositional odor analysis database. *J Forensic Sci* 49(4):760–769.

Wilder HH and Wentworth B. 1918. *Personal Identification: Methods for the Identification of Indivduals, Living or Dead*. Boston: Gorham.

Additional information

Useful websites

American Academy of Forensic Sciences (www.aafs.org)

American Association of Physical Anthropologists (www.physanth.org)

American Board of Forensic Anthropology (www.theabfa.org)

Maxwell Museum of Anthropology Documented Skeletal Collection (http://www.unm.edu/~osteolab/coll_doc.html)

Midwest Bioarchaeology and Forensic Anthropology Association (http://archlab.uindy.edu/barfaa/index.php)

Mountain, Desert, and Coastal Forensic Anthropologists (http://foil.ucsc.edu/mdc/)

National Commission on Forensic Science (https://www.justice.gov/ncfs)

National Institute of Standards and Technology (http://www.nist.gov)

Organization of Scientific Area Committees (http://www.nist.gov/forensics/osac.cfm)

Scientific Working Group for Forensic Anthropology (www.swganth.org)

Skeletal Collections Database website—includes a list of collections from around the world (http://skeletal.highfantastical.com/)

Southeast Texas Applied Forensic Science Facility (http://www.cjcenter.org/stafs/)

Texas State University San Marcos Forensic Anthropology Center (http://www.txstate.edu/anthropology/facts/)

The Ellis Kerley Foundation (www.kerleyfoundation.org)

The Hamann-Todd Osteological Collection (http://www.cmnh.org/site/ResearchandCollections/PhysicalAnthropology/Collections/Hamann-ToddCollection.aspx)

The NAS Report (http://www.ncjrs.gov/pdffiles1/nij/grants/228091.pdf)

The Robert J. Terry Anatomical Collection (http://anthropology.si.edu/cm/terry.htm)

The University of Tennessee Forensic Anthropology Center (http://web.utk.edu/~fac/)

Nonfiction forensic anthropology resources

Nonfiction books

Bass, William M. 2004. *Death's Acre: Inside the Legendary Forensic Lab the Body Farm Where the Dead Do Tell Tales*. New York: Berkley Books.

Maples WR and Browning M. 1995. *Dead Men Do Tell Tales: The Strange and Fascinating Cases of a Forensic Anthropologist*. New York: Broadway Books.

Rhine S. 1998. *Bone Voyage: A Journey in Forensic Anthropology*. Albuquerque: University of New Mexico Press.

Textbooks

Bass WM. 2004. *Human Osteology: Laboratory and Field Manual, 5th edn.*. Columbia:Missouri Achaeological Society.

Burns KR. 2012. *Forensic Anthropology Training Manual*. New York: Routledge. 384 pp.

France DL. 2011. *Human and Nonhuman Bone Identification: A Concise Field Guide, 6th edn.*. Boca Raton: CRC Press.

Schaefer M, Black S and Scheuer L. 2009. *Juvenile Osteology: A Laboratory and Field Manual*. London: Academic Press.

Steadman DW (Ed). 2008. *Hard Evidence: Case Studies in Forensic Anthropology*. New York: Routledge. p. 360.

Tersigni-Tarrant MA and Shirley NR (Eds.). 2012. *Forensic Anthropology: An Introduction*. Boca Raton: CRC Press. p. 486.

Ubelaker DH (Ed). 2013. *Forensic Science: Current Issues, Future Directions*. West Sussex, UK: Wiley Blackwell.

White TD. 2005. *The Human Bone Manual*. London: Academic Press. p. 488.

Chapter 2

Skeletal Remains as Evidence

Marin A. Pilloud and MariaTeresa A. Tersigni-Tarrant

CONTENTS

LEARNING OBJECTIVES

1. Describe the process by which forensic anthropologists first assess whether the material in question is bone.
2. Explain how forensic anthropologists ascertain whether bone is human.
3. Describe how forensic anthropologists determine if human skeletal remains are modern.
4. Explain how forensic anthropologists determine whether modern human skeletal remains are of forensic significance.

INTRODUCTION

When a forensic anthropologist is presented with remains suspected to be human skeletal material, it is necessary to assess the materials for evidentiary value. Forensic anthropologists utilize a **biocultural** approach to determine **medico-legal** significance. Most forensic anthropologists are trained to evaluate the cultural, archaeological, and physical evidence (both bone and other material) to determine if materials have forensic value. Forensic anthropologists ask a series of questions to conclude if a forensic investigation is warranted. These questions include: (1) Is the material bone? (2) Is the material human bone? (3) Is the material modern? and (4) Is the material of interest to the medico-legal community; that is, could it be related to a civil or criminal matter?

These are not mutually exclusive categories; for example, nonhuman or nonmodern bone may still be of medico-legal interest. For example, in 2009, the Michigan State University Forensic Anthropology Laboratory assisted with a legal dispute between two parties regarding the disappearance of 160 heads of cattle. The forensic anthropologists were asked to determine the number of cattle and to estimate a postmortem interval (Megyesi et al. 2011). Additionally, archaeological remains may be of interest in antiquities dealings or other illegal activities. Native American human remains are protected under the Native American Graves Protection and Repatriation Act (NAGRPA) enacted in 1990 ("Native American Graves Protection and Repatriation Act" 1990). One of the provisions of NAGRPA is that criminal penalties may result from the illegal trafficking of remains protected under this provision (Section 4).

Regardless of the outcome of these questions, each one must be asked by the forensic anthropologist. The response to each will guide future analyses and aid law enforcement or civil parties in deciding how to proceed with the case. The processes involved in addressing each of these questions are outlined below.

IS IT BONE?

Many materials can look like bone to the untrained eye. Qualified biological anthropologists use their skills as osteologists to determine if the material is **osseous** in nature. If the fragment is large enough, it should be relatively easy to determine the nature of the material. Smaller pieces may be more difficult to assess, particularly if the material is natural, as small pieces of wood, plants, charcoal, and shell can be mistaken for bone. Other materials such as rocks, plastic, and ceramics are also commonly mistaken for bone. Any circumstance where these materials may become intermixed with bone or bone fragments requires the assistance of an anthropologist to differentiate osseous from nonosseous materials (Figure 2.1).

There are several means to distinguish human from nonhuman material if gross examination cannot answer the question. Microscopic examination is the first step (Ubelaker 1998). Bone has a distinct surface that can be detected at even low magnification. Skeletal material has a compact cortical outer surface that appears dense and smooth. This layer covers a trabecular structure that looks like disorganized strands of bone under low magnification. The forensic anthropologist should have known exemplars of bone in the laboratory with which to compare the unknown specimen. A comparison of visual properties aids in determining if a material is osseous.

Radiographs are another means to determine if a material is osseous. Skeletal material is radiopaque, in that it absorbs and scatters radiation, giving it a white appearance on film (Fleckenstein and Tranum-Jensen 2001). A radiograph may quickly differentiate radiopaque material from radiolucent material, as a crude means to identify dense materials similar to bone in a large sample of material. For example, a good practice for a forensic anthropologist is

Figure 2.1 An example of separating osseous material from nonosseous material.

to radiograph a body bag after skeletal material has been sorted and removed for analysis. An examination of the radiographs helps the analyst identify any skeletal material (such as a phalanx or tooth) that may have been overlooked. This practice may be particularly important if the bag contained other materials or debris, such as wood, that obscured the skeletal material.

Finally, elemental analysis may aid in determining if a material is bone. A scanning electron microscope with energy dispersive spectroscopy (SEM-EDS) or an X-ray fluorescence (XRF) analyzer can identify the elemental composition of an object and help determine if the material is osseous or nonosseous (Christensen et al. 2012; Ubelaker et al. 2002). Both tools utilize characteristic X-ray emissions to determine the elements that are present (Houck 2015). Bone is primarily made of hydroxyapatite, which is a mineral composed of calcium, phosphorus, hydrogen, and oxygen (Kuhn 2007). SEM-EDS and XRF are best at detecting heavier elements (Houck 2015); therefore, when identifying bone, the analyst is most interested in identifying the presence of calcium and phosphorus, and hydrogen and oxygen are of less interest.

IS IT HUMAN?

If the material is found to be bone or teeth, the next step is to assess if the remains are human. Determining human versus nonhuman bone and teeth requires a trained osteologist. All aspects of the material must be scoured for evidence of human morphology, especially if the material is fragmentary or taphonomically compromised. Given the proximity of humans to other animals, particularly large mammals, it is common for the forensic anthropologist to receive a mixed assemblage of **faunal** and human remains for examination. In those cases, it is important to separate all nonhuman and human remains.

If the specimen in question is relatively large or contains diagnostic morphology, a determination of whether the bone is human or not can usually be made through gross visual examination. The unique size and mode of locomotion of humans result in distinct **articular** surfaces and bone shapes (Figure 2.2). However, several bones from large mammals can closely resemble human skeletal material. For example, a highly decomposed bear paw may surprisingly approximate the appearance of a human hand. A trained forensic anthropologist, however, can differentiate the two based on distinct morphological differences. Given these similarities in mammalian species, forensic anthropologists frequently make assessments of human versus nonhuman bone via photographs (with scales) provided by law enforcement (Figure 2.3).

If the osseous remains are highly fragmentary, it may be difficult to use either gross morphology or size to determine if the remains are human. In these cases, it is useful to examine a histological sample of the remains by using a light microscope to assess whether the remains have characteristic human micromorphology. Typical adult

Figure 2.2 Faunal remains received for examination.

Figure 2.3 An example of a photograph sent from law enforcement to determine if the remains are human. In this case, the teeth were not human.

human micromorphology contains osteonal bone throughout the entirety of the bone section. (See Chapter 5 for a more detailed discussion on human bone micromorphology.) Other nonhuman mammals have varied micromorphology, including plexiform bone, which is easily distinguished from human remains (Figure 2.4). However, some mammals have full-thickness osteonal bone; therefore, it may not be possible to differentiate human from nonhuman based on micromorphology. In these cases, additional analysis may be required. (See Chapter 4, Box 4.3, for further details.)

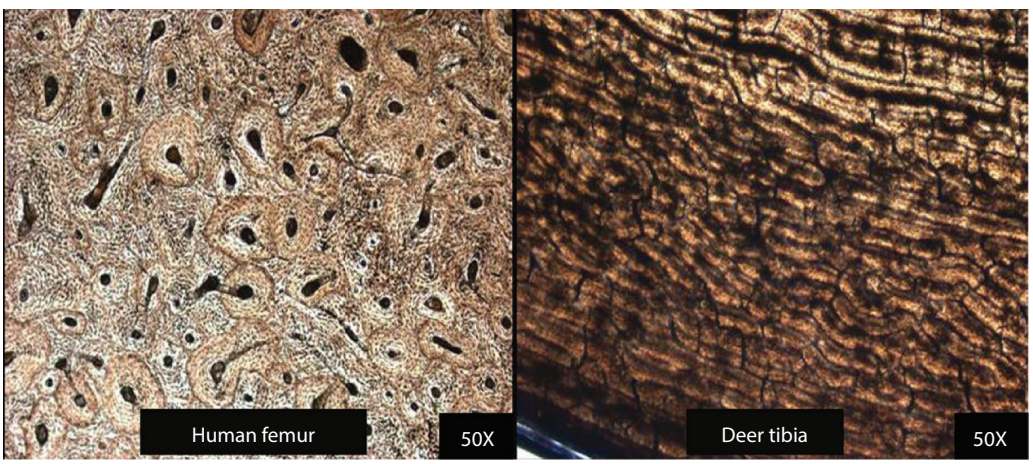

Figure 2.4 Differentiating human from nonhuman bone based on histology. Note that the human bone has round osteons, while the deer bone has brick-shaped plexiform bone.

Finally, it is possible to determine if a piece of bone is human or not through an analysis of DNA. Studies have achieved success at species identification through tests of the highly conserved regions of mitochondrial 12S and 16S ribosomal RNA (Yang et al. 2014).

How many individuals are present?

Once bone and teeth are determined to be human, the next step is to identify how many individuals are present. This assessment is referred to as the determination of the **minimum number of individuals** (MNI). A detailed discussion of MNI assessment is provided in Chapter 18 of this volume. Briefly, an MNI estimate is made by assessing present skeletal elements or fragments of skeletal elements to look for duplicates or duplicating segments of bone. If there are two complete *right femora*, then you may assume that the MNI would be two, as each human only has one right femur.

Elements can also be segregated by age to aid in the estimation of the MNI. For example, if a right femur with an *unfused* femoral head is present (representing a skeletally immature individual) and a left femur with a *fused* femoral head is also present (representing a skeletally mature individual), the assumption could be made that these femora represent two different people. Large differences in size also aid in determining the MNI (Figure 2.5). Small differences should be approached cautiously, as slight **bilateral asymmetry** is not uncommon in a single individual. Taphonomic differences may also provide clues as to number of individuals present. Elements that have been in dissimilar postdepositional environments may look very different from each other.

Figure 2.5 An example of human remains (left femora) that can be sorted into distinct individuals based on size.

IS THE MATERIAL MODERN?

Human remains are often recovered in remote locations, during construction activities, or even among personal belongings. When human remains are discovered, they are delivered to law enforcement or to the coroner. Depending on the state or the county, the coroner is usually not qualified to make a determination about forensic significance, so a nearby medical examiner or forensic anthropologist, or both, must evaluate the remains. This assessment involves looking at the following characteristics of the material: state of preservation, **antemortem** body modifications, associated personal belongings, and the conditions of **interment**.

Initially, a consideration of postmortem interval may be appropriate. If soft tissue is in a relatively fresh state and adheres to the remains, the remains are probably relatively recent. However, if remains are mummified and tissues are **desiccated**, then environmental conditions must be considered carefully, since, in the right conditions, soft tissue can preserve for an extended period of time. See Chapter 15 for a discussion on the postmortem interval.

If remains are completely skeletonized, it may be difficult to determine the modernity of the elements. Various clues indicate the age and potential origin of remains. For example, working in the United States may require determining if remains are of archaeological significance and/or prehistoric (i.e., Native American). Several skeletal and dental characteristics and other physical evidence may indicate the antiquity of the remains or if they are Native American. Such an analysis includes a consideration of the color of the remains, as archaeological skeletal material will often be of a brownish color, as bones take on coloration from the surrounding matrix in which they are buried. The condition of the teeth may also be an indicator of antiquity. Prehistoric skeletons typically have severely worn teeth (Figure 2.6). Cultural indicators, such as grave goods and artifacts associated with the remains, may also be indicators of antiquity. Moreover, if known, the circumstances of the interment can indicate the age (e.g., if the burial was in a flexed position or found in an archaeological matrix). An assessment of ancestry also assists in determining if remains are of archaeological significance and Native American. If the antiquity cannot be definitively ascertained through gross examination, radiocarbon dating can be employed to estimate the date of the skeletal material.

IS THE MATERIAL OF FORENSIC SIGNIFICANCE?

Once it is determined that the remains are human and relatively modern, it is necessary to determine if the remains are forensically important. The forensic anthropologist can determine whether the remains are of medico-legal interest, that is, relevant to a civil or criminal matter. There are several other reasons human remains may be encountered that are of no interest to the medico-legal community. These alternative scenarios are outlined below and should be eliminated as possible sources of the remains, before a full forensic investigation can begin. Nonetheless, the remains may still be of forensic significance, even if found to be prehistoric or faunal.

On occasion, historic skeletal remains are recovered that are not of forensic significance. Indicators of historic remains might include evidence of embalming, such as embalming artifacts and heightened levels of embalming fluid in the

Figure 2.6 An example of archaeological teeth (Left: mandible, Right: maxilla). The teeth are severely worn, with little enamel remaining; teeth in this condition may indicate that the remains are not modern.