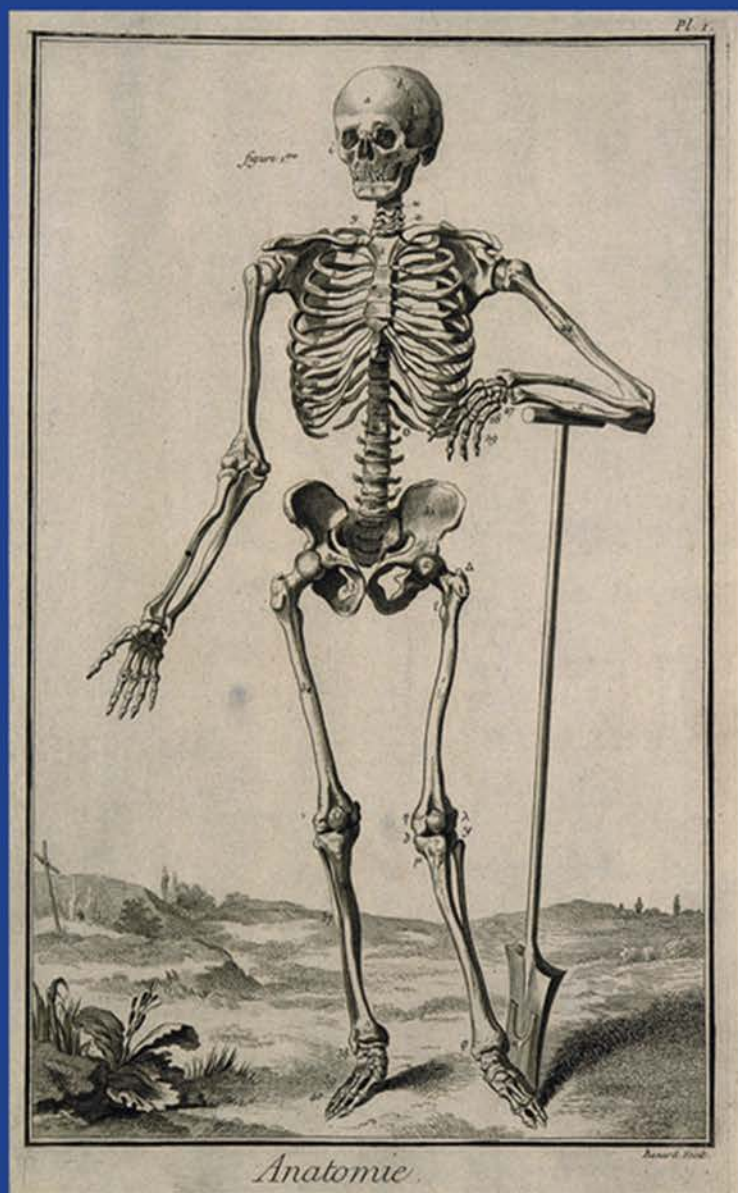


WORLD ARCHAEOLOGICAL CONGRESS RESEARCH
HANDBOOKS IN ARCHAEOLOGY

HANDBOOK OF FORENSIC ANTHROPOLOGY AND ARCHAEOLOGY

SECOND EDITION



EDITED BY SOREN BLAU AND DOUGLAS H. UBELAKER

ROUTLEDGE

Handbook of Forensic Anthropology and Archaeology

With contributions from 70 experienced practitioners from around the world, this second edition of the authoritative *Handbook of Forensic Anthropology and Archaeology* provides a solid foundation in both the practical and ethical components of forensic work. The book weaves together the discipline's historical development; current field methods for analyzing crime, natural disasters, and human atrocities; an array of laboratory techniques; key case studies involving legal, professional, and ethical issues; and ideas about the future of forensic work—all from a global perspective. This fully revised second edition:

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- expands the geographic representation of the first edition by including chapters from practitioners in South Africa and Colombia;
- adds exciting new chapters on the International Commission on Missing Persons and on forensic work being done to identify victims of the World War I Battle of Fromelles.

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All royalties generated by sales of books in this series go directly to the World Archaeologic Congress.

Use of Images of Human Remains

As noted by the series editors in the first edition of the *Handbook of Forensic Anthropology and Archaeology* (2009), a volume on this subject would be expected to contain images of human remains since they are integral for teaching and learning. Nevertheless, the series editors also noted that because this book series is sponsored by the World Archaeological Congress (WAC) it was important to make every effort to comply with the Tamaki Makau-rau Accord on the Display of Human Remains and Sacred Objects (WAC 2006), as well as other codes and accords promulgated by WAC. The Tamaki Makau-rau Accord, developed in New Zealand in 2005 and adopted in Osaka in 2006, states that anyone wishing to publish or otherwise display human remains or images of human remains should first seek permission from affiliated descendants or descendant communities.

As directed by the series editors, Soren Blau and Douglas Ubelaker (the volume editors) requested that each author whose chapter (in both the first and second editions of the volume) includes images of human remains comply—or at least attempt to comply—with the Accord and be able to affirm that appropriate permissions sought or received for use of any illustrations containing photographs of human remains. Images that appear in both the first and second editions of this volume that fall under the Accord range from photographs of a single human bone to several portraying victims of mass genocide to photomicroscopic images of human bone tissue.

In keeping with our ethical responsibility of working with human remains we emphasize that access to and use of images of deceased individuals is an important part of the professional forensic anthropologist's casework and/or research. As part of the forensic anthropologist's professional ethical code of practice, when one depicts aspects of a case, the deceased individual must be de-identified (that is, nothing can identify the person). Consequently, in all cases in this edition where human remains (whether complete or partial, macroscopic or histology section) are depicted to illustrate a point there are no identifying features on the image. All research based on deceased individuals (whether identified or not), including the use of images, has ethical approval.

The request for compliance and the interpretation of the Accord by those working in a forensic context has been addressed by making an effort to advise readers of images that may contain sensitive material. In light of this, all photographs of human remains are identified by an asterisk in the list of figures.

Reference

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Contributors

Bradley J. Adams (Ph.D., D-ABFA) is Director of the Forensic Anthropology Department for the Office of Chief Medical Examiner (OCME) in New York City. Dr. Adams and his team are responsible for all forensic anthropology casework in the five boroughs of New York City (Manhattan, Brooklyn, Queens, the Bronx, and Staten Island). Dr. Adams and his team are also integral players in the ongoing work related to identification efforts of 9/11 victims of the World Trade Center attacks. From 1997 to 2004 Dr. Adams was a Forensic Anthropologist and Laboratory Manager at the Central Identification Laboratory (CIL) in Hawaii. He is a Diplomat of the American Board of Forensic Anthropology, a Fellow with the American Academy of Forensic Sciences, and on the editorial board for the *Journal of Forensic Sciences*.

Melanie Archer (B.Sc. [Hons.], Ph.D., MBBS) has made five visits to the Solomon Islands to assist Dr. Malcolm Dodd with autopsies mainly related to the ethnic tensions. She is one of only two practicing forensic entomologists in Australia and works primarily as a medical doctor. She is currently undergoing specialty training in pathology with the aim of becoming a forensic pathologist.

Eric Baccino (M.D.) is Head of the Medico-Legal and Prison Medicine Unit at University Hospital, Montpellier. He is also president of the Forensic Anthropology Society of Europe (FASE) and Secretary General of the Société de Médecine Légale et de Criminologie de France.

Lori Baker (B.A., M.A., Ph.D.) is Assistant Professor in the Department of Anthropology, Forensic Science, and Archaeology at Baylor University. She obtained her doctorate from The University of Tennessee, Knoxville, where she conducted DNA analysis from hair shafts collected by Franz Boas and colleagues for the World's Columbian Exposition in 1893. Currently Dr. Baker oversees the DNA section of Sistema de Identificación de Restos y Localización de Individuos (SIRLI), a database established by the Government of Mexico designed to locate living and to identify deceased Mexican nationals abroad. Her research interests lie in molecular analysis of ancient and modern bone, teeth, and hair samples to better understand population variation. Dr. Baker has numerous publications regarding mitochondrial DNA sequences analysis and molecular sex identification from forensic and ancient specimens.

Caroline Barker originally schooled in traditional archaeological and osteology in the late 1990s; she was asked to apply this knowledge and experience in a forensic capacity for the United Nations International Criminal Tribunal for the Former Yugoslavia (UN ICTY). This foundation experience has subsequently developed into an international forensic career spanning nearly two decades working in the humanitarian and development sector. She has worked

on a number of interdisciplinary programs and projects for the United Nations Department of Peace Keeping Operations (UNDPKO), U.K. Foreign Commonwealth Office (FCO), inter-governmental organizations (INGOs), and nongovernmental organizations (NGOs), addressing the issue of missing persons in challenging conflict, postconflict, and disaster contexts in the Balkans, Western Europe, Latin America, Asia, and Africa. She has designed and led adult capacity building and training initiatives in forensic anthropology and archaeology and developed strategies, policies, and working methods to strengthen and promote the rule of law, the protection of human rights, and the implementation of forensic best practice.

William Basler received his Bachelor's degree in business from the University of Northern Iowa before joining the Iowa Division of Criminal Investigation (DCI) in 1975 as a Special Agent. He has worked over 500 cases in northern Iowa and testified in more than 100 trials. In 2003 he became the Special Agent in Charge and held this position until he retired from the DCI in 2006. Since then he has been the Criminal Justice Program Leader at North Iowa Area Community College, from which he retired in 2010.

Sue Black is Director of the Centre for Anatomy and Human Identification at the University of Dundee and Deputy Principal. She is a forensic anthropologist and an anatomist, founder and past President of the British Association for Human Identification, and advisor to the Home Office and Interpol on issues pertaining to forensic anthropology in disaster victim identification (DVI). She is a fellow of the Royal Society of Edinburgh, a Fellow of the Royal Anthropological Institute, a Fellow of the Royal College of Physicians (Edinburgh), a Fellow of the Society of Biology, and a certified forensic anthropologist. She was awarded an O.B.E. in 2001 for her services to forensic anthropology in Kosovo, the Lucy Mair medal for humanitarian services and a police commendation for DVI training in 2008, the Brian Cox and the Stephen Fry awards for public engagement with research in 2013, and the Fletcher of Saltoun award for her contribution to Scottish culture in 2014; her Centre was awarded the Queen's Anniversary Prize for Higher and Further Education also in 2014. She is Hon. Prof. of Anatomy for the Royal Scottish Academy; her research was shortlisted for the Times Higher Education research project of the year.

Soren Blau (B.A. [Hons.], M.Sc., Ph.D.) is the Senior Forensic Anthropologist at the Victorian Institute of Forensic Medicine, where she has been employed since 2005. She is an Adjunct Senior Lecturer in the Department of Forensic Medicine at Monash University, Founding Fellow Faculty of Science, the Royal College of Pathologists of Australasia, and a recipient of a Churchill Fellowship (2013). Dr. Blau undertakes domestic forensic anthropology casework, including Disaster Victim Identification. In addition, she has participated in the recovery and analysis of human remains from archaeological and forensic contexts in numerous countries, including Democratic Republic of Congo, Guam, Indonesia, Israel, Solomon Islands, Timor-Leste, United Arab Emirates, United Kingdom, and Uzbekistan. She has undertaken consultancies for the International Criminal Court and the International Committee of the Red Cross and nongovernment organizations, and she has delivered training to forensic practitioners and related stakeholders in Australia, Botswana, Indonesia, Jordan, Nepal, Solomon Islands, Sri Lanka, Timor-Leste, Thailand, Turkey, and Uganda.

Kathryne Bomberger was appointed Director-General of the ICMP in 2004, having led the development of the ICMP from 1998. Bomberger has 20 years' working experience within international organizations, including the United Nations, the Organization for Security and

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Cooperation in Europe (OSCE), and the International Commission on Missing Persons (ICMP) on issues related to human rights, politics, and conflict prevention. Before working on international human rights issues, she worked for the United States Senate and as a journalist. She has an undergraduate degree in history and a graduate degree in international relations, with a focus on Middle East Studies, from the Elliot School of International Relations at The George Washington University in Washington, D.C. In 2007 Kathrynne Bomberger was made Chevalier de la Legion d'Honneur by the President of France.

Christopher A. Briggs has been a consultant forensic anthropologist at the Victorian Institute of Forensic Medicine (VIFM) since 1991. He is Honorary Associate Professor in the Department of Forensic Medicine at Monash University and Associate Professor in the Department of Anatomy and Neuroscience at the University of Melbourne. He has participated in recovery of skeletal remains from archaeological sites in Turkey, Georgia, and Britain and in his work at the VIFM has assisted the Victorian State Coroner, the Victorian Police Force, and the Australian Federal Police in crime scene examination, in cases of homicide and in determination of human rights abuse. He was consultant forensic anthropologist with the United Nations in East Timor in 2000, the Australian Federal Police in the 2002 Bali incident, and the New Zealand police following the Christchurch earthquake in 2011. He was also one of the forensic anthropologists involved in the Victorian bushfire disaster in 2009. He has published widely in forensic and anatomical journals and provided contributions to book chapters in forensic science and anthropology.

Kristina Bowie (B.A.) is a graduate in physical/biological anthropology from University of Victoria (2004) and has a certificate in International Human Rights Law from Oxford University (2005). She has worked for the American Museum of Natural History in the High Arctic islands of the Northwest Territories of Canada prospecting for Late Pleistocene vertebrates. She also worked as a forensic archaeologist for the Royal Canadian Mounted Police Major Crimes Section, Missing Persons Unit. She currently works for a Victoria, B.C., archaeological consulting firm, contracted out over the province of British Columbia to lead field crews in the surveying of and testing for archaeological sites. She plans on continuing with graduate studies to follow her interests in the recovery of missing or disappeared persons, drawing on her background in human osteology and human rights violations.

Alanah M. Buck began employment as the forensic anthropologist with PathWest in 1995. She has a background in physical anthropology and completed a Ph.D. with the University of Western Australia in 1998. Her casework consists of human remains recovery, homicide, and cold case investigations and routine identifications. Her special interests are post-blast reconstructions of human remains and the forensic aspects of shark-related fatalities. Buck has assisted the Australian Federal Police with mass fatality incidents such as the Bali bombings in 2002, the Australian Embassy bombing in 2004 and the Marriott and Ritz-Carlton hotel terrorist attacks in 2009. She was also part of the forensic anthropology team during the 2009 Victorian bushfires and assisted the disaster victim identification response following the Christmas Island boat disasters in 2010 and 2012. Dr. Buck has also provided regular training programs for the Western Australian Police and the Australian Federal Police and has delivered forensic training courses in Indonesia, Sri Lanka, and Cambodia. She is a Founding Fellow of the Faculty of Science, Royal College of Pathologists of Australasia, and an Honorary Research Associate with the Western Australian Museum.

John E. Byrd (Ph.D., D-ABFA) received his Ph.D. from the University of Tennessee, Knoxville, in 1994 and is a Diplomate of the American Board of Forensic Anthropology. He joined the Defense POW/MIA Accounting Agency Laboratory in August 1998 as a Forensic Anthropologist. Dr. Byrd became a Laboratory Manager in 1999 and the Laboratory Director in 2009. He currently serves on the editorial board of the *Journal of Forensic Sciences* and on the Forensic Advisory Board of the International Committee of the Red Cross. Dr. Byrd has published on Tuscarora subsistence practices through the North Carolina Archaeological Council, coedited the books *Recovery Analysis and Identification of Commingled Remains* and *Commingled Human Remains: Methods in Recovery, Analysis, and Identification*, and written articles for the *Journal of Field Archaeology*, *Journal of Anthropological Archaeology*, *Forensic Sciences International*, and *Journal of Forensic Sciences*, among others.

Cristina Cattaneo (M.D., Ph.D.) graduated from McGill University in biomedical sciences, received her M.A. and Ph.D. in osteology and anthropology at University of Sheffield, and later graduated in medicine and specialized in forensic pathology (Medicina Legale) at Università Statale di Milano (Italy). She is now Associate Professor of Legal Medicine in the Faculty of Medicine of University of Milano and teaches anthropology at the Faculty of Sciences and of Arts of the same university. In 1996 she founded and now heads the Laboratorio di Antropologia e Odontologia Forense (LABANOF) of the Institute of Legal Medicine of the University of Milano, is Secretary of FASE (Forensic Anthropology Society of Europe, a subsection of the International Academy of Legal Medicine [IALM]), and is Associate Editor for the Osteology section of *Forensic Science International*.

Paul N. Cheetham is a Senior Lecturer in Archaeological Science at Bournemouth University and is currently leading its *MSc Forensic Archaeology* degree program. Graduating in 1985 from the School of Archaeological Sciences, University of Bradford, he worked closely with John Hunter in developing and promoting awareness of forensic archaeology in the United Kingdom, subsequently working with both Margaret Cox and Ian Hanson at Bournemouth. He has been involved in over 40 U.K. police cases, and in international mass grave investigations. He is a founding member of both the U.K. Forensic Search Advisory Group and the International Society for Archaeological Prospection. He has also been a forensic archaeology assessor for the U.K. Council for the Registration of Forensic Practitioners, an Inforce Scientific Advisor, and a trainer for the International Commission on Missing Persons. He has worked on notable archaeological sites, including Stonehenge, Jarlshof, and Pompeii and is currently codirector of the Durotriges project.

Peter Claes obtained a Ph.D. in engineering in June 2007, within the field of medical image computing under the supervision of Prof. Paul Suetens and Prof. Dirk Vandermeulen at the Katholieke Universiteit Leuven, Belgium. During his Ph.D. work he developed a computer-based craniofacial reconstruction approach for victim identification purposes. Afterward he established his own research trajectory and vision, with fundamental interest in pattern recognition and predictive modeling within computational imaging and biology. He was a postdoctoral student at the Melbourne Dental School, University of Melbourne, Australia, until January 2011. During that time he built an international and versatile network of collaborations that is still very useful and active. Currently he is an honorary fellow at the Murdoch Children's Research Institute, Australia, and a research expert at the Katholieke Universiteit Leuven, ESAT/PSI/MIC, Belgium. The basis of his line of research lies in computer vision and medical image

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analysis with gained and proven extensions in biostatistics, genetics, human biology, and disease, as well as cognitive psychology.

John Clement is Professor and Inaugural Chair of Forensic Odontology at Melbourne Dental School in the University of Melbourne. He is also a visiting Honorary Research Fellow at the Forensic Institute of the Defence Academy of the U.K. at Cranfield University. Prof Clement is past president of both the British and Australian associations/societies for Forensic Odontology (BAFO and ASFD) and a founder member of the International Association for Craniofacial Identification (IACI) and Dental Ethics and Law Society (IDEALS). For more than 40 years Prof. Clement has had hands-on practical experience of working in the area of mass-disaster victim identification. He has also convened and served on an expert advisory panel to the International Committee of the Red Cross (ICRC) dealing with the problem of the identification of missing persons and human remains following conflicts and civil strife. He was also a member of the Scientific Steering Committee on Forensic Science Programs to the International Commission on Missing persons (ICMP). Prof Clement has published two books and more than a dozen book chapters on forensic identification issues, in addition to more than 90 peer-reviewed scientific articles.

Derek Congram (M.Sc., M.A., Ph.D.) teaches, consults, and conducts research in archaeology and anthropology, with a focus on medico-legal and humanitarian applications. He has worked for governments, universities, nongovernmental, and international organizations in 18 countries. His principal research interests are spatial analysis and GIS-modeling of unmarked burials from armed conflict and applied ethics. He is the editor and a contributor to the book *Missing Persons: Multidisciplinary Perspectives on the Disappeared* (Forthcoming 2016, Canadian Scholars' Press, Inc.).

Samuel V. Connell received his Ph.D. from University of California, Los Angeles. He has published in Antiquity and Latin American Antiquity and has coedited a volume on Ancient Maya Rural Complexity. From 2002 to 2005 he was a member of the Department of Defense Central Identification Laboratory, where he led missions to Southeast Asia and worked with geophysical instrumentation to search for, recover, and identify missing U.S. military dead. Dr. Connell is Assistant Professor of Anthropology at Foothill College, Los Altos Hills, California. His current research focuses on fortresses of the Ecuadorian highlands. Dr. Connell has presented at numerous conferences worldwide and is a member of the Institute of Andean Studies Society for American Archaeology, American Anthropological Association, and Register of Professional Archaeologists.

Margaret Cox began her career in archaeology with the ground-breaking Christ Church Spitalfields (London) project in the 1980s. She undertook her Ph.D. at University College London, and a varied career in archaeology followed before she became involved in the early 1990s with the application of archaeology and anthropology to forensic contexts. Her experiences in Kosovo in 1999 led her to establish the Inforce Foundation in 2001 (CEO 2009, President 2015). The Foundation's work included missions in Iraq and Rwanda, and their capacity-building mandate included the innovative use of experiential education—simulated mass graves, air crash sites, and temporary mortuaries. While at Bournemouth University (1994–2007), she developed the world's first M.Sc. in forensic archaeology and the United Kingdom's first M.Sc. in forensic anthropology. Awarded a personal chair at Bournemouth, she

later also held their established Chair in Forensic Archaeology and Anthropology, and similarly at Cranfield University from 2007 to 2009. European Union Woman of Achievement in 2002, she has over one hundred publications. Scientific Advisor (archaeology, anthropology, identification) to the Australian and British governments for the Fromelles project (2008–2014), she now works part-time as an independent consultant forensic anthropologist.

Christian M. Crowder received his M.A. from the University of Texas at Arlington and his Ph.D. from the University of Toronto. He is currently Director of the Forensic Anthropology Laboratory for the Harris County Institute of Forensic Sciences (HCIFS) in Houston, Texas. Before accepting the position with HCIFS Dr. Crowder was the chief forensic anthropologist for the Office of the Armed Forces Medical Examiner, which is the center of medical-legal investigations for the Armed Forces Medical Examiner System (AFMES). Other positions held previously by Crowder include Deputy Director of Forensic Anthropology Unit for the Office of Chief Medical Examiner, New York City, and Forensic Anthropologist for the Joint POW/MIA Accounting Command Central Identification Laboratory (JPAC CIL) in Hawaii. In addition to being a practitioner Crowder is adjunct faculty at Pace University, NYC and the University of Toronto, Ontario, Canada.

Eugénia Cunha is a Full Professor, University of Coimbra. She has been the National Consultant in Forensic Anthropology for the National Institute of Legal Medicine and Forensic Sciences in Portugal, where she is the Forensic anthropologist of the South Delegation. She has been the President of the Forensic Anthropology Society of Europe (FASE) since 2009, and she has been C-FASE-Honoris Causa Certified in Forensic Anthropology by FASE/IALM since 2014. She coordinates the Forensic Anthropology Laboratory of Coimbra University. She has 31 years of experience with human bones, including hundreds of forensic anthropology cases. She received a Ph.D. in Sciences, Physical Anthropology, University of Coimbra, 1994, and has been doing field and laboratory work in Portugal, Brazil, Kenya, Niger, East Timor, Mali, Mozambique, and Guinea. She has been giving key-note talks, teaching, and organizing forensic anthropology workshops/courses in several countries: Portugal, Brazil, Kosovo, Italy, Spain, Denmark, Turkey, Sri Lanka, Mexico, United States, and Saudi Arabia. She is the Coordinator of the Post-Graduation in Forensic Anthropology and of the Masters on Skeletal Biology and Human Evolution, University of Coimbra.

Tania Delabarde (Ph.D.) is a forensic anthropologist from the University of Strasbourg working in the Institutes of Legal Medicine in Paris and Strasbourg. She previously worked for the United Nations in the Office on Missing Persons and Forensic in Kosovo and in the Balkans for the International Criminal Tribunal for the Former Yugoslavia (ICTY). She has also worked in various countries in South America with training programs for the recovery and examination of skeletonized bodies. Her research focuses on the histological analysis of bone trauma and biological profiling, including phenotypes traits.

Marija Djurić received her M.D. in 1983, M.S. in 1988, and Ph.D. degree in 1991. Her current academic position is Full Professor of Anatomy at the Faculty of Medicine University of Belgrade, Serbia. Prof. Djurić is Head of Laboratory for Anthropology, expert consultant in forensic anthropology, and head of the Advisory Board of the Ph.D. program, Skeletal Biology. Her research focuses on bone histomorphometry and structural basis of bone fragility, age markers on the skeleton, and anthropological and pathological analysis of skeletal remains from archaeological and forensic context. Prof. Djurić is the head of very successful research grants,

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author of numerous publications in influential international journals, supervisor of many Ph.D. students, and course trainer in anthropology. Her field experience is related to the investigation of mass graves created in the recent wars in the Balkan area.

Malcolm J. Dodd (MBBS, FRCPA, DMJ [Path.], Assoc. Dip. MLT, MACLM, AAIMLT, FACBS, Grad. Cert. Health Prof. Ed.) is a senior forensic pathologist at the Victorian Institute of Forensic Medicine. He has visited the Solomon Islands 12 times, both to perform autopsies and to give evidence for Operation RAMSI. He has also worked for the United Nations in East Timor and Kosovo and was part of the first Australian response team following the 2005 Boxing Day Tsunami. Malcolm was part of a group of RAMSI and RSIP personnel who received the 2005 Founders Award of the International Homicide Investigators Association for their contribution to investigating the Marasa Village killings (see Archer and Dodd this volume). He has particular expertise in ballistics and is the author of *Terminal Ballistics: A Text and Atlas of Gunshot Wounds* (2005). Malcolm's experiences as a forensic pathologist involved in overseas operations are also documented in *Justice for the Dead: Forensic Pathology in the Hot Zone* (2006).

Victoria M. Dominguez received her M.A. in Human Skeletal Biology at New York University. She is currently pursuing a Ph.D. in anatomy at Ohio State University. Her research interests include bone biology, biomechanics, human versus nonhuman differentiation, and creating a better approach to osteological research by incorporating knowledge of anatomy. Her current research focuses on the propagation and accumulation of microdamage in the ribs.

Denise Donlon is curator of the Shellshear Museum of Physical Anthropology and a senior lecturer in the Department of Anatomy and Histology, University of Sydney. She has a Ph.D. in physical anthropology and a B.A. (Hons.) in archaeology. She coordinates courses in comparative primate anatomy and forensic osteology and supervises postgraduate students. Research interests include forensic anthropology of the Sydney region, dental and postcranial skeletal variation, and Australian Aboriginal burial archaeology. Recent publications include "Forensic Osteology" in Freckelton and Selby, *Expert Evidence* (with C. Briggs) (2013), and "Survival and Recovery of DNA from Ancient Teeth and Bones," with Adler, Haak, and Cooper, *Journal of Archaeological Science* (2011). She is a consultant to the NSW Department of Forensic Medicine and a member of the RAAF Specialist Reserves, where her role is in the recovery and identification of Australian war dead.

Claudia Rivera Fernández graduated in archaeology from the University of San Carlos, Guatemala, and is an experienced traditional and forensic archaeologist. Since early 1997 she has worked with the Guatemalan Forensic Anthropology Foundation (FAFG), on conflict-related cases of national significance such as Panzós, Chel, and Acul, among others. She has worked internationally, in a forensic capacity for the United Nations in their crimes against humanity investigations in Bosnia-Herzegovina and Kosovo, and given presentations on Guatemala's forensic anthropology investigations to audiences in the United States and several countries in Latin America. She is the Director of Forensic Sciences at the FAFG and responsible for the day-to-day running of the technical departments of forensic archaeology, forensic anthropology, and forensic genetics and the management of several hundred conflict-related forensic anthropological investigations during her leadership; she has also appeared as an expert witness in a number of high-profile trials, including the genocide trial of former general Efraín Ríos Montt in Guatemala's court for high-risk crimes.

Oran Finegan is the current Deputy Head of Forensics at the International Committee of the Red Cross (ICRC) and is based in Geneva, Switzerland. He previously served the ICRC in the field in both the Western Balkans and Iraq. Oran was born and grew up in Ireland but has spent most of his academic and working life outside the country. Through his studies he specialized in the field of Forensic Anthropology and began applying this knowledge more than 16 years ago in the Balkans. He has also undertaken postgraduate studies in the field of human rights and political theory. Oran has worked for a number of different organizations, including the International Criminal Tribunal for the Former Yugoslavia (ICTY) and the United Nations Committee on Missing Persons in Cyprus (CMP), where he has continued to apply his forensic expertise and share his experiences with scientists around the world, including in the Philippines and Cyprus.

Ambika Flavel is a Research Associate in Forensic Anthropology in the Centre for Forensic Science, University of Western Australia. She is currently focusing on research directed toward the development of population specific forensic standards for Western Australian individuals and geophysical methods of locating buried objects and human remains. Her career includes a combination of consultancy and training on international forensic and humanitarian platforms, primarily in locating and excavating clandestine graves and analyzing human remains for identification and repatriation. She has undertaken this work in Australia, Latin America, the Middle East, the Balkans, and Europe. Flavel is an osteoarchaeologist who completed a Bachelor of Science with Honors in Archaeology (UWA) and a Masters in Forensic Archaeology (Bournemouth University).

Luis Fondebrider, Honorary PhD., (Licenciado) is a forensic anthropologist and cofounder and current Director of the Argentine Forensic Anthropology Team, Equipo Argentino de Antropología Forense (EAAF). As a member of EAAF Luis has participated in forensic investigations in Argentina, Chile, Brazil, Bolivia, Peru, Paraguay, Colombia, Venezuela, Guatemala, El Salvador, Haiti, Croatia, Bosnia, Kosovo, Romania, Iraq, Philippines, Indonesia, Cyprus, Georgia, South Africa, Zimbabwe, Ethiopia, Sudan, Kenya, and Namibia. He worked as a consultant for Truth Commissions of Argentina, El Salvador, Haiti, Peru, and South Africa; International Criminal Tribunal for the Former Yugoslavia; Committee of Missing Persons of Cyprus; UN Secretary General Investigation Team for Democratic Republic of Congo; UN Commission of Inquiry on Darfur; Special Commission search of Che Guevara remains; Panel of Experts for Chile; Special Prosecutor Office of the Transitional Government of Ethiopia; International Committee of the Red Cross (ICRC) for the project “The Missing”; and the Medico Legal Institute of Colombia, among others.

Shari Forbes completed a Bachelor of Science (Hons.) in Applied Chemistry and Forensic Science and a Ph.D. (Forensic Chemistry) at the University of Technology Sydney (UTS) in Australia. From 2005 to 2012, she was an Assistant/Associate Professor and founding Director of the Forensic Science program at the University of Ontario Institute of Technology (UOIT) in Canada. In 2012 she returned to UTS as a Professor and ARC Future Fellow in the Centre for Forensic Science. Forbes is an invited member of the Australian Academy of Forensic Sciences and a member of the Australian and New Zealand Forensic Science Society (ANZFSS) and Canadian Society of Forensic Science (CSFS). She is the Pacific Officer for the Initiative on Forensic Geology, a directive of the International Union of Geological Sciences. Her research focuses on identifying an accurate chemical profile of decomposition odor using advanced

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Daniele Gibelli (M.D., Ph.D.) is assistant professor of human anatomy in the Department of Biomedical Sciences for Health—University of Milan, and member of LABANOF, Laboratorio di Antropologia e Odontologia Forense, Laboratorio di Antropologia e Odontologia Forense—University of Milan. He is author of more than 50 articles published in peer-reviewed journals and chapters of books concerning forensic anthropology, forensic anatomy, age estimation of the living, facial assessment, personal identification from video surveillance systems, sexual abuse, child maltreatment, and juvenile pornography.

Dr. Julia C. Goodin, Iowa Chief State Medical Examiner, is a native of Columbia, Kentucky. She graduated from Western Kentucky University in Bowling Green in 1979 and earned her Doctorate of Medicine from the University of Kentucky in 1983. Dr. Goodin received her training in anatomic and clinical pathology at Vanderbilt University Medical Center and was a fellow in forensic pathology at the Office of the Chief Medical Examiner in Baltimore, Maryland. She has held positions in the medical examiner's offices of Nashville, Tennessee, Albuquerque, New Mexico, and the Alabama Department of Forensic Sciences in Mobile, Alabama. Dr. Goodin is certified by the American Board of Pathology in anatomic pathology, clinical pathology, and forensic pathology. She is licensed to practice medicine and has been certified as an expert in the field of forensic medicine in courtrooms in several states. She is currently on the clinical faculty for the University of Iowa Medical School and Des Moines University.

Angélica Guzmán is a forensic anthropologist with seven years' experience working as a forensic specialist for international and governmental organizations, mainly in Latin America, before she joined the International Committee of the Red Cross (ICRC) in 2015. In Colombia she began work in the forensic context in 2010 with the National Institute of Legal Medicine and Forensic Sciences. She started coordinating the Laboratory of Forensic Anthropology in Meta-Colombia, and in 2010 she worked in the National Group of Forensic Pathology, supporting the implementation of forensic anthropology protocols and the analysis and identification of high profile medico-legal cases. Guzman has specialized in forensic anthropology and human right violations cases. Currently she is working for the ICRC, assisting with the management of forensic data and the improvement of the ICRC's data management tool for forensic investigations and human identification, especially for postconflict and developing country contexts.

Ian Hanson is Deputy Director, Forensic Science, Anthropology and Archaeology, for the International Commission on Missing Persons (ICMP), responsible for managing the operations and scientific process of search, location, recovery, and examination globally for the ICMP. He has 28 years of archaeological experience, undertaking field investigations, supervising and directing archaeological and forensic field teams, and supporting human rights and forensic investigations for UN ICTY, UNDPKO, FCO, ICMP, governments, and other agencies in the Balkans, Middle East, Central America, and Africa. From 2002 he lectured at Bournemouth University, developing archaeological excavation and forensic scene recovery methods, training courses, and management strategies for human rights and mass grave investigations. Having led forensic archaeology and anthropology M.Sc. degrees and supervised Ph.D. students to completion, he is now a Research Fellow at the university. He became an expert advisor for the National Police Improvement Agency (NPIA) in 2007 and a member of the U.K. Expert Panel for Forensic Archaeology in 2009, setting guidance and standards in the United Kingdom for

the Home Office Forensic Regulator. He has been a Member of the Chartered Institute for Archaeologists (MCIfA) since 2011. He joined the American Academy of Forensic Sciences (AAFS) in 2003 and was made Fellow in 2012.

Karl Harrison specializes in the field of forensic archaeology. He holds a Ph.D. that focused on archaeology and forensic science from the University of Reading, an M.Sc. in Forensic Archaeology from Bournemouth University, a Diploma in Crime Scene Examination from the University of Durham, and a B.A. (Hons.) in Archaeology and Ancient History from the University of Reading. In addition, he is a trained Crime Scene Examiner and Manager with seven years' experience of working in these roles within U.K. police forces. He is listed as an external adviser in forensic archaeology and ecology with the National Crime Agency and is a Member of the Forensic Archaeology Expert Panel, a specialist subgroup within the Chartered Institute for Archaeologists. Dr. Harrison has acted in the capacity of Forensic Archaeologist for the past 14 years, for LGC Forensics, the Forensic Science Service and Forensic Access, before becoming a founding Director of Alecto Forensics, a specialist forensic ecology provider in the United Kingdom. During this time he has lent his expertise to more than to investigations, including extended police searches for clandestine burials, the direction and conduction of forensic searches and excavations, and the recovery of human remains and associated evidence types. He lectures in Forensic Archaeology at Cranfield University, where his research interests include the construction of complex forensic strategies for no-body murder investigations and the reconstruction of structural fires preserved in the archaeological record.

Joseph T. Hefner is an Assistant Professor of Anthropology specializing in forensic anthropology and quantitative methods, with interests in forensic anthropology that include the estimation of ancestry using morphoscopic (cranial nonmetric) traits and cranial and postcranial metrics. The focus of his research is the standardization and quantification of morphoscopic traits with robust and appropriate classification statistics, including data mining techniques and machine learning methods. Dr. Hefner's professional activities center on forensic anthropological method and theory and statistical approaches to biological anthropology, including biodistance analysis, categorical data analysis, geometric morphometric methods, data excavation, and parametric/nonparametric classification statistics. He is a board certified forensic anthropologist (D-ABFA) and a member of the American Academy of Forensic Sciences.

Jarred T. Heinrich received his M.A. in Human Skeletal Biology from New York University and his Ph.D. from the Department of Anthropology at the University of Toronto. His research interests include skeletal biology, reconstructing past life conditions from bone microstructure, and advancing bone histology methodologies. His Ph.D. work focuses on spatially characterizing human cortical bone microstructure through the use of novel GIS-based methods to better understand the effect of nutritional and physiological stresses on bone remodeling processes.

Maciej Henneberg is the Foundation Wood Jones Professor of Anthropological and Comparative Anatomy in the Medical School, The University of Adelaide (since 1996). Formerly he was the Professor of Anatomy and Human Biology at the University of the Witwatersrand, Johannesburg, South Africa. He also held full-time academic positions at the University of Cape Town, The University of Texas at Austin, and Adam Mickiewicz University in Poznań, Poland, where he obtained his doctorate in 1976 and a higher doctorate in 1981. In 2002 Maciej was awarded the title Professor of Biological Sciences by the State President of Poland. Maciej's

research interests include all subdisciplines of biological anthropology and macroscopic anatomy of humans and vertebrates. These are documented in over 300 full-length journal papers and book chapters and 7 books and monographs. Maciej has also a keen interest in education and academic governance. He has supervised to successful graduation 20 doctoral students. Since 1976 he served as an expert witness for both prosecution and defense in Poland, Texas, South Africa, and Australia.

Michael J. Hochrein has been a Federal Bureau of Investigation Special Agent since 1988. He is currently assigned to the Laurel Highlands Resident Agency within the FBI's Pittsburgh Division. There he investigates a variety of federal violations including violent crimes, computer crimes, public corruption, and financial crimes. Before joining the FBI, Agent Hochrein was a field archaeologist and analyst on salvage and research projects. Specializing in historical archaeology, he worked for the Carnegie Museum of Natural History and University of Pittsburgh Cultural Resources Management Program. As an FBI Evidence Response Team member, Agent Hochrein develops and conducts research, teaches, publishes articles, and testifies in areas of geotaphonomy and forensic archaeology, as well as crime scene mapping and general evidence collection. As an FBI certified police instructor, Agent Hochrein has traveled to the Middle East, Africa, and Southeast Asia to assist in crime scene investigation training for national police organizations.

Thomas D. Holland (Ph.D., DABFA) received his Ph.D. from University of Missouri, Columbia. He has published in *American Journal of Physical Anthropology*, *American Antiquity*, *Journal of Forensic Sciences*, *Current Anthropology*, *Studies in Archaeological Method and Theory*, *Quaternary Research*, and *Plains Anthropologist*. Since 1992 Dr. Holland has been Scientific Director of the Department of Defense Central Identification Laboratory and is responsible for the recovery and identification of U.S. military dead. He has supervised excavations of aircraft crash sites and burial sites in China, North Korea, South Korea, Iraq, Kuwait, and Southeast Asia. Dr. Holland is Diplomate of the American Board of Forensic Anthropology, Fellow of the American Academy of Forensic Sciences, and a member of the American Society.

Matthew Holliday is Head of Western Balkans Program at the International Commission on Missing Persons. Before joining ICMP, Matthew worked extensively within the nongovernmental sector in the Western Balkans, assisting NGOs to develop programs that aim at dealing with the legacy of violent conflict and massive and systematic violations of human rights. He obtained a B.A. degree in East European Language, Literature, and Regional Studies from the School of Slavonic and East European Studies of the University of London and later an M.A. in History from University College London.

John Hunter (O.B.E., B.A., Ph.D., FSA, MCIfA, FCSFS) was appointed Professor of Archaeology and Ancient History at the University of Birmingham in 1996. Apart from following an extensive scheme of research excavation and survey in Scotland, he began to develop forensic archaeology in 1988 and has coauthored three books on the subject. He has been involved operationally throughout the United Kingdom, has also worked in Bosnia, Serbia, Kosovo, Iraq, and the Falklands, and routinely lectures to police and forensic professionals. He helped to found the Forensic Search Advisory Group, was a lead assessor for the former Council for the Registration of Forensic Practitioners (CRFP), and was primary in setting up the current validation system for forensic archaeology within the Chartered Institute for

Archaeologists. As an active field archaeologist he directs a small commercial organization (MFL Archaeology), which works within the development industry. Hunter is also a Royal Commissioner on the Ancient and Historical Monuments of Scotland, an appointee of the Cathedral Fabrics Commission for England at Worcester Cathedral, and sits on the National History Museum Scientific Advisory Panel (human remains). In 2011 he was awarded an O.B.E. for services to scholarship.

Etty Indriati (Ph.D.) practiced dentistry for several years before obtaining a Ph.D. in anthropology at The University of Chicago (1998). She is currently Head of the Laboratory of Bio and Paleoanthropology at the Faculty of Medicine, Gadjah Mada University. Etty was awarded the Albert A. Dahlberg Prize as a dental anthropologist (1996), the Kenneth Holland Award as a Fulbright scholar (1998), and the Women's International Science Collaboration from the American Association for the Advancement of Science, New York (2002). She has published in *American Journal of Physical Anthropology* and *Proceeding of the National Academy of Sciences*, among others, and is the author of *Antropology Forensik*, a textbook on forensic anthropology in Indonesia.

Peter Jones is the CEO of Icenica, an independent biotechnology consultancy providing expertise and know-how to a wide variety of organizations working on biological and business related problems. He has a B.Sc. and an M.Sc. from University of St. Andrews and a Ph.D. from the Council for National Academic Awards, obtained while working at the Laboratory of Molecular Biology, Cambridge. His Ph.D. was part of the foundations of the Human Genome Programme, and he was instrumental in developing a number of instruments and technologies to increase throughput. He moved into commercial biotechnology having developed new methods for the purification of DNA from difficult and forensic samples. This activity led to work on ancient DNA, as well as intellectual property and business development. In 2001 he was one of the first scientific advisors of the Inforce Foundation, and for the past six years he has worked on the Fromelles Project overseeing the genetics and DNA-related aspects.

Erin H. Kimmerle (B.A., M.A., Ph.D.) has worked as a forensic anthropologist for the United Nations, International Criminal Tribunal for the Former Yugoslavia as on missions in Kosova, Croatia, and Bosnia-Herzegovina. She has also worked as an osteologist for the National Museum of Natural History, Smithsonian Institution, in Washington, D.C. Erin currently holds a Visiting Assistant Professor position in the Department of Anthropology at the University of South Florida. Her current research areas include medico-legal investigations of human rights abuses and the application of virtual technologies to study skeletal biology and variation such as geometric morphometric analysis of craniofacial shape variation, facial reconstructions, and 3D imaging of skeletal trauma.

Dennis F. Klein (M.D.) is Deputy State Medical Examiner at the Iowa Office of the State Medical Examiner. He is also an Adjunct Clinical Assistant Professor at the University of Iowa School of Medicine and an Adjunct Associate Professor of Forensic Pathology at Des Moines University. Dr. Klein received his medical degree from the University of Vermont and his post-graduate training in pathology at the Beth Israel Hospital in Boston. His fellowship training in forensic pathology occurred at the Office of the Medical Investigator at the University of New Mexico. Klein is board certified by the American Board of Pathology in Anatomical, Clinical, and Forensic Pathology.

Ericka N. L'Abbé (Ph.D., D-ABFA) is an Associate Professor in Physical Anthropology at the Department of Anatomy, University of Pretoria. Her research focuses on modern human skeletal variation and the interpretation of bone trauma, with specific application to the forensic sciences. She is active in research with the national and international postgraduate students and is the curator of a large, modern South African skeletal collection (Pretoria Bone Collection). She has published numerous papers on forensic anthropology as applied to a South African context and frequently compiles reports on skeletal remains for forensic pathologists and the South African Police Service.

Louise Loe is currently Head of Heritage Burial Services for Oxford Archaeology, one of the United Kingdom's largest archaeology and heritage practices. She manages a team dedicated to all aspects of burial archaeology and has led projects on large archaeological assemblages including postmedieval and industrial period cemeteries and a rare Viking age mass execution burial from Weymouth, Dorset. Louise directed the excavation and analysis of WWI mass graves at Pheasant Wood, Fromelles (Northern France) and serves as the archaeology and anthropology expert on the data analysis team for the Fromelles Identification Board. Before joining Oxford Archaeology she was a lecturer in biological anthropology on forensic degree programs at Bournemouth University. She holds a Ph.D. in biological anthropology from the University of Bristol and is visiting research fellow at the University of Reading. She is lead author on Oxford Archaeology's monographs on Fromelles and the Weymouth Viking mass grave and has also published on perimortem skeletal trauma in relation to trench warfare and explosive munitions.

Gaille MacKinnon is a Lecturer in Forensic Anthropology and Archaeology at the Centre for Anatomy and Human Identification, University of Dundee, Scotland, where her research interests encompass conflict and battlefield archaeology, deliberate trauma, and forensic science and the law. She is a certified FA-1 forensic anthropologist of the Royal Anthropological Institute of Great Britain and Ireland and a MifA member of the Forensic Archaeology Expert Panel of the Chartered Institute for Archaeologists. In addition she is an expert practitioner in forensic archaeology and anthropology for the National Crime Agency, a member of the U.K. Home Office Disaster Victim Identification team, and a founding director of Alecto Forensics, a forensic ecology service provider in the United Kingdom. For the past 17 years, Ms. MacKinnon has been a consultant forensic anthropologist and archaeologist and has worked for a large number of police forces, military investigators, international government and nongovernmental organizations, and humanitarian agencies. Internationally her expertise in forensic anthropology and archaeology has been utilized in investigations of war crimes, crimes against humanity and genocide, mass fatality and terrorist incidents, transportation accidents, and natural disasters. In the U.K. domestic arena, she has worked on criminal investigations of murder, suspicious death, child abduction, historic child abuse, slavery and servitude, and clandestine grave search, location, and recovery.

César Sanabria Medina has a Ph.D. in human evolution, physical anthropology, and forensic anthropology from the Faculty of Medicine in University of Granada, Spain. Since 1999 he has been working at the National Institute of Legal Medicine and Forensic Sciences in Bogotá, Colombia, where he coordinated the Forensic Anthropology Service from 2004 to 2011. He is currently working on medico-legal cases of human remains resulting from social and political violence and enforced disappearances where identification is required. Besides his work as a forensic anthropologist, César has developed scientific research projects and currently provides

lectures to undergraduate and postgraduate students in the Faculties of Medicine and Law at the University Antonio Nariño.

Dawn M. Mulhern (B.Sc., M.A., Ph.D.) received her B.Sc. from Cornell University and her M.A. and Ph.D. from the University of Colorado at Boulder. She is Associate Professor of Anthropology at Fort Lewis College in Durango, Colorado. Her primary research areas are skeletal histology and paleopathology. She has worked as an osteologist for the National Museum of Natural History, Smithsonian Institution. She assists local law enforcement with forensic cases and is a forensic anthropologist for the Disaster Mortuary Operational Response Team (DMORT).

Amy Z. Mundorff (Ph.D.) is currently an Assistant Professor in the Department of Anthropology, at the University of Tennessee. She is a biological anthropologist specializing in forensic anthropology and disaster victim identification management. Much of her research focuses on managerial aspects of Disaster Victim Identification (DVI) and developing new techniques to locate clandestine burials. From 1999 to 2004 Amy was the Forensic Anthropologist for the Office of Chief Medical Examiner, the City of New York, where she analyzed forensic cases involving unidentified individuals and bone trauma. She helped direct mortuary operations for several disasters, including the World Trade Center attacks, the crash of American Airlines Flight 587, and the Staten Island Ferry crash. She consulted with the Netherlands Forensic Institute on the DVI operations following the crash of Malaysia Airlines 17 and was in Phuket, Thailand, following the 2004 Indian Ocean tsunami. She is a Fellow of the American Academy of Forensic Sciences. Her scientific articles have appeared in several professional journals and textbooks. She earned a B.A. in anthropology from Syracuse University in 1991, an M.A. in anthropology from California State University, Chico, in 1999, and a Ph.D. in anthropology from Simon Fraser University in 2009.

Jolandie Myburgh is a Senior Technical Assistant at the Department of Anatomy, School of Medicine, University of Pretoria. She received her B.Sc. degree in Physical Anthropology and her M.Sc. degree in Anatomy from the University of Pretoria. Her research interests are in the areas of decomposition and taphonomy as well as the study of secular trends in the human body. She is currently completing her Ph.D. on the secular trend in limb proportions of South African population groups. She is a member of the Anatomical Society Southern Africa and the American Academy of Forensic Sciences. Since joining the Department of Anatomy in 2009 she has been actively working in the Forensic Anthropology Research Centre (FARC) as the laboratory coordinator. She is responsible for maintaining all activities involved in the identification of unknown human remains received from pathologists and the South African Police Service (SAPS). She has over seven years' experience in the organization and maintenance of a forensic anthropology laboratory and is actively involved in the maceration and handling of human remains. Myburgh has over eight years' experience in the field of osteology and has analyzed over 60 cases of a forensic nature since her appointment.

Stephen P. Nawrocki received his M.A. and Ph.D. from the State University of New York at Binghamton. He has taught anatomy and forensic science at the University of Indianapolis since 1991 and is the Director of its Graduate Program in Human Biology. In 1996 Stephen became certified as a Diplomate of the American Board of Forensic Anthropology. For 23 years he served as the primary consulting forensic anthropologist for the state of Indiana, handling hundreds of human remains cases and developing the region's first dedicated forensic archaeology outreach

program. Recent research interests include the statistics of age estimation from the skeleton, human decomposition and estimation of the postmortem interval, the taphonomy of mountain gorilla burials in highland Rwanda, and the social history of antituberculosis campaigns.

Kimberly Nugent obtained a Bachelor of Science (Hons.) in Physical Anthropology and a Master of Science from the University of Toronto in Canada. She is an active member of the Canadian forensic science community and General Section Chair of the Canadian Society of Forensic Science (CSFS). Nugent is a Senior Lecturer at the University of Ontario Institute of Technology (UOIT) in the accredited undergraduate Forensic Science Program, where she launched the UOIT Crime Scene House teaching facility, the first of its kind in Canada. Her focus is on undergraduate education and curricula development in a forensic context.

Thomas Parsons joined the ICMP as Director of Forensic Sciences in 2006. He has served on the Scientific Advisory Board of the ICMP since 2000 and in 2005 was appointed Chairman of the ICMP Steering Committee on Forensic Sciences. Before joining the ICMP, Dr. Parsons was Chief Scientist at the U.S. Armed Forces DNA Identification Laboratory (AFDIL), where he had worked since 1994, and where one of his primary roles was to direct the AFDIL Research Section. He is also an adjunct faculty member in the Department of Genetics and the Department of Forensic Sciences at George Washington University. He received a Ph.D. in Biochemistry from the University of Washington in 1989. As a postdoctoral fellow at the Smithsonian Institution in Washington, D.C., and during research faculty appointment at the University of Nebraska, Dr. Parsons focused on molecular evolution and population genetics.

João Pinheiro is the Vice-President of the Portuguese National Institute of Forensic Medicine (INMLCF) and the Director of its Central Portugal Regional Branch. He is an M.D. (University of Coimbra 1983) and M.S. (University of Coimbra 2006). He is a Senior Forensic Doctor with 25 years of professional experience, including more than 3,300 autopsies, 7,300 clinical forensic exams, and hundreds of forensic anthropologic exams. He worked for the United Nations and International Criminal Tribunal for the Former Yugoslavia, initiative to document crimes against humanity, first in Kosovo (2000) and then in Bosnia-Herzegovina (2001). He directed the Forensic Pathology Department of the Central Portugal Regional Branch between 2006 and 2007. He authored a total of more than 250 publications, including peer-reviewed articles in the national and international scientific literature, oral communications, and conference proceedings, mostly on forensic pathology, sudden infant death syndrome, and drug abuse. He regularly contributes for forensic anthropologic and pathology books in the United States and the United Kingdom, having authored or coauthored eight independent chapters. He has been the Professor of Anatomy at the School of Health Technologies at the Coimbra College for 23 years, and he has taught several graduate courses in Forensic Pathology and Anthropology in Portugal, France, South Africa, Spain, the United Kingdom, and the United States.

José L. Prieto (M.D., D.D.S., Ph.D.) earned the post of forensic doctor in 1988 and soon linked his activity to forensic anthropology, setting up first forensic anthropology laboratory inside the Spanish forensic system (Madrid Forensic Institute), which he headed from 1992 to 2008. Cofounder of the Forensic Anthropology Society of Europe (FASE) and the Spanish Association of Forensic Anthropology and Odontology (AEAOF), Prieto took active part in the development of the Latin American Association of Forensic Anthropology and Odontology (ALAF) certification process. Since 2006 his professional activities have been linked with humanitarian action, as a forensic consultant for international organizations and institutions in a variety of

contexts and scenarios around the world. He is currently a member of the Forensic Advisory Board of the International Committee of the Red Cross (ICRC) and has also contributed to work undertaken by the Argentine Forensic Anthropology Team (EAAF). At a national level he has been involved in cases related to the missing from the Spanish Civil War (1936–1939) and also works as a consultant for the Ombudsman Office in the National Mechanism of Prevention of Torture.

David Ranson is a medical practitioner and specialist anatomical pathologist (histopathologist) and forensic pathologist with qualifications in both medicine and law. He is Deputy Director of the Victorian Institute of Forensic Medicine, Director of the National Coroners Information System, and heads the specialist death investigation unit at the Institute. He has published widely in the field of forensic medicine and medical law and is the author and editor of a variety of texts in this area. He has produced medico-legal policy and research reports for government and private agencies and has given evidence to parliamentary and senate inquiries on matters relating to forensic medicine. Internationally, he has taken part in the investigation of mass fatalities occurring in civil and military contexts and has been a visiting International Expert in Forensic Pathology at the Health Sciences Authority in Singapore.

Tracy L. Rogers is the Director of the Forensic Science Program at the University of Toronto Mississauga and an Associate Professor in the Department of Anthropology. She is a forensic anthropologist and has completed casework for the Ontario Forensic Pathology Service, the British Columbia Coroner's Service, the Royal Canadian Mounted Police, and several other police agencies in British Columbia and Ontario and has worked as the primary forensic anthropologist during the investigation of serial killer Robert Pickton's property. Her research program centers on personal identification, including methods of assessing ancestry, estimates of age, establishment of positive identification, and the development of a morphological method of assessing skeletal sex from the distal humerus. She is also studies taphonomy, trauma analysis, and crime scene reconstruction.

Ann H. Ross (B.A., M.A., Ph.D.) is Assistant Professor of Anthropology at North Carolina State University. She is a physical anthropologist with a subspecialty in forensic anthropology and bioarchaeology and a specialty in human identification and trauma analysis. She received her education from the University of Tennessee. Her research focus includes developing population-specific identification standards using traditional measurement techniques and modern 3D methods. She has participated in human rights missions in Bosnia and the Republic of Panama and also consults on a regular basis for the Republic of Panama Institute of Legal Medicine and occasionally on local cases in North Carolina.

Samantha K. Rowbotham is a doctoral student with the Department of Forensic Medicine, Monash University. Her Ph.D. research is exploring the morphology and distribution of skeletal fractures with falls using computed tomography applications. Samantha has previously completed a Bachelor of Arts (Archaeology) at the University of Queensland and a Master of Archaeological Science (Research) (First Class Honors) at the Australian National University. Since 2009 she has been involved with archaeological excavations, osteology research, and bioarchaeology teaching projects in Asia, Europe, Central America, and Australia. She has worked as a research assistant with the Australian National University and as an archaeological consultant in Western Australia and is currently a forensic anthropology research assistant in Melbourne.

Dominic Salsarola is a forensic archaeologist and, since the mid-1980s one of the senior managers of SLA, Società Lombarda di Archeologia; he is also member of LABANOF, Laboratorio di Antropologia e Odontologia Forense—University of Milan, having been the organization's forensic archaeologist since the mid-1990s. He has been called on by Italian judicial authorities as an expert witness in the capacity of search manager and director for the recovery of evidence in over 50 searches regarding hidden human remains, illegally detained weapons, and stolen goods.

Norman J. Sauer (Ph.D.) is Professor Emeritus of Anthropology and retired Director of the Forensic Anthropology Laboratory at Michigan State University. He is past Chair and Secretary of the Physical Anthropology section of the American Academy of Forensic Sciences and served on the Board of Directors of the American Board of Forensic Anthropology. He is currently Vice President of the American Academy of Forensic Sciences (2015–2016). Dr. Sauer has lectured in forensic anthropology throughout the United States, Europe, and China. A regular consultant to a number of local, state, and federal law enforcement agencies, he has been interested in the concept of “race” in anthropology throughout his career.

Mark Skinner Since 1978 Dr. Skinner (B.A. [Hons.], Ph.D.) has assisted Canadian law enforcement agencies with the field recovery of (semi)skeletonized human remains from crime and noncrime contexts. Up to December 2009 was consulted in Canada on 536 instances involving 356 human remains cases, of which 202 were recent deaths. Dr. Skinner has testified as an expert witness in forensic anthropology in Provincial and Supreme Courts of British Columbia on 13 occasions (including preliminary hearings). Between 1997 and 2003 he investigated allegations of mass graves in Afghanistan (1997 UNHCHR)—10 casualties; Bosnia (1998 Physicians for Human Rights)—335 casualties; East Timor (1999 UNTAET)—10 casualties; and Yugoslavia (2001 International Commission on Missing Persons)—423 casualties. In 2003 he examined approximately 80 sets of remains for ICMP. In 2004 to 2005 he became the Director of Forensic Sciences for the International Commission on Missing Persons (Sarajevo), where he managed the activities of more than 120 employees (nationals and internationals). He supervised the Heads of DNA labs, Coordination Centre, Excavations and Examinations, and Bioinformatics. He helped create the Lukavac Re-Association Centre in Tuzla, to deal with commingled remains from secondary graves from the fall of Srebrenica. He held this post for one year and then returned to Simon Fraser University, where he provided expertise (23 autopsies in Pristina) to the U.K.-based Defense Team for former Kosovo Prime Minister Ramush Haradinaj, charged with war crimes. Through 2009 He directed the Forensic Osteology Group at SFU, which provides forensic anthropology consulting service to the Office of the Chief Coroner. In late 2007 he became Codirector of the Centre for Forensic Research, Simon Fraser University. He retired from consulting in 2010 but continued to assist with various Innocence Projects. Mark has relinquished his status as a Diplomat to become a Professor Emeritus and visiting scholar at University of York, where he works primarily on developmental stress in recent and fossil apes.

Paul Sledzik is Director of the NTSB's Transportation Disaster Assistance Division. Paul joined the Board in 2004 after serving for six years as the team leader for the Region 3 Disaster Mortuary Operational Response Team, a division of the U.S. Department of Health and Human Services, where he managed a team of 100 forensic scientists and mortuary specialists in mass fatality response. During his career he participated in the victim identification and recovery efforts in over 30 mass fatality events and transportation accidents. For 15 years he served as a

forensic anthropologist and museum curator at the National Museum of Health and Medicine of the Armed Forces Institute of Pathology. As a forensic scientist he has consulted for the Joint POW/MIA Accounting Command/Central Identification Laboratory, the National Center for Forensic Science, the National Center for Missing and Exploited Children, and the U.S. Soldier Biological and Chemical Command. He is a Fellow of the American Academy of Forensic Sciences. Paul's scientific articles have appeared in several professional journals and textbooks. He earned a B.A. in anthropology from the University of Rhode Island in 1984 and an M.S. in biological anthropology from the University of Connecticut in 1988.

Dawnie Wolfe Steadman received her Ph.D. from the University of Chicago and is currently the Director of the Forensic Anthropology Center and Professor of Anthropology at the University of Tennessee. Her research interests include trauma, pathology, taphonomy, bioarchaeology, human identification, and forensic human rights investigations. Dr. Steadman is a Diplomate of the American Board of Forensic Anthropology and serves as a forensic anthropological consultant for law enforcement and medical examiners. She assisted in the identification efforts at the World Trade Center, the Tri-State Crematorium in Noble, Georgia, and the crash of Colgan Air Flight 3407.

Carl N. Stephan is a Senior Lecturer at the School of Biomedical Sciences, The University of Queensland, Australia, and former ORISE Research Participant and Anthropologist at the DoD Central Identification Laboratory, Hawaii (JPACCIL). He is an anatomist and biological anthropologist with a special interest in craniofacial identification and radiographic comparison. Currently he heads the Laboratory for Human Craniofacial and Skeletal Identification at UQ (HuCSID Lab). Dr. Stephan is a fellow of the American Academy of Forensic Sciences and editorial board member for the *Journal of Forensic Sciences*. Since completing his Ph.D. in 2003 he has published more than 45 scientific research articles targeting improvements of craniofacial identification methods, in particular facial approximation.

Jon Sterenberg is a Consultant Archaeologist with over 30 years of experience as a field archaeologist. He has extensive experience in all types of archaeological fieldwork, including diverse historical sites from Neolithic to the present. Sterenberg also has extensive experience in forensic excavation and recovery and has been involved in investigations with governmental and international forensic teams on sites in the United Kingdom, the former Yugoslavia (Bosnia and Herzegovina, Croatia, and Serbia), West and Central Africa, Iraq and Kurdistan, East Timor, the Solomon Islands, and Papua New Guinea. Since 2007 he has been working as a consultant archaeologist for archaeological companies on sites within Australia.

Maryna Steyn is a physical anthropologist who initially qualified as a medical doctor in 1983 (University of Pretoria) and subsequently obtained a Ph.D. from the University of the Witwatersrand in 1994. As a specialist in human skeletal remains, she consults to the South African Police Service on decomposed and skeletonized human remains. She conducts research on human remains from forensic contexts and archaeological sites, focusing on skeletal identification and paleopathology. She has a National Research Foundation (NRF) rating and has published more than 100 papers in scientific journals, as well as several book chapters. She is coauthor of *The Human Skeleton in Forensic Medicine* (2013). Steyn is a member of the editorial board of *Forensic Science International* and is the director of the Forensic Anthropology Research Centre (FARC).

Kevin Sullivan is Senior Communications Manager at the International Commission on Missing Persons. Formerly a newspaper correspondent, he worked for many years in Asia and Southeast Europe, covering key events including the conflict in Bosnia and Herzegovina. He joined the Office of the High Representative in Bosnia and Herzegovina in 2001 as a spokesperson and speechwriter, and ICMP in October 2014. He has published several books, including *Out of the West*, a study of political violence set in Greece in the late 1940s.

Tim Thompson is a Professor of Applied Biological Anthropology at Teesside University. Before coming to Teesside Tim studied for his Ph.D. at the University of Sheffield (Faculty of Medicine) and was a Lecturer in Forensic Anthropology at the University of Dundee. He has published over 50 papers in peer-reviewed journals and books and is a renowned expert on heat-induced apatite and crystallinity changes in bone. Tim's main areas of research focus on the human body and how it changes, particularly in the modern context. Here most of his research examines the effects of burning on the skeleton and the development of new analytical tools to examine this challenging biomaterial. Tim is also interested in the relationship between the biological and social body (again particularly in the modern context) and the role of forensic anthropology/ists in the world at large. He is the Editor-in-Chief of the journal *Science & Justice* and is on the editorial boards for the *Journal of Forensic Sciences*, *Journal of Forensic and Legal Medicine*, and *Human Remains and Violence: An Interdisciplinary Journal*. He is a Fellow of the Forensic Science Society and the Royal Anthropological Institute and is a practicing forensic anthropologist who has worked at home and abroad in a variety of forensic contexts.

Douglas H. Ubelaker is a curator and senior scientist at the Smithsonian Institution's National Museum of Natural History. He has served as a consultant in forensic anthropology and has testified in numerous legal proceedings. He is a lecturer at George Washington University, as well as an adjunct professor at Michigan State University. Ubelaker has published extensively in the general field of human skeletal biology with an emphasis on forensic applications and has served on the editorial boards of numerous leading scientific publications. He is a Fellow of the American Academy of Forensic Sciences and has received numerous honors from both American and international organizations.

Priscilla F. Ulguim is currently a Ph.D. researcher at Teesside University; her work is focused on bioarchaeology, burned bone analysis, cremation, and South American archaeology. She completed an M.Sc. in Bioarchaeology (Human Osteology) at the University of Exeter as a Wenner-Gren Foundation scholar, supervised by Prof. Christopher Knüsel, and her undergraduate education resulted in a first-in-class History degree from the Universidade Federal de Pelotas (Brazil). Her doctoral research will apply advanced analytical methods to cremated human remains from archaeological mound and enclosure complexes in the southern Brazilian highlands in order to understand the individuals involved and to interpret the nature of the funerary process. She has another two chapters on her research in this area in press and has worked on related international academic projects. Her other research has focused on zooarchaeological analyses of southern Brazilian Cerritos sites and Guaraní occupations. She is a Research Associate at LEPAARQ, UFPEL; collaborator in the Jê Landscapes of Southern Brazil project and the Alfred Russel Wallace Correspondence Project (Natural History Museum, London); and an active member of BABAO (British Association for Biological Anthropology and Osteoarchaeology) and ABRAF (Associação Brasileira de Antropologia Forense), among other organizations.

Jane C. Wankmiller is the Unidentified Remains Coordinator for the Michigan State Police (MSP) Missing Persons Coordination Unit (MPCU), which was established by the department in December of 2014, and she serves as a forensic artist for the MSP Forensic Art Unit. She is also a Medical Examiner Investigator with the Ingham County, MI, Office of the Medical Examiner, where she has been employed for over three years and has investigated more than 150 deaths. Before starting her position within the MPCU, she worked for the MSP Digital Analysis and Identification Section for two years. Wankmiller is a Ph.D. candidate at Michigan State University in the Department of Anthropology and holds master's degrees in anthropology and forensic science, with a focus in forensic anthropology. She earned her Bachelor of Science Degree in Archaeology from Towson University in 2001. Wankmiller has represented her agency on the Facial Identification Scientific Working Group (FISWG) since November of 2010 and is a voting member on the Facial Identification Subcommittee under the NIST Organization for Scientific Area Committees.

P. Willey (Ph.D., D-ABFA) is a semiretired professor at Chico State, California, where he has taught courses in physical anthropology since 1989. Before moving there he curated the Bass Skeletal Collection at the University of Tennessee. In addition to stature estimation his research interests include human skeletons resulting from battles and massacres, footprints left by pre-historic cavers, and illnesses suffered by Seventh Cavalry troopers in the post-Civil War period. He has authored more than 100 publications on those and other subjects. In the area of forensic applications he has written more than 150 forensic case reports, served JPAC CIL as an external consultant, and was senior anthropologist for the Regime Crimes Liaison Office's work on Iraqi mass graves in 2004.

Richard Wright (M.A.) is Emeritus Professor of Anthropology at the University of Sydney, Australia. His interest in forensic archaeology, mass graves, and execution sites developed in 1990–1991, when the Australian government employed him to investigate mass graves in Ukraine originating from the Holocaust of World War II. From 1997–2000 he was Chief Archaeologist for the International Criminal Tribunal for the Former Yugoslavia (ICTY). In that role he led an international team of archaeologists and anthropologists whose job was to locate mass graves, examine the evidence contained in them, and recover the bodies. He specialized in interpreting body disposal sites following the Srebrenica massacre and has given expert testimony at several war crimes trials in The Hague. In 2009 he was Senior Forensic Adviser to Oxford Archaeology during their exhumation and anthropological study of 250 soldiers from World War I mass graves at Fromelles, in northeastern France. He is the author of CRANID, a multivariate package designed to identify ancestry from craniometric data.

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Forensic Anthropology and Archaeology

Moving Forward

Soren Blau and Douglas H. Ubelaker

Since the first publication of this volume in 2009 the disciplines of forensic anthropology and archaeology have continued to develop, albeit at different rates depending on the context. While some countries lack formalised recognition of the disciplines and therefore make limited use of forensic anthropologists and archaeologists in domestic context, other countries have sought to bring the disciplines into the mainstream through the formalisation of accreditation of practitioners, development of structured university courses, and increased support for detailed research. Following the expanded use of forensic anthropologists and archaeologists in the mid-1990s in postconflict locations, the role of the disciplines in international contexts (for example, international criminal tribunals) in locating, recovering, recording, and analysing physical evidence to prosecute major human rights abuses involving mass killings is now well established.

The media continue to feed the public's continued fascination with "forensic" subjects. A glance at the television guide on any night provides more than one show involving death, foul play, bodies, and forensic investigations. Moving beyond simulations of death and dead bodies, reality TV facilitates depictions of dissection of a human cadavers¹ (Chan 2002; Goeller 2007) and decomposition of human bodies (Carvajal 2004; Deans & Plunkett 2004). Living in a time that has been described as "the postmortem condition" (Whitehead 1993), students of forensic anthropology and archaeology must have an accurate understanding of the role that forensic anthropologists and forensic archaeologists play in investigations and a solid foundation in both the practical and ethical components of the disciplines.

Forensic anthropology has been diversely defined by practitioners as:

- "that branch of physical anthropology, which, for forensic purposes, deals with the identification of more-or-less skeletonized remains known to be, or suspected of being, human" (Stewart 1979: ix);
- "a multidisciplinary field combining physical anthropology, archaeology and other fields of anthropology with the forensic sciences, including forensic dentistry, pathology and criminalistics" (İşcan 1981: 10);
- "a subdiscipline of physical anthropology that applies the techniques of osteology and biomechanics to medicolegal problems" (Reichs 1998a: 13);

- “an applied branch of biological anthropology whose scientists analyze skeletal remains for both legal and humanitarian purposes” (Walsh-Haney & Lieberman 2005: 121);
- “the identification of the human, or indeed the remains of the human, for medico-legal purposes” (Black 2006);
- “the application of knowledge and techniques of physical anthropology to problems of medicolegal significance” (Ubelaker 2006: 4);
- “the application of physical anthropology to the forensic context” (Cattaneo 2007: 185);
- “the field of study that deals with the analysis of human skeletal remains resulting from unexplained deaths” (Byers 2011: 1).

These definitions range from the broad to the specific and reflect the complexity of the discipline and the diverse applications of forensic anthropology (İşcan & Loth 1997; Cattaneo 2007). Although all definitions acknowledge the importance of the legal aspects of the work, practitioners have moved from examinations of “more-or-less skeletonized” remains (Stewart 1979: ix) to those that involve the living person (Black, Aggrawal, & Payne-James 2010). The contributions to this volume reflect the wide-ranging applications of forensic anthropology.

Forensic archaeology is defined as the application of archaeological principles and techniques within a medico-legal and/or humanitarian context involving buried evidence. Since the late 1907s and early 1980s, when the potential of archaeology to augment the utility of evidence recovered from a crime scene was recognised (for example, Morse, Crusoe, & Smith 1976; Skinner & Lazenby 1983), we have seen reminders of why anthropologists need archaeologists (Owsley 2001), discussion about the future of forensic archaeology in forensic science (Scott & Connor 2001), and a series of journal articles and textbooks detailing technical aspects (such as Killam 1990; France et al. 1992; Hunter et al. 2001; Hunter & Cox 2005; Dupras et al. 2006; Cox et al. 2008; Hunter, Simpson, & Sturdy Colls 2013; Ruffell, Pringle, & Forbes 2014).

In North America archaeology has typically fallen under the general umbrella of “anthropology,” and in Latin America there is no distinct division between the disciplines. But in Britain, and now increasingly in the United States, professionals are pushing to distinguish archaeology and anthropology as separate disciplines. The distinct yet heavily connected contributions made by the two disciplines to forensic investigations are illustrated in this book.

Since the increasing formalisation of forensic anthropology in many countries various publications have examined the history of its development (for example, Snow 1982; İşcan 1988, 2000, 2001; Reichs 1992; Rodriguez 1994; Reichs 1998a; Ubelaker 2000, 2004, 2006), current status (such as France: İşcan & Quatrehomme 1999; United Kingdom: Black 2000; Hungary: Susa 2007; Turkey: Gülec & İşcan 1994; Europe in general: Hunter et al. 2001; Kranioti & Paine 2011; Latin America: İşcan & Olivera 2000), as well as new perspectives (Cattaneo 2007; Dirkmaat et al. 2008). General textbooks have also appeared (for instance, Stewart 1979; Morse, Duncan, & Stoutamire 1983; Krogman & İşcan 1986; Reichs 1998b; Burns 1999; Cox & Mays 2000; Klepinger 2006; Schmitt, Cunha, & Pinheiro 2006; Komar & Buikstra 2008; Medina 2008; Pickering & Bachman 2009; Byers 2011; Dirkmaat 2012; Christensen, Passalacqua, & Bartelink 2014; Delabarde & Ludes 2014), along with a wealth of peer-reviewed journal articles (too numerous to list) demonstrating and critiquing technical methodologies, particularly as related to the refinement and development of population-specific techniques (for example, İşcan & Shihai 1995; Jantz & Jantz 1999; Ross & Konigsberg 2002; Dayal, Steyn, & Kuykendal 2008; Bassed et al. 2011; Franklin et al. 2012, 2014), and papers detailing case studies (such as Rathburn & Buikstra 1984; Steyn, Meiring, & Nienaber 1997; Fairgrieve 1999; Komar 2003; Steadman 2003; Brickley & Ferllini 2007). Until recently (for example, Groen, Márquez-Grant, & Janaway 2015; Ubelaker 2015) at the regional level publications typically dealt separately with forensic

anthropology and forensic archaeology (such as Cox & Mays 2000 in Britain; Steadman 2003 in the United States). This second edition of *Handbook of Forensic Anthropology and Archaeology* aims to provide the reader with an updated, comprehensive work that includes a compilation of histories and current states of the disciplines from several different (although unfortunately not totally representative) parts of the world, a summary of updated technical aspects of analyses, and examples of current practice (case studies).

To demonstrate the scope of the disciplines, this volume brings together contributions from a diverse range of highly experienced forensic anthropology and forensic archaeology practitioners from different countries.

- 1 All authors from the first edition were invited to revise and update their chapters for this second edition, and the majority accepted.²
- 2 Authors chose to either update their chapter alone or to enlist coauthors, some of whom are well established and others who are up and coming in their fields. In two cases (Chapters 2 and 8) the original authors suggested entirely new authors and chose not to be included in the second edition.
- 3 Four new chapters are included in the second edition. The contributors present descriptive and critical evaluations of standard techniques in addition to discussing new methodologies.³

Organisation

The book is divided into five sections that cover the depth and breadth of forensic anthropology and archaeology. Part I, History of the Disciplines, provides overviews of the development and current state of forensic anthropology from different regional perspectives, including European (British—Gaille MacKinnon and Karl Harrison; Italian—Cristina Cattaneo; French—Tania Delabarde and Eric Baccino; and Spanish—José Prieto); North and South American (Douglas Ubelaker, Mark Skinner, Kristina Bowie, Luis Fondebrider, Angélica Guzmán, and César Sanabria Medina); Australian (Denise Donlon); Indonesian (Etty Indriati); and South Africa (Maryna Steyn, Ericka N. L'Abbé, and Jolandie Myburgh). These contributions include historical perspectives detailing the contributions made by early practitioners in each context, discussions about the development of education, training, and accreditation, and presentations of case studies illustrating some of the strengths and weaknesses in approaches to casework and research in different regions. Part I illustrates the different ways in which the discipline has developed and reflects diverse social and political contexts.

The level of detail of information that the forensic anthropologist can provide—whether relevant to differentiating human from nonhuman, commenting on the postmortem interval, assisting with identification and/or forming an opinion about skeletal trauma—is fundamentally determined by the condition and the preservation of the remains. It is, therefore, fundamentally important that complete and accurate recovery of skeletal remains (regardless of their condition and preservation), and information on their associations with one another and other items, are undertaken at a crime/disaster scene. Such recovery relies on controlled excavation employing archaeological techniques. Part II, Forensic Archaeology, thus details current practices in forensic archaeology with a focus on methodologies employed in the search, location, and recovery of various types of evidence associated with crime and disaster scenes.

Thomas Holland and Samuel Connell outline traditional methods, including surveying and testing (probing, coring, and limited excavation), as well as covering remote sensing techniques (including resistivity, magnetometry, and ground-penetrating radar). Paul Cheetham and Ian Hanson discuss the importance of involving archaeologists in the excavation and recovery of

human remains, detailing the skills required. They outline the important notion that there is no “normal” way to excavate a site and that the key concept is to be flexible and to adapt to each unique scene. The ability to select appropriate field methods and therefore obtain results has important legal implications, which are also considered.

Part III, Forensic Anthropology, includes 15 revised chapters that provide information about the fundamental types of analyses undertaken by forensic anthropologists. The contributors provide a background to techniques employed by practitioners and discuss the advantages and limitations of specific methodologies. Dawn Mulhern provides a comprehensive discussion about what is often the initial responsibility of the forensic anthropologist: to determine whether the remains are human or nonhuman. Gross, microscopic, chemical, and biomolecular approaches are detailed.

Shari Forbes and Kimberly Nugent examine one of the more challenging aspects of forensic anthropology—determination of the postmortem interval. They provide an insight into the history of attempts to determine time since death from the analyses of skeletal remains detailing morphological, chemical, immunological, and radioisotopic analyses. The potentially significant effects of environmental conditions on estimating time since death are also considered.

John Byrd and Bradley Adams examine how forensic anthropologists manage cases of commingled remains, a problematic aspect of many anthropological analyses on both small and large scales. They consider the effects of field recovery techniques in dealing with commingled remains and then detail the techniques used to sort such remains, including visual pair-matching, articulation, size and shape comparison, robusticity, taphonomy, and DNA analysis. Another important aspect of dealing with commingled remains includes quantification. Byrd and Adams outline two main techniques: minimum number of individuals (MNI) and most likely number of individuals (MLNI). Finally, they discuss ethical considerations associated with managing commingled remains.

The development of a biological profile involves providing information about deceased individuals when they were alive from analyses of their skeletons. A biological profile includes information concerning the deceased's ancestry, sex, age at death, and stature. Such information does not typically identify the deceased person but rather provides the parameters of a possible identity (for example, Caucasoid male, aged 20–30 years with a stature of 170–180 cm) and therefore assists in narrowing the search pool. Techniques employed by the forensic anthropologist to establish an individual's biological profile are extensively examined in several chapters.

Norman Sauer, Jane Wankmiller, and Joseph Hefner discuss the relationship between race and ancestry in forensic anthropology. They detail the methods developed by anthropologists to estimate ancestry and some of the relevant philosophical and ethical issues. Samantha Rowbotham provides an outline of the historical development of scientific research into sexual dimorphism and then details the key morphological and metric techniques used by forensic anthropologists to estimate the sex of an individual. This is followed by Tracy Rogers's in-depth discussion on adult and subadult morphological ageing techniques. Well-established histological methods of age estimation are explored by Christian Crowder, Jarred Heinrich, and Victoria Dominguez, who also look at the problems associated with the acceptance of these methods as a conventional tool for the estimation of age at death. The final aspect of the biological profile, stature, is detailed in Patrick Willey's chapter. The process of estimating adult stature from skeletal remains and comparing that estimation with antemortem height is discussed, as are issues affecting the accuracy of stature comparisons.

Although cause and manner of death are fundamentally the responsibility of the forensic pathologist (cf. Roberts 1996: 101), the forensic anthropologist can make a significant contribution to the recording and interpretation of skeletal trauma. Consequently, considerable attention

is given to the forensic anthropologist's role in examining trauma. Eugénia Cunha and João Pinheiro examine all aspects of the analysis of antemortem trauma, and Louise Loe provides a detailed discussion of the principles of perimortem trauma, synthesising the current theoretical and practical issues associated with this analysis of skeletal remains recovered from forensic contexts. This chapter is followed by Stephen Nawrocki's discussion of postmortem alterations.

Forensic anthropologists deal with human remains from a number of different contexts, many of which involve heat-induced transformation. Tim Thompson and Priscilla Ulguim provide a critical summary of the work undertaken on burnt human remains to date, highlighting specific investigative techniques.

Carl Stephan and Peter Claes examine craniofacial identification, including techniques of facial approximation and craniofacial superimposition. They detail the history of the development of craniofacial identification summarising the tested and untested guidelines for a range of specific techniques. They also examine the genetic determinants of facial morphology and outline how a DNA-based prediction of visible external features can now be undertaken to supplement and assist craniofacial identification techniques. The role of the forensic odontologist is discussed in detail by John Clement, who outlines the techniques used by odontologists to estimate age and identify individuals.

Part IV, *The Crime and Disaster Scene: Case Studies in Forensic Archaeology and Anthropology*, provides the reader with a selection of case studies illustrating the ways in which forensic anthropologists and archaeologists contribute to the investigation of domestic homicides and atrocities that have been inflicted as a result of ethnic, religious, and/or political violence, as well as to the management and identification of deceased people following mass disasters. Dawnie Steadman, William Basler, Michael J. Hochrein, Dennis Klein, and Julia Goodin present a detailed case study illustrating the role of the forensic anthropologist in a North American context. With seven years having passed since the publication of the first edition, this updated chapter illustrates not only the collaborative effort required to obtain and collate evidence for court but also the extensive time that is often required to achieve an outcome.

John Hunter discusses the legal setting in which a forensic archaeologist could expect to practise in the United Kingdom and offers 11 short case studies to illustrate the diverse casework of a forensic archaeologist. Paul Sledzik and Amy Mundorff examine the role of the forensic anthropologist in responding to disaster scenes. They provide a series of case studies that document the history of forensic anthropology in responding to mass disasters in the United States. These case studies highlight the traditional role of forensic anthropologists as well as newly established contributions they can make to the planning and preparation for, and management of, mass disasters.

The range of disaster scenario investigations to which forensic anthropologists have (or should have!) contributed are highlighted by discussions of the role of forensic anthropology in the investigation of militia violence in the Solomon Islands (Melanie Archer and Malcolm Dodd), the 2004 Boxing Day Tsunami (Sue Black), and the 2002 and 2004 Bali Bombings (Alanah Buck and Chris Briggs). Other chapters examine the contributions that forensic anthropology has made to investigations of mass killings following periods of conflict in the former Yugoslavia (Marija Djurić), Guatemala (Caroline Barker, Ambika Flavel, and Claudia Rivera Fernández), and Iraq (Derek Congram, Jon Sterenberg, and Oran Finegan). The final chapter in Part IV is provided by Margaret Cox, Louise Loe, and Peter Jones and focuses on key aspects of investigations undertaken to recover and identify Australian and British WWI soldiers from mass graves located at Fromelles, northeastern France.

The final section, Part V, *The Professional Forensic Archaeologist and the Forensic Anthropologist*, examines topics that are essential to the professional practice of forensic

anthropology and archaeology. These include a discussion about important ethical considerations associated with training, accreditation, the development of anthropological techniques, limitations of evidence, and research (Soren Blau); working for large organisations such as the United Nations (Richard Wright and Ian Hanson); the use of statistics in forming conclusions and opinions (Ann Ross and Erin Kimmerle); and presenting expert testimony in court (Maciej Henneberg). The next chapter in this section presents a detailed overview of the legal and scientific process of death investigation (David Ranson). Both the practical and personal (community) aspects of the investigation process are discussed. The final chapter provides an overview of the mandate and technical capacity of the International Commission on Missing Persons (Hanson and colleagues).

Conclusion

In revising this volume, we have attempted not only to augment the traditional and now widely published North American perspective of forensic anthropology but also to provide the reader with a synthesis of contemporary theories and methods in forensic anthropology and archaeology. The North American contributions are fundamental to understanding the origins and development of the discipline; however, we also acknowledge that a lack of publications in the English language does not mean that significant contributions from other parts of the world have not been made.

This book illustrates the degree to which forensic anthropology and archaeology are disciplines that have the potential to make significant contributions to the search, location, and recovery of evidence as well as to the analysis of a variety of differential preserved human remains from both crime and disaster scenes; ultimately, the contributions made by forensic anthropology and archaeology assist in investigations undertaken for humanitarian and judicial purposes. Such contributions are achieved through methodological rigour and effective collaboration and communication.

We hope that this second edition provides a comprehensive and useful resource for students and emerging practitioners of forensic anthropology and forensic archaeology, as well as other interested professionals from legal, medical, and law enforcement backgrounds. The wide-ranging content ensures that the book is of interest to both experienced practitioners and those interested in learning more about the fascinating and rewarding fields of forensic anthropology and forensic archaeology.

Notes

- 1 In 2002 the anatomist Dr. Gunther von Hagen performed a public dissection in London that was broadcast live and is available on YouTube. It was the first public autopsy in England since public autopsies had been banned in 1832 (Goeller 2007: 278).
- 2 Spelling used is in accordance with the author's origin—that is, both American and English versions of words are used (for example, “aging” and “ageing”).
- 3 Only 7 of the 41 original chapters in the 2009 edition were not revised.

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Part I

History of the Disciplines

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Forensic Anthropology and Archaeology in the United Kingdom

Are We Nearly There Yet?

Gaille MacKinnon and Karl Harrison

In her chapter in the first edition of this volume Margaret Cox, one of an early group of forensic archaeologists to both undertake casework in a criminal context and reflect on their work in writing, broadly considered the development of forensic anthropology and archaeology in the United Kingdom (Cox 2009). While Cox drew on the historical background of both disciplines, her main focus was the 20 or so years of initial development that preceded this publication, from the earliest formal applications to what was then the nascent professional development of the disciplines of forensic anthropology and archaeology (Mant 1950, 1987; Hunter, Roberts, & Martin 1996; Cox & Bell 1999; Cox 2001, 2003; Black 2003; Thompson 2003; Hanson 2004; Hunter & Cox 2005; MacKinnon & Mundorff 2007; Hunter 2009). Cox's breadth of approach to the development of forensic anthropology and archaeology is also apparent in the way in which she combines and conflates the practice of international mass atrocity exhumations with the identification, search and location, and excavation of clandestine single inhumations more commonly associated with domestic major crime investigation—a theme that could be argued to be a direct reflection of the development period of these disciplines (Cox & Bell 1999; Cox 2001; Hunter & Cox 2005; Cox et al. 2008).

From the mid- to late 1990s onward there were a small number of practitioners and postgraduate students then associated with forensic anthropology and archaeology in the United Kingdom who were confronted with an unprecedented call on their professional skills by the International Criminal Tribunal for the Former Yugoslavia (ICTY) (Klinker 2008). The ICTY's investigations of mass graves associated with the conflict in the Western Balkans was the first time that United Kingdom-based practitioners had been utilised abroad, and their deployment represented an extraordinary advance, not only because of the contribution that both disciplines could make to the forensic investigation of war crimes, crimes against humanity and genocide, but also because of the large scale, coordinated, international response for forensic recovery, identification, and repatriation of victims of conflict and associated forensic evidence, which has not been repeated in Europe since that time (Juhl 2005; Skinner & Sterenberg 2005; Wright, Hanson, & Sterenberg 2005; Ranio, Lalu, & Sanjantila 2007; Klinker 2008; Sterenberg 2009).

Subsequent to these initial experiences in the Balkans, United Kingdom (U.K.) and international forensic anthropologists and archaeologists have been utilised in similar investigations of both recent and historic atrocity crimes in many countries, including (but not limited to) Kosovo, Serbia, Cyprus, Spain, Central and South America, West and Central Africa, Iraq, Libya, Afghanistan, East Timor, and Oceania (Juhl 2005; Steadman & Haglund 2005; Cox et al. 2008; Steele 2008; Sterenberg 2009; Blau & Fondebrider 2011; Márquez-Grant (2015); Equipo Argentino de Antropología Forense–EAAF; Equipo Peruano de Antropología Forense–EPAF; Fundacion de Antropología Forense de Guatemala–FAFG; International Commission on Missing Persons–ICMP; International Commission for the Red Cross–ICRC; Physicians for Human Rights–PHR). As a consequence of these deployments and experiences, numerous forensic anthropology and archaeology practitioners have since returned to their home countries to engage in major crime investigation and, in a few instances, continue to participate in casework in both international humanitarian and domestic major crime environments, often balancing such activities in conjunction with an academic post (Steadman & Haglund 2005; Cox et al. 2008; Hunter, Simpson, & Sturdy Colls 2013; Groen, Márquez-Grant, & Janaway 2015; Janaway 2015).

The relatively short period of time since the publication of Cox's chapter (2009) has proved to be a phase of particular importance in the consolidation of forensic anthropology and archaeology in the U.K. In 2009 the demise of the government-sponsored Council for the Registration of Forensic Practitioners (CRFP)—an organisation that provided separate advisory and accreditation panels for practitioners of a number of forensic science disciplines, including forensic archaeology and anthropology—created a vacuum that ultimately led to the formation of two separate expert organisations supported by independent professional bodies. Anthropology was led by the British Association for Forensic Anthropology and its professional body, the Royal Anthropological Institute (RAI) of Great Britain and Ireland, and archaeology was led by the Forensic Archaeology Expert Panel supported by its professional body, the Chartered Institute for Archaeologists (CIfA).

Over the past four years a comprehensive consultation of both RAI and CIfA members has occurred, resulting in the establishment of robust and transparent accreditation frameworks for both forensic anthropology and archaeology that conforms and, crucially, is considered to be fit for purpose for the U.K. criminal justice systems (Crown Prosecution Service 2010, 2014; Law Commission of England and Wales 2011; Crown Office and Procurator Fiscal Service N.d.; Black & MacKinnon 2014; Gamble & MacKinnon 2014; Janaway 2015). Ultimately, the creation of professional accreditation frameworks for forensic anthropology and archaeology has seen a formally enshrined separation of these disciplines by professional registration. It is perhaps a noteworthy development (from a U.S. progenitor model) that currently only one practitioner (MacKinnon) has, to date, dual membership of both organisations, with the vast majority of practitioners identifying as either a forensic anthropologist or archaeologist. It is, however, hoped that the proliferation of combined postgraduate courses in forensic anthropology and archaeology currently offered in the U.K. will ensure that this paucity of dually accredited practitioners will be a short-lived phenomenon that will necessitate a healthy collaboration between the two professional bodies.

Each disciplinary accreditation framework for forensic anthropology and archaeology has been further advanced in collaboration and consultation with the Home Office Forensic Science Regulator (FSR). The post of the FSR was created to “develop a comprehensive framework of quality standards for forensic science providers, forensic science practitioners and for forensic science techniques/methods to ensure that the courts and the public may have confidence in the reliability of forensic science evidence. . . . compliance from authorities in Scotland and Northern Ireland has also ensured that the standards will apply to all three Criminal Justice Systems across the United Kingdom” (Skills for Justice 2009, clause 7.59: 70).

A number of acceptable approaches to forensic casework have since been agreed to by the FSR, in consultation with the various forensic science professional bodies, that have resulted in the production of relevant documents for forensic science, forensic anthropology, and forensic archaeology (CifA 2014; Home Office Forensic Science Regulator 2014; Gamble & MacKinnon 2014; Janaway 2015; Royal Anthropological Institute Forthcoming).

In addition, a considered effort has been made in the U.K. to pursue and form closer links with peers and colleagues internationally, including the U.S. Scientific Working Groups (SWGs) (particularly the Anthropology group—SWGANTH) and its successor, the new Anthropology Subcommittee of the Organisation of Scientific Area Committees (OSAC) of the Forensic Science Standards Board (FSSB), recently established by the National Institute of Standards and Technology (NIST). Such links have also been actively sought by U.K. practitioners with peers working under European legislatures, where collegiate forensic anthropological and archaeological collaborations and interactions are being explored and established (Márquez-Grant, Litherland, & Roberts 2012; Groen 2015; see also various contributions in Groen, Márquez-Grant, & Janaway 2015; Project Group for Forensic Archaeology, European Network of Forensic Science Institutes—ENFSI).

The conceptual changes that underpin many of the less-tangible developments in both disciplines can be considered in terms of fundamental principles, typified by a general movement away from the comprehensively broad-ranging, independent practitioners who characterised the initial phase of both forensic anthropology and archaeology and toward greater specificity and increasing practitioner specialisation. This growing alignment with the professional considerations and the increasing concerns and requirements (shared in common with forensic science as a whole) of the U.K. criminal justice system has prompted a move toward a professional rather than an emotive motivation underlying the desire to undertake casework (Cox 2001, 2009; Association of Forensic Service Providers 2009; Redmayne et al. 2011; Gallop & Brown 2014).

Despite the continuing combined disciplinary approach within associated postgraduate courses in the U.K. the organisational and institutional structures that have developed around practitioners also expresses a growing distinction between the nature of work undertaken and the standard methods adopted by forensic anthropologists and archaeologists (Chartered Institute for Archaeologists 2014; Royal Anthropological Institute for Great Britain and Ireland Forthcoming). In addition, the International Organisational Standards (ISOs) that are now applied within forensic science also highlight the great divide between methods assessed under ISO/IEC 17025 and ISO/IEC 17020. ISO/IEC 17025 is the international standard that specifies the general requirements for the competence to carry out tests and calibrations, including sampling, and assesses the competence of an organisation and its individuals, the validity of methods and impartiality. ISO/IEC 17020 is the international standard for organisations carrying out inspection activities; it has been deemed more appropriate than ISO/IEC 17025 for crime scene examinations (British Standards Institute BS EN ISO/IEC 17025 2005; British Standards Institute BS EN ISO/IEC 17020 2012). The International Laboratory Accreditation Cooperation (ILAC) has produced a document with the purpose of providing guidance for laboratories, scenes of crime investigation units, and other entities (called “forensic units” within the document) involved in examination and testing in the forensic science process (ILAC G19:08 2014). These standards naturally distinguish between the work of the forensic anthropologist and archaeologist, respectively; however, these disciplines require more clearly defined methods of working in order to acquire reliable results on which to base expert interpretations that will be admissible in the criminal justice system.

The scope of many individuals practicing in both or either discipline has also been seen to narrow measurably in recent years. In large part, and as previously stated, this situation is due

to a decrease in mass grave exhumation deployments for international teams in the Balkans (Juhl 2005; Klinker 2008) and a general move away from large-scale mass grave investigative casework toward small-scale investigations or humanitarian exhumation, recovery, and identification operations and the provision of forensic training and capacity building in conflict and postconflict countries (as seen particularly in the efforts of Equipo Argentino de Antropología Forense–EAAF; Equipo Peruano de Antropología Forense–EPAF; Fundacion de Antropología Forense de Guatemala–FAFG; International Commission on Missing Persons–ICMP (see Hanson and associates, Chapter 45 this volume); the International Commission for the Red Cross–ICRC; Physicians for Human Rights–PHR; Doretti & Snow 2009; Fondebrider 2012). As a consequence, there are simply fewer employment opportunities for existing practitioners and therefore fewer opportunities for new practitioners to develop their skills to an accepted standard. In addition, the increasing complexity of the application of forensic science in U.K. murder investigations—and the increasing requirement for all experts to operate seamlessly as part of a multidisciplinary team of professionals and feed into a clearly defined forensic strategy (Association of Chief Police Officers 2006)—has meant that the skillsets of the international and the domestic practitioner have necessarily begun to diversify.

While early practitioners noted the importance of justice, a distinction was implied between concepts of justice and the legal process (Cox 2009). The prime importance to some practitioners appeared to be that the forensic anthropologist and/or archaeologist serve a concept of justice that addressed aggrieved and bereaved communities and individuals directly and personally and that superseded statutory responsibilities or the agency of investigating or prosecuting bodies. While justice remains paramount as a fundamental concept in forensic science and society in general, the drive toward impartiality and professional frameworks of operation has underlined the importance of multidisciplinary practice in more recent times. Practitioners in both forensic anthropology and archaeology now operate in the U.K. within multidisciplinary investigative teams and as such must recognize and accept the process of justice as understood through the operation of the law, regardless of how this fact might cause a tension with more emotive responses to the challenging nature of our casework (Steele 2008; Sterenberg 2009; Crossland 2013; Janaway 2015; Márquez–Grant Forthcoming).

Having considered the development of forensic anthropology and archaeology in the U.K. and how our understanding has changed in recent years, this chapter outlines the nature of contemporary operations and practice in both disciplines and the challenges and opportunities that may occur in the near future.

Forensic Anthropology

The most significant professional development for forensic anthropology in the U.K. over the past four years has been the formalisation and professionalisation of the discipline and the establishment of a system for professional certification of forensic anthropology practitioners working in the field. This professionalisation of the discipline has involved an extraordinary collaboration between the RAI, the British Association of Forensic Anthropology (BAFA), and the Office of the Forensic Science Regulator (FSR). The Royal Anthropological Institute represents and promotes all aspects of the discipline of anthropology and subsequently has become the professional body for forensic anthropology in the U.K. Through a process of robust and transparent public and professional consultation and refinement, a structured framework for certification of competence to practice in the U.K. was agreed on and has now some three years later been implemented (Black & MacKinnon 2014; Gamble & MacKinnon 2014).

Three levels of certification relate to professional experience and expertise; this robust framework permits investigating authorities, lawyers, the judiciary, and other relevant professional bodies to gauge the level of practitioner expertise that is required for their purposes and to identify the most suitable practitioner to engage, which may ultimately be based on geographical location. The highest level of certification (FA-I) confirms that the holder is a highly experienced forensic anthropologist who has demonstrated independent credibility both within his or her profession and in respect of expert witness duties in the U.K. courts. The second level (FA-II) represents a forensic anthropologist who is competent to practice but may have limited or no experience of high-profile/complex casework or court room skills. An FA-III forensic anthropologist is competent in basic skills but may not have had experience with active casework responsibility. The career structure embedded within this framework is one of collegiate mentoring and support that is designed to raise the standards of this scientific discipline for the U.K. courts and to facilitate competent succession training and development of skills and experience (Royal Anthropological Institute Forthcoming).

Over the previous 18 months, a series of FA-I, FA-II, and FA-III certification examinations have been held, and a number of U.K. certified forensic anthropology professionals (FA-I, FA-II and FA-III) have been approved. As with other legal jurisdictions around the world (and certainly since Cox 2009), forensic anthropologists working in the U.K. criminal justice system are increasingly being challenged with regard to their professional certification and expert witness credentials. Therefore, establishing appropriate accreditation criteria, standard operating procedures, and quality assurance processes and examinations, together with formalising our relationship with the RAI as the professional organisation for forensic anthropology, has been a very important milestone in ensuring that our discipline is fit for purpose for the police, the judiciary, and indeed the future (for further information, see <https://www.therai.org.uk/forensic-anthropology/certified-fai>).

Similar to other educational facilities elsewhere around the world, the U.K. also currently suffers from a surfeit of higher education forensic science and forensic anthropology courses and degrees, with the proliferative nature of these programs unfortunately producing an abundance of graduates for whom there will be little prospect of employment in their chosen discipline (Skills for Justice 2009). When considering the appropriate succession training of our students and the survival of the discipline into the future, the RAI has also established a Forensic Anthropology Curriculum map for U.K. Higher Education Institutions (HEI) who offer forensic modules and degree programmes in forensic anthropology. The curriculum map has been both designed and approved by practitioners in the discipline to ensure that U.K. HEIs who wish to claim RAI approval for their programmes as being fit for the professional curriculum map can now do so. In this way a link exists between the HEIs and the professional body that will ensure that students and trainee practitioners are equipped appropriately for their future professional roles and responsibilities, and, significantly, will indicate the HEIs who incorporate the curriculum into their teaching regimes.

As has been documented in the forensic science and forensic anthropological literature particularly from North America, Canada, and Australia, forensic practitioners in the U.K. are increasingly aware that there is now an evidential requirement that we evaluate the methodologies and professional standards of—and provide error rates of—the techniques that we routinely use, to ensure the viability and admissibility of the evidence that we may present in court (Crowder & Rogers 2007; Grivas & Komar 2008; Association of Forensic Service Providers 2009; Christensen & Crowder 2009; National Research Council 2009; Campbell 2011; Redmayne et al. 2011; Holobinko 2012; Edmond 2013).

When considering the reliability of opinion evidence, the Crown Prosecution Service of England and Wales ruled that the court will be expected to have regard to Criminal Practice Directions in the determination of the reliability of expert opinion, and especially of expert scientific opinion (Court of Appeal [Criminal Division], Criminal Practice Directions, Amendment No.2 [2014] EWCS Crim. 1569 at paragraph 33A.5 [a-h]), in regard to

- 1 the extent and quality of the data on which the expert's opinion is based, and the validity of the methods by which they were obtained;
- 2 whether the expert's opinion relies on an inference from any findings, whether the opinion properly explains how safe or unsafe the inference is (whether by reference to statistical significance or in other appropriate terms);
- 3 whether the expert's opinion relies on the results of the use of any method (for instance, a test, measurement, or survey), whether the opinion takes proper account of matters, such as the degree of precision or margin of uncertainty affecting the accuracy or reliability of those results;
- 4 the extent to which any material on which the expert's opinion is based has been reviewed by others with relevant expertise (for instance, in peer-reviewed publications) and the views of those others on that material;
- 5 the extent to which the expert's opinion is based on material falling outside the expert's own field of expertise;
- 6 the completeness of the information that was available to the expert and whether the expert took account of all relevant information in arriving at the opinion (including information as to the context of any facts to which the opinion relates);
- 7 whether there is a range of expert opinion on the matter in question, wherein which the expert's own opinion lies, and whether the expert's preference has been properly explained; and
- 8 whether the expert's methods followed established practice in the field and, if they did not, whether the reason for the divergence has been properly explained.

In addition, in considering reliability, and especially the reliability of expert scientific opinion, the court should be astute to identify potential flaws in such opinion that detract from its reliability, such as (Court of Appeal [Criminal Division], Criminal Practice Directions, Amendment No.2 [2014] EWCS Crim. 1569 at paragraph 33A.6.a-e):

- 1 being based on a hypothesis that has not been subjected to sufficient scrutiny (including, where appropriate, experimental or other testing) or that has failed to stand up to scrutiny;
- 2 being based on an unjustifiable assumption;
- 3 being based on flawed data;
- 4 relying on an examination, technique, method, or process that was not properly carried out or applied, or was not appropriate for use in the particular case; or
- 5 relying on an inference or conclusion that has not been properly reached.

A recent scientific discussion meeting entitled *Paradigm Shift in Forensic Science*, held at the Royal Society in London in February 2015, gathered a large number of forensic scientists and lawyers from around the world and sought to address the serious issues that currently confront the presentation of forensic science in the courtroom, striving to instigate a discussion that will ultimately lead to the development, design, and promotion of a robust, effective, and efficient capability that will best serve justice (The Royal Society 2015). It is certainly the case

that not only the established methodologies that are currently used in forensic anthropology and discussed in the literature (Crowder & Rogers 2007; Grivas & Komar 2008; Christensen & Crowder 2009) but also those that are currently utilised and considered as acceptable across a number of forensic science disciplines need to be reconsidered and reconfigured to ensure that they are fit for purpose and meet the admissibility requirements for an increasingly rigorous and demanding criminal justice system (Association of Forensic Service Providers 2009; Campbell 2011; Redmayne et al. 2011; Holobinko 2012; Edmond 2013; Kassir, Dror, & Kukucka 2013; Lord Thomas 2014).

Forensic Archaeology

The heart of forensic archaeology remains the excavation and recovery of human remains and associated items from clandestine graves, with the methods associated with this activity having remained largely unchanged since their initial description in the U.K. literature (Hunter, Roberts, & Martin 1996). The consideration of opportunities presented by the exploitation of DNA evidence has increased in parallel with the development of the sensitivity and reliability of extraction and profiling techniques, and this situation has brought with it a more intense focus on anticontamination procedures in general on the crime scene (Association of Chief Police Officers 2006). Beyond this, the most apparent recent developments in forensic archaeology have been the establishment of the concept of forensic ecology as an overarching framework (Márquez-Grant & Roberts 2012); the growth of the multidisciplinary approach to searches for clandestine body depositions (Association of Chief Police Officers 2006; Hunter, Simpson, & Sturdy Colls 2013; Groen, Márquez-Grant, & Janaway 2015); and as previously mentioned, the establishment of the Forensic Archaeology Expert Panel and the Forensic Archaeology Special Interest Group within the Chartered Institute for Archaeology (CIfA) as the disciplines' representative professional body (Chartered Institute for Archaeology 2014).

Similar to the forensic anthropology accreditation framework, the CIfA has three levels of professional membership for both archaeology and forensic archaeology, with applications assessed by a centrally constituted membership committee (Janaway 2015). In addition, CIfA has produced a skills matrix for corporate grades of membership for forensic archaeology that provide competency standards and levels, namely: Practitioner (PIfA), Associate (AIfA), and Member (MIfA). The MIfA practitioner is the highest level of forensic archaeologist and similar to the FA-I level; a forensic anthropologist is expected to have undertaken simple and complex forensic archaeological casework; have a broad knowledge of police structure, criminal investigation, and scene of crime infrastructure; and be competent to give evidence in the U.K. criminal justice systems (CIfA 2014). These three CIfA competency levels are similar in structure to those provided to practicing forensic anthropologists through the RAI. The benefits of the CIfA multiple membership grades are that they too provide a progression route for younger practitioners (which the old CRFP model did not) and allow for recognition of mentored working and succession planning and training within the discipline (Janaway 2015). (The CIfA Forensic Archaeology skills matrix can be downloaded from <http://www.archaeologists.net/groups/forensic/faep>.)

Over the past 20 years, the discipline of forensic archaeology has established itself in the U.K. as a primary method of detection for buried human remains. It tends to be regarded as one of a suite of techniques within the disciplines of forensic ecology, which includes sedimentology, botany, palynology (pollen), diatom analysis, entomology, stable isotope studies, radiocarbon and other dating techniques, archaeology, and anthropology (Márquez-Grant & Roberts 2012).

As a concept, *forensic ecology* hides a number of conflated and confused terms. Numerous definitions for the term *ecology* were discussed and synthesised by Rana (2007) to produce a current, overarching description: “ecology is the study of interactions between living organisms and their environment, and the pattern of distribution of plants and animals on the earth” (Rana 2007: 1). Thus it is reasonable to assume that forensic ecology might be the application of such science in a judicial context. However, the definition of the discipline differs when considered in the context of industrial application, in which anthropology and archaeology are included within forensic ecology. This situation is similar to the development of forensic chemistry, which when considered from the perspective of organisation within the forensic science commercial provider industry is now largely an amalgam of mark enhancement and comparison, physical fit analysis, and fire investigation. The examples of forensic ecology and chemistry serve to illustrate how far the application of forensic disciplines can stray from their scientific roots; see, for example, Newton (2007), who lists both DNA analysis and toxicology as subdisciplines of forensic chemistry, neither of which would be classified as such with a U.K.-based forensic service provider.

Forensic ecology is a composite of independently developed disciplines applied in a legal context (Márquez-Grant & Roberts 2012). Indeed, the quote by Grime (2007) that introduces Scheiner and Willig’s consideration of a general theory of ecology is most fitting: “In the absence of agreed protocols and overarching theory, Ecology with its numerous subdisciplines, can sometimes resemble an amorphous, post-modern hotel or rabbit warren with separate entrances, corridors and rooms that safely accommodate the irreconcilable” (2011: 3). Although an orthodox view of forensic ecology might consider botany, palynology, sedimentology, and entomology as core disciplines, in an industrial context within the laboratories of U.K. Forensic Service Providers (FSPs) these disciplines would habitually be paired with anthropology and archaeology (Márquez-Grant & Roberts 2012); indeed, there have been times when the study of these human sciences has embraced an ecological perspective (Butzer 1982).

The development of multidisciplinary search efforts that combine scientific and investigative assets has been achieved predominantly through the recognition of specific variations, patterning and disturbances in landscape, and geological, botanical, and ground signatures (Ruffell & McKinley 2008). These interpretations have subsequently been greatly enhanced by an increasingly sophisticated understanding, adoption, and utilisation of geophysical search equipment and techniques (Fenning & Donnelly 2004). In addition, the application of traditional archaeological excavation methodologies to criminal investigations that involve buried human remains has been an important milestone in optimising the ability to elucidate and extract evidence from the grave and burial environment (Hunter, Simpson, & Sturdy Colls 2013; Hanson 2015). As a consequence, forensic archaeology has negotiated an important position within criminal investigation, existing as it does between the outdoor crime scene most usually controlled by the Crime Scene Manager (CSM) and the Police Search Advisor (POLSA), the mortuary setting typically dominated by the forensic pathologist and anthropologist, and the laboratory environment of the forensic scientist.

In our experience, a multidisciplinary and strategy-led approach to the search for human remains offers by far the highest chance of success for the subsequent location and recovery of remains, while also maintaining an effective control of the search area and preserving the integrity of the crime scene and any associated evidence contained therein.

In considering the search for, and location of, clandestine burials, it is crucial to understand the range of responses that might be considered as appropriate police actions. Depending on the nature and veracity of directed intelligence, an enquiry team may be able to identify specific

sites of interest. Where such sites can be defined with specific parameters, they can be treated as crime scenes from the outset (Association of Chief Police Officers 2006). Such a decision might be regarded as a high-risk one: deployment of staff onto a crime scene associated with a major enquiry entails the production of a forensic strategy and the consideration of extensive sequential evidence collection and the potential for significant expenditure.

In contrast with the more fixed framework associated with the definition and examination of a major crime scene, it is more common that the no-body murder investigation is characterised by a period of search. Where directed intelligence associated with specific identified sites is absent or uncorroborated, a Senior Investigating Officer (SIO) would be unlikely to consider speculative forensic examination. More probably, a POLSA, normally a middle-ranking police officer (sergeant or inspector) with significant specialist training in search coordination, would be given the responsibility for identifying anomalous locations that might be associated with body deposition within a wide landscape of possibilities. Such coordination would usually comprise the deployment of search-trained police officers as well as the integration of specialist services, such as findings derived from forensic telephonic examination or aerial reconnaissance.

Over the past 20 years, the multiple types of forensic scientist involved in the location of buried and concealed remains have grown used to considering themselves part of a multidisciplinary effort. Forensic geoscientists, palynologists, entomologists, geophysical search specialists, and forensic archaeologists are generally more comfortable conceiving of their disciplines as part of a suite of methods broadly classified under the banner of “forensic ecology,” and they consider their functions as frequently complimentary and at their most effective when coordinated as an ensemble, which Davenport and associates (1992) were strongly advocating over 20 years ago, rather than as any one specialism offering superior capability within a crime scene investigation (Márquez-Grant & Roberts 2012).

The application of these various natural sciences to forensic search scenes is not new. Inception dates for the various elements of forensic ecology range from the beginning of the 20th century for forensic geosciences (see Murray & Tedrow 1975, for a consideration of Popp’s earlier work) to the 1970s for early published considerations of the archaeologist to the crime scene (Boyd 1979). However, their formal affiliation with one another in the syncretic science of forensic ecology is novel. The synthesis of these disciplines has not always been straightforward, despite their shared stated goal of harnessing their various scientific specialisms to assist the courts. Despite this, the various disciplines of forensic ecology have made progress in development and consolidation with one another, particularly in the last decade. This development appears to be two-pronged, deriving at about the same period of time from a small number of academic authors with an interest in forensic search and body location and recovery as an overt development of their science (Ruffell & McKinley 2004; Márquez-Grant & Roberts 2012) and in a less obvious manner from the maintenance of a range of forensic ecology provision solutions offered by a number of Forensic Service Providers (FSPs) in the U.K. over the same period of time (Gallop & Brown 2014). Various solutions offered in the U.K. by FSPs have ranged from teams of salaried forensic ecologists to retained consultants and contractors. All have similarly sought to define, address, and market forensic ecology solutions as a single identifiable unit.

There is another side to multidisciplinary interaction between the forensic ecology disciplines that has thus far attracted less attention from academic authors and FSPs: the integration of the forensic ecologist within the structure of the police investigation and specifically alongside police search officers and crime scene investigators (CSIs) in the context of “no-body” murder search and location operations. The forensic ecologist present at such scenes arguably has longer

and more in-depth contact with the police than do their counterparts who work primarily as laboratory-based analysts. No-body murder investigations frequently represent some of the longest and most complex investigations, requiring greater initial reliance on human and technical intelligence than do most other responses to major crime outside the arena of counterterrorism. Within this context, forensic ecologists must retain their independence and objectivity to ensure they meet the robust requirements of the court while being able to facilitate the specialist needs of the police investigation.

Conclusion

This chapter has attempted to synthesise the enormous changes that have occurred in the disciplines of forensic anthropology and archaeology in the United Kingdom in the relatively short period of time since the first edition of this volume in 2009. From the initial mobilisation and deployment of practitioners of these disciplines by the International Criminal Tribunal for the Former Yugoslavia (ICTY) to the ensuing humanitarian missions undertaken in subsequent years by a variety of national (for example, EAAF, EPAF, FAFG) and international nongovernmental organisations (such as ICMP, ICRC, PHR) across the world, U.K.-based forensic anthropologists and archaeologists are now utilised routinely by domestic police forces, private clients, and the U.K. criminal justice system. What is more important, the accreditation of practitioners of both disciplines is also now firmly established with transparent, robust, and structured frameworks in place. This situation provides an accredited certification of competence to practice in the U.K. criminal justice system that permits investigating authorities, lawyers, the judiciary, and other relevant professional bodies to gauge the level of practitioner expertise required for their purposes, and identifies the most suitable practitioner with whom to engage. With the establishment of these certification frameworks, an educational curriculum map for forensic anthropology has also been developed and endorsed by the RAI. In the case of forensic archaeology, a career progression framework has been established by CIfA. Both these frameworks ensure that the students, trainee, and early career practitioners in these disciplines are educated and equipped appropriately for their future professional roles and responsibilities. And both frameworks ensure that robust succession training and mentorship is provided that will guarantee that those following after us will be fit for purpose.

One of the most significant challenges our disciplines, and indeed forensic science as a whole, currently face is to ensure that we rise up to meet the challenge of increasingly stringent and rigorous admissibility criteria that will best serve justice and the criminal justice systems in which we operate (Association of Forensic Service Providers 2009; National Research Council 2009; Law Commission of England and Wales 2011; Home Office Forensic Science Regulator 2014; The Royal Society 2015). The Right Honourable the Lord Thomas of Cwmgiedd, Lord Chief Justice of England and Wales remarked in a recent keynote speech that the implementation of reforms to the laws governing expert forensic evidence need to continue to be pursued diligently to reduce the risk of miscarriages of justice caused by junk forensic science and rogue practitioners (Lord Thomas of Cwmgiedd 2014). It is certainly the case that with novel and complex forensic science increasingly being presented in courts of law the methodologies employed will be subject to rigorous scrutiny and robust cross-examination (*ibid.*). Collectively, the onus is now on forensic science globally to ensure that the quality and integrity of the forensic science evidence that we present in court is rigorously tested, diligently presented, and is of the highest evidentiary standards to ensure that miscarriages of justice are avoided whenever possible.

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Forensic Anthropology and Archaeology

Perspectives from Italy

Cristina Cattaneo, Daniele Gibelli, and Dominic Salsarola

Giving a perspective on forensic anthropology in Italy is, to say the least, difficult owing to the fact that academic and professional aspects are confused. However, there is a bright side: after years of painstaking insistence pathologists, magistrates, and judges are beginning to understand and appreciate the discipline and its expertise. In addition, the recognition of contributions that forensic anthropology can make to examinations of the living is steadily increasing (for example, facial identification), creating more demand for anthropologists within forensic contexts. Although forensic anthropology in the Italian setting can still be considered as “developing,” the medicolegal culture is slowly changing, and ever more often descriptions of forensic scenarios include the words *anthropology* and *archaeology*. This chapter provides a brief history of forensic anthropology in Italy and illustrates the present status through examples of operative cases concerning several fields of application.

Forensic Anthropology in Italy: History, Politics, and Academics

Forensic anthropology in Italy was first applied almost two decades ago, with the work of two major Italian Universities: Bari in the south and, shortly after, Milan in the north. These two academic centers started to undertake research and to publish in areas concerning sexing, ageing, personal identification, and other related issues. This activity not only contemplated academic matters but also included the task of enlightening magistrates, judges, and institutional investigating bodies regarding the potential benefits that could be obtained through the study of skeletal remains. The University of Milan went on to create what has now become the Laboratorio di Antropologia ed Odontologia Forense (LABANOF), an internal center based in the Institute of Legal Medicine within the State University of Milan. LABANOF promotes research in the fields of forensic anthropology and odontology, teaching, and professional activity. There are 13 university departments of Legal Medicine in Italy that offer postgraduate training in forensic pathology and 11 universities that offer undergraduate training in physical anthropology. However, the University of Milan is currently the only institution that offers postgraduate training in forensic anthropology in the form of a Masters course (MSc) or a *Corso di Perfezionamento* (a course of 50 hours that includes both theoretical and practical teaching). Since the academic year 2008/2009 LABANOF–University of Milan, the University of Bologna, and the University of Pisa have

collaborated in developing a Masters course in bioarchaeology, palaeopathology, and forensic anthropology. To date, the MSc represents the most comprehensive opportunity for learning osteology, palaeopathology, and forensic anthropology in Italy. Finally, since 2012 the University of Milan has organised an annual summer school in anthropology for students of arts, natural sciences, medicine, and trainees in legal medicine, which is held in Pontestura, in the nearby region of Piedmont. It offers students a one-week intensive course in practical osteology and forensic anthropology.

No undergraduate courses in forensic anthropology are currently offered in Italy. Many forensic pathology and physical anthropology professors occasionally include lectures regarding forensic anthropology in their pathology or anthropology course. However, proper training is practically non-existent. This is true for two main reasons: first, because forensic anthropology is a relatively new applied discipline and, second, no one really knows whether the forensic anthropologist should come from an anthropological background or that of pathology. This question has been considered in a recently published textbook on forensic anthropology and pathology:

What is a forensic anthropologist? Particularly across Europe, this is a very delicate issue, and it may concern experience and training more so than specific academic qualifications, at least at the moment. In Anglo-Saxon countries, namely the U.S. and the U.K., the forensic anthropologist at least falls into a defined category, i.e., that of he/she who practices forensic anthropology, this being “the application of physical anthropology to the forensic context.”

(Cunha & Cattaneo 2006)

Compared to forensic anthropology in the United States, in Europe the subject is lacking in organisation as far as training is concerned. One of the obstacles that must be overcome in Europe is cultural. In many European countries there is a distinct division between experts who work in a forensic context—namely, forensic pathologists and those who work in the anthropological context, mainly anthropologists working on archaeological material. For example, the scientific and forensic community have come to realise that there is a void when human remains are found in a forensic scenario: most forensic pathologists do not have anthropological or osteological expertise, and classical anthropologists may not be used to working with human remains still bearing residual soft tissue or that have been recovered from a modern crime scene. In addition to ethnographers, cultural anthropologists, and geneticists who work on human variation, physical anthropologists have always included practitioners, considered to be experts in human osteology. Thus the anthropologist's contribution to anything coming from a forensic context traditionally deals with the estimation of ancestry, sexing, ageing, and stature; in other words, similar assessments to those undertaken by the anthropologist when studying skeletal remains of ancient populations.

However, traditional anthropology is not sufficient for the forensic context. Forensic anthropologists must also deal with questions regarding identification and manner of death, which have both legal and social implications. The anthropologist and pathologist both have to deal with the human body *in toto*; the more soft tissue is still attached, the more it is within the domain of the pathologist; the more skeletonised, decomposed or burnt, the more it falls into the domain of the anthropologist.

One could go as far as to say that forensic anthropology is a field that works in parallel with forensic pathology. In other words, just as the pathologist deals with the human cadaver from the crime scene in order to establish time and cause of death, the anthropologist, when nothing remains of a victim but bones, must deal with the search for and correct retrieval of the skeleton

(turning to disciplines such as forensic archaeology) and with such issues as victim identification and the detection of signs ascribable to trauma that may lead to establishing the cause and manner of death.

While forensic anthropologists typically deal with the dead, practitioners are increasingly requested to handle the identification and ageing of living individuals. In the past few years specialists have applied notions of anthropology and associated disciplines to ageing juvenile perpetrators (Cameriere et al. 2012), identifying bank robbers taped on video surveillance systems (De Angelis, Cattaneo, & Grandi 2007; De Angelis et al. 2009), and establishing whether presumed victims of pedopornography are or are not under age (Cattaneo 2007; Cummaudo et al. 2014).¹

Returning to the Italian scenario, one notes a frequent problem: cases involving human remains are dealt with by forensic pathologists, who have no training in forensic anthropology. However, regardless of who should apply forensic anthropology, the main issue lies in the fact that the discipline be taught, either to pathologists or anthropologists, so that human remains can be examined in the best possible manner. At the moment, in Italy a pathologist has better chances than an anthropologist of working as a forensic anthropologist—because, by tradition, magistrates give cases to pathologists who subsequently choose and create a team of experts (which may include geneticists, toxicologists, entomologists, ballistic experts, and so on). Frequently the pathologist feels suitably qualified to do the forensic anthropology. However, properly trained anthropologists may one day be attributed expert witness status.

If training and lack of expert pathologists and anthropologists are still issues, research in forensic anthropology in Italy is present even though sporadic. If we look at the literature regarding this discipline on a national basis, we see only three textbooks on forensic anthropology: *Lo Studio dei Resti Umani: Testo Atlante di Antropologia ed Odontologia Forense* (Cattaneo & Grandi 2004), *Elementi di Antropologia Forense: Dalle Indagini di Sopralluogo agli Accertamenti di Laboratorio* (Marella 2003), *Principi di Patologia e Antropologia Forensi* (Arcudi & Marella 2006), and a small booklet on forensic odontology, *Identificazione in Odontologia Forense* (Cameriere 2003). In the last 10 years, Italian articles dealing with forensic anthropology have been published in international journals; a search on PubMed with “Italy” in association with “forensic anthropology” in every field revealed approximately 100 articles, 93% of which were published in the last 10 years. Such figures register the increasing interest of Italian forensic experts toward the discipline. The content of the articles included both biological profile and trauma: 13% dealt with assessment of lesions, 19% with generic identification, and 8% with personal identification and estimation of postmortem interval. In addition, the number of articles concerning the living is increasing, with 15% concerning age estimation and 7% regarding facial identification. Forensic archaeology, however, is less popular among scholars, which leads to a limited involvement of archaeologists in both operative forensic scenarios and related academic activities.

Although the discipline of anthropology in Italy may appear still to be merely in a phase of development, some elements of interest on behalf of the public can be noted, as shown by the creation of a reference collection of skeletal remains. Thanks to collaboration with the municipality of Milan, the largest known skeletal collection in Italy has been assembled counting some 1,600 skeletons of known individuals who died between the 1990s and 2010.

As far as scientific groups and associations are concerned, Italy has only one group dedicated to forensic anthropology—the Gruppo Italiano di Antropologia ed Odontologia Forense (GIAOF). Established in 1996, unfortunately this group has over the years become mainly interested in aspects regarding the medicolegal malpractice of forensic odontology, subsequently drifting away from forensic anthropology. The Gruppo Italiano di Patologi Forensi (GIPF) sometimes organises events related to forensic anthropology but consists mainly of pathologists, whereas

the Associazione Antropologi Italiani (AAI) is striving to create a forensic anthropology section but lacks ties to the forensic environment. Therefore, at present, the Forensic Anthropology Society of Europe (FASE) is the only organisation that includes Italian forensic anthropologists and forensic pathologists with an interest in forensic anthropology. In 2014 FASE started its certification campaign.

Forensic Archaeology in Italy

Although a lot less practised and still in its early infancy with respect to forensic anthropology, one of the disciplines that is becoming more visible in the Italian scenario is forensic archaeology. Only in recent years has the importance of an archaeological approach to forensic cases been considered by pathologists and magistrates alike. In the case of the search and recovery of buried human remains, currently initial activities are typically organised by unskilled personnel with no experience of excavation or the necessary knowledge of subterranean environments and interactions that can take place within a grave. Rough attempts at recovering remains without specific tools or know-how, causing consequential damage to bones and the loss of information—regarding not only human remains but also the grave as a wider context—are common. Also, whereas a trained forensic archaeologist will understand the implications of almost intangible traces recorded within a grave and can recognise the necessity to integrate other specific forensic specialists into a recovery operation, unskilled police officers armed with picks and shovels along with the abuse of excavating machinery can be devastating to a crime scene or even an entire investigation. Thanks to a few high-profile cases, search, excavation, and the recovery of human remains in a forensic context have gained growing attention and have begun to be requested by investigating authorities.

In a similar way public interest in archaeology and archaeological research in the forensic field has also increased. This interest resulted in one of the largest Natural Parks in Italy (Parco del Ticino) allowing scholars and Universities in Northern Italy to use a portion of its territory for experiments regarding victim decomposition and various techniques implemented in the search for clandestine burials, all of which involved the implementation of pig carcasses that had deceased through causes unrelated to any of the experimental projects. In recent years collaboration with the national park has allowed many researchers to test various search and excavation methods (geophysics, in particular ground penetrating radar and electric resistivity), victim recovery techniques, and cadaver dog training. Additional activities include forensic botany, forensic soil science, and forensic entomology (Figure 3.1).

Forensic Anthropology and Archaeology in Practice

In looking at the international scenario, one notes that in Italy there is an urgent need for the practice of forensic anthropology. It is impossible to have a clear picture of the activity in all Italian medicolegal institutes; for example, the number of requests made to the University of Milan on an annual basis should be considered to be representative of the size of the problem.

Milano is a city with a population of around 1.5 million. The medicolegal institute performs around 800 autopsies every year, and there are, on average, 50 cadavers requiring personal identification and, in general, anthropological attention. Approximately 10 cases require the construction of a biological profile through sexing, ageing, stature, ancestry estimations, and sometimes facial reconstruction. In all the cases mentioned here forensic anthropology is crucial, if not the only discipline that could have been sensibly implemented. The other cases involving remains

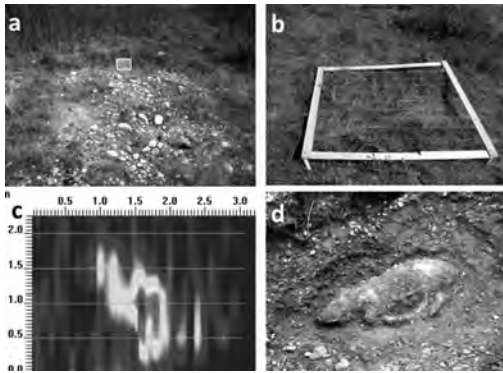


Figure 3.1 Testing methods for search and recovery on a buried pig carcass: (a) area of burial, signed with red lines: one can observe the modification of flora; (b) construction of reticular grid for archaeological recovery; (c) analysis by ground penetrating radar; (d) phases of recovery of the pig carcass.

that are skeletonised, burnt, or in an advanced state of decomposition arrive with a suspected identity. Identity is typically confirmed, in approximately one-third of the cases, through DNA analysis, whereas the other two-thirds are achieved through anthropological and odontological investigation (Cattaneo & Grandi 2005).

In many of these cases, where soft tissue is scarce forensic anthropology is also fundamental in the verification of the presence of traumatic lesions to bone. In addition, every year there are on average two to three requests involving crime scene activities that require forensic anthropology and archaeology expertise in the operational search and recovery of human remains. Increasingly, anthropological expertise is also requested for identifying the living captured in images taken from video surveillance systems; on average, there are about eight cases every year. Although forensic anthropology is not implemented on a daily basis in the typical Italian medicolegal scenario, it is quite frequently requested.

Thus forensic anthropology in Italy still needs to be developed both professionally and academically. However, the situation is slowly changing as illustrated by the four operative case reports that follow. These cases highlight the essential role that forensic anthropology and archaeology play in investigative contexts and the extent to which it is beginning to be recognised by magistrates, investigating authorities, and pathologists.

Emblematic Cases: Forensic Anthropology

Case 1

In the summer of 2001 human remains were found in the cellar of an abandoned building in a town near the outskirts of Milan. The body was completely skeletonised, still dressed, and surrounded by rubbish, with its feet bound in chains attached to a wall. Crime scene investigators collected most of the bones, along with many animal bones, initially considered to be human; the relevant finds then underwent full anthropological, odontological, and genetic investigation. First a biological profile of the deceased was established according to standard sexing and ageing methods; estimation of ancestry, height, and dental status were also undertaken (Ubelaker 1999). The biological profile subsequently led to a possible identity. Antemortem data relating to a young North-African male who had gone missing and postmortem data belonging to the skeleton were compared, with particular attention to the victim's dental status. Finally, craniofacial superimposition and genetic analysis were carried out (Yoshino et al. 2001). Trauma analysis was also undertaken in order to establish postmortem, perimortem, and antemortem trauma. This

was done by macroscopic and stereomicroscopic observation of the bone lesions and radiological analysis. Age assessment of antemortem trauma was also attempted.

Results showed that the skeleton belonged to a 35- to 44-year old male of Caucasian (Mediterranean) origin approximately 1.69m tall whose two central superior incisors had been lost long before the time of death. Craniofacial superimposition, along with consistent antemortem and postmortem data concerning the missing incisors (the man had a removable prosthetic appliance that corresponded to the two upper incisors) indicated a high probability of identification (Figure 3.2). The identification of the individual was later confirmed by genetic analysis. However, as is often the case with illegal immigrants, genetic antemortem or parental material was not available.

This case highlights the importance of anthropological and odontological methods for the purpose of identification, particularly in those cases in which DNA analysis is not practicable.

Trauma analysis (see Cunha & Pinheiro, Chapter 23 this volume; Loe, Chapter 24; and Nawrocki, Chapter 25) showed signs of sharp force perimortem trauma to the blade of the left scapula along with antemortem trauma probably resulting from blunt-force injury to the left scapula and the right fibula. The radiographic and macroscopic study of the initial osseous remodelling of the antemortem trauma, still at the stage of “periostitis” (Figure 3.3), indicated that these lesions had probably been produced from 15 to 30 days before death. The highly qualified forensic pathologist who had previously studied the skeleton had not noticed the periosteal reaction, a detail that if missed would have led to a loss of important information. Hence, the intervention of a forensic anthropologist in the case resulted in conclusive findings that may otherwise have been ignored. The indications described confirmed a witness’s report, which stated that the victim had initially been hit with a blunt object and then chained to the wall. Anthropological evidence further showed that the victim survived these blows but after a period roughly between 15 and 30 days was stabbed and died shortly after. The case report demonstrated to both magistrates and investigators the importance of an anthropological approach to forensic investigation, not only regarding the subject of victim identification but also in the matter of bone-trauma interpretation.



Figure 3.2 Craniofacial superimposition

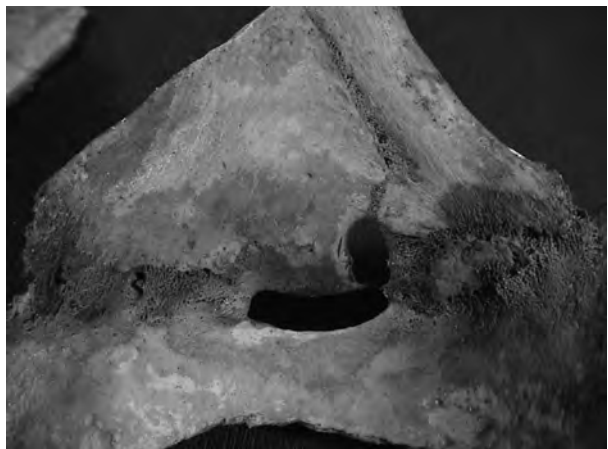


Figure 3.3 Detail of the right scapula, supraspinal portion, showing a recent fracture with initial healing and woven bone



Figure 3.4 Detail of the position of the charred body (in the circle toward the back) inside the burnt car

Case 2

In October 2013 in woodlands in the province of Sondrio, in Northern Italy, a charred body was found in a car that had been severely damaged by fire. The recovery was carried out in accordance with anthropological protocols by dividing the vehicle into sectors and sieving each one in the search for minute human remains (Porta et al. 2013) (Figure 3.4).

The car was identified, which in turn led to the development of a hypothesis about the identification of the deceased. The vehicle was traced to a man who notoriously had suicidal tendencies and had previously been admitted to psychiatric institutions. The autopsy highlighted the lack of extremities of the upper and lower limbs and the advanced charring of the unidentifiable corpse.

The anthropological analysis of bones and bone fragments recovered during the crime scene investigation did not provide information suggesting a possible traumatic cause of death. Toxicological analyses on the residual soft tissues sampled during autopsy, indicated a 71% concentration of carboxyhemoglobin. The toxicological results, the anthropological analysis of bones, and the circumstantial data were concordant with the hypothesis of suicide through asphyxiation and poisoning from motor vehicle exhaust fumes. As a result of the suicide attempt the car caught fire, consequently charring the body.

The main issue in this case report concerns victim identification; the odontological analysis revealed a number of dental restorations that were considered to be useful for identity confirmation. The dentist of the deceased was located in order to obtain antemortem dental records for comparison with postmortem data. Unfortunately, the dental practitioner admitted to not having preserved any clinical records, a common problem in reference to identification in many jurisdictions (for example, Blau et al. 2006). Genetic identification could not be performed owing to the absence of close relatives able to provide reference DNA material for profile comparison (Figure 3.5).

All the available clinical information was then recovered in order to find elements that may have helped in providing either positive or negative confirmation of identity; a clinical record reported that 23 years before his death, the subject had been the victim of a car accident and was affected by a fracture of the distal part of the left femur with detachment of multiple fragments and fracture of the right wrist. He also underwent a surgical operation of osteosynthesis—that is, for several months he had a metallic device applied to the left femur. In 2005 the individual had a radiological examination that verified signs of arthrosis on both the hip joints and deformation of the femoral heads.



Figure 3.5 Detail of the charred body at the autopsy



Figure 3.6 Superimposition of the 3D model of both the right femur (left) and left femur (right) from the charred body (photo on the right) and the antemortem X-ray examination

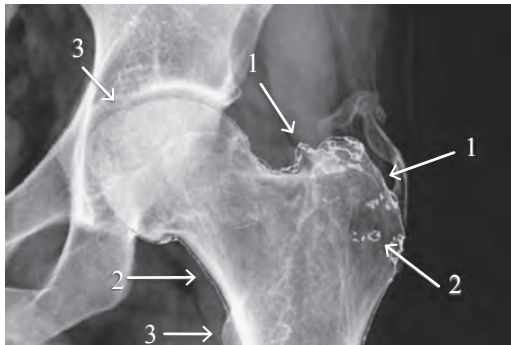


Figure 3.7 Points of concordance between the 3D model of the left femur from the unknown decedent and the antemortem X-ray examination from the identity suspect: the anatomical features: (1) profile of the greater trochanter; (2) profile of the femoral neck; (3) profile of the lesser trochanter and the pathological signs (osteophytes on the greater trochanter); (2) litic areas in the greater trochanter; (3) deformed profile of the femoral head.

Only the pathological alteration of the femoral heads was of use in ascertaining the identity of the body, since bones from the right wrist had not been recovered. The distortion of the limbs due to the pugilistic position, typical in burnt remains, prevented the possibility of performing a conventional X-ray examination for comparison. Therefore, both femora were removed from the body, completely skeletonised, and cleaned from residual soft tissue; the two bone specimens then underwent a 3D acquisition (Vivid 910, Konica Minolta, Osaka, Japan), acquiring a software generated 3D model of the bones to superimpose on the original antemortem X-ray images. The superimposition highlighted a perfect concordance between the general morphology of the recovered femora and the antemortem radiological documentation (Figure 3.6). A more precise comparison was performed with the aim of recording all the points of congruence from both an anatomical and pathological point of view, between the post and antemortem X-rays; the full correspondence between the two profiles allowed forensic operators to confirm the identity of the charred body (Figure 3.7).

This case is a perfect example of the potential of forensic osteology to identify unknown decedents when other information such as odontological or genetic data is not available. In

addition it demonstrates the importance of advanced technologies in improving procedures of comparison when conventional methods are not applicable.

Emblematic Cases: Forensic Archaeology

Case 1

In 1998 a mafia affiliate confessed to a magistrate that 10 years earlier a man had been murdered and buried in the woods on the outskirts of Milan. The magistrate proceeded in the recovery of the remains that were buried at a depth of approximately 1 m, employing non-expert personnel armed with picks and shovels. The end result was that the skeleton was severely damaged and was identified with great difficulty. This activity also complicated the distinction between peri- and postmortem lesions to the skeleton (Figure 3.8).

In Italy it used to be quite rare that archaeological methods were used in the recovery of skeletal remains or that the anthropological analyses of a skeleton was requested in order to create a biological profile that could be conveyed to the media (newspapers and television) for possible recognition of a victim's identification by readers or viewers. Following the experience of the mafia case mentioned here, magistrates began to acknowledge the value of expert forensic archaeological recovery and anthropological analysis. This acknowledgement was exemplified in a case that occurred in 2001.

On October 5, in a woodland area on the outskirts of a small town near Milan, a group of children playing in the vicinity of a primary school noticed a single boot emerging from the ground and, in kicking it, exposed a partly buried tibia and fibula. Investigating authorities immediately isolated the area and called the Institute of Legal Medicine in Milan. A team of forensic pathologists, anthropologists, archaeologists, and botanists arrived immediately at the



Figure 3.8 Damage, including fractures and commingling of the single skeletal elements, caused by a gross excavation methodology. The lack of a controlled recovery led to loss of information on identity, position of burial, postmortem interval, and trauma.

burial site, and the forensic archaeological recovery was performed. Over the late afternoon and night the skeletal remains were uncovered through stratigraphical excavation. The excavation was geared to precisely separating the edges, sides, and bottom of the burial from the backfill, in such a way as to respect the integrity of the burial while at the same time being certain of not adding post-mortem lesions or modifying already existing lesions to the skeleton. The respect of the integrity of grave and victim applied to both biological and cultural elements that could have been internal to the burial. A stratigraphic approach to the recovery also assured the separation of elements preserved within the clandestine burial considered to be pertinent to the crime scene from unrelated elements in the surrounding soil (Figure 3.9). The rigorous archaeological excavation allowed for the nondestructive recovery and the correct topographic recording of both skeletal and cultural elements (synthetic clothes, earrings, accessories, and so on) while a strict botanic sampling strategy, in particular the recording and recovery of roots crossing the femur and the auditory meatus of the cranium, proved to be essential to the determination of the postmortem interval.

After recovery the skeleton was cleaned and reassembled in the laboratory, where classical anthropological studies were performed (Ubelaker 1999): estimation of ancestry (see Sauer, Wankmiller, & Hefner, Chapter 18 this volume); sexing (Rowbotham, Chapter 19); ageing (Rogers, Chapter 20, and Crowder, Heinrich, & Dominguez, Chapter 21), height (Willey, Chapter 22), assessment of pathologies (Cunha & Pinheiro, Chapter 23); and dental status (Clement, Chapter 29). The anthropological analysis led to the construction of a biological profile consistent with a young (20–25-year-old) white female, approximately 1.60 m in height and possibly of Balkan origin. Finally a plaster model was cast from the recovered cranium, on which facial reconstruction was performed. Given the peculiar dentition (a large diastema between the two central upper incisors



Figure 3.9 The skeleton was recovered using archaeological methods. One can see the difference between the case in Figure 3.1 and this case. It was possible to recover every bone and personal effect, determine postmortem interval (PMI), and interpret skeletal lesions as perimortem trauma.

and the absence of the lateral upper incisors), laboratory personnel decided to reconstruct the face in a “smiling” pose to highlight the almost singular dental conformation.

A replica of the dentition was made in white resin for the teeth and pink plasticine for the gums. Since tufts of hair of a brownish colour and of medium length were found near the cranial vault during excavation, several possible hairstyles were also prepared for the final reconstruction. The facial reconstruction also took into consideration three earrings that were recorded in their original position during excavation. Thanks to the precise topographical recording of these accessories it appeared evident that the jewellery was not applied in a traditional manner, but all three objects were worn in the right ear at the same time, in particular two small yellow metal flowers in the right helix and one white metal ring in the right lobe. This detail, in association with forensic-anthropological and forensic-odontological data proved to be of the utmost importance in the identification of the victim. Furthermore, analyses of tree roots and clothing placed the time of death between 1995 and 1998; macroscopic and microscopic analysis of the costal margins revealed a cut mark with “green fracture” characteristics on the lower margin of the tenth left rib. Thus, at this stage, biological profile, time of death, and probable cause of death had been revealed. The final image of the victim’s face was then passed on to national newspapers and to Italian state television (RAI) (Figure 3.10).

The images of the facial reconstruction of the victim were transmitted on a popular television program that concerns cases involving missing persons. During and following the program several calls were made to the producers of which one in particular caught the interest of the investigating authorities. Information from the call led to the victim being positively identified and the subsequent prosecution of members of a prostitution ring who were accused of her murder. Specifically the caller recognised the victim because of her peculiar dental conformation. This identification was heavily reinforced, if not confirmed, by the caller owing to the particular arrangement in which the earrings were worn. Thanks to archaeological recovery and recording, forensic anthropologists were able to apply the earrings correctly to the reconstruction. It was later discovered that the jewellery was not worn in this particular manner by chance, but the specific conformation functioned as a “mark of property” of women involved with the prostitution ring.

This case, to our knowledge, is the first in Italy in which investigating authorities requested and allowed forensic pathologists, anthropologists, archaeologists, and botanists to deal with buried skeletal remains from the moment of their discovery. This manner of forensic investigation led to the

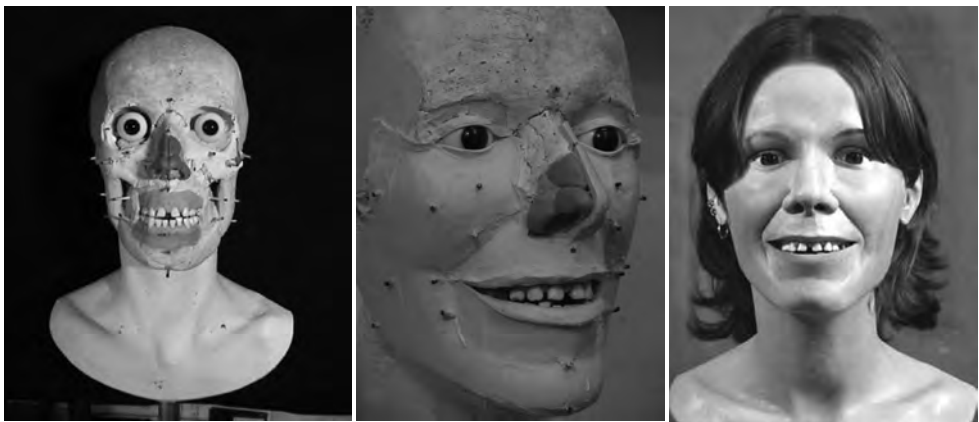


Figure 3.10 Various phases of facial reconstruction that followed the anthropological analysis of the skeleton

determination of postmortem interval, the construction of an accurate biological profile, identification of the victim, and diagnosis of the possible cause and manner of death. This process stresses how important it is for skeletal remains to be recovered by specialists in order to preserve the integrity of a clandestine burial through the use of stratigraphic excavation and botanical sampling strategies. In conclusion, this case proved to magistrates and investigating bodies the important advantages that forensic anthropologists and archaeologists can bring to a crime scene. With organised and respectful collaboration between specialists, investigating authorities, and the media, it is possible to deal accurately and in the proper manner with the retrieval of human remains, perhaps solving or contributing to the resolution of what may have initially appeared to be a hopeless case.

Case 2

In January 1998 two adolescents, a male and a female, disappeared. After the confession of one of their suspected murderers, their skeletonised corpses were found in May of 2004 in woodlands near the town of Varese in Northern Italy. The perpetrator belonged to a group that was later baptised by the media *Le Bestie di Satana* ("Satan's Beasts") because of their involvement in Satanism and the use of heavy narcotics. The witness indicated a deposition site, stating that he and another member of the group were responsible for the excavation of the clandestine grave but that he, at least, was not present during the murder, which took place directly at the burial site during the function of a satanic ritual. Both victims were reported to have sustained various sharp force lesions with two different knives; the male victim was also allegedly hit in the face with a mallet and sustained a sharp force lesion to the neck.

The indications of the witness led to an area of approximately 53 m² of woodland in a national park (Parco del Ticino). In the initial phase of the search for the exact location of the grave, five cadaver dogs investigated the area one by one. The dogs demonstrated interest in certain portions without, however, actually indicating a precise location. The second phase of the search strategy took into account the absolute necessity of either confirming the search area as being that of the burial site or its definite elimination from the search. The area was therefore investigated directly by means of the mechanical removal of topsoil to a depth of approximately 20 cm, with the subsequent investigation of the underlying substrata. This operation revealed homogeneous, natural deposits that bore no signs of disturbance. The area was consequently eliminated beyond doubt from the search, and the inspection was interrupted. After approximately one week the witness suggested that he may have been confused during his first visit to the area and led the search operators to a different, nearby portion of the woods. In this case the strategy involved an initial cadaver dog campaign followed by a surface survey and finally the removal of topsoil with the objective of investigating the area's substrata. Following the negative cadaver dog search of the new area and during the field survey, the head of a pick axe and a knife sheath were located in heavy undergrowth. These objects were considered to be important indicators of the possible vicinity of the clandestine burial. The topsoil of the surrounding area was removed with the help of a small mechanical excavator and, following archaeological cleaning of the immediate subsurface with trowels, a disturbance in the natural sedimentary deposits was recognised. Excavation of the grave lasted for the duration of a whole day and carried on into the night, when the two victims were finally recovered. The grave measured 1.90 m by 0.90 m, presenting a depth of 1.90 m. During the excavation various objects were found and recorded in their original positions; these included two pairs of latex medical gloves, document holders with personal effects still inside and legible, and, at approximately 60 cm depth, the blade of a shovel with part of a snapped wooden shaft still in place. The shovel handle undoubtedly snapped during what was probably the hurried backfill of the grave. At a depth of approximately 1.6 m from the surface two skeletonised corpses (male



Figure 3.11 Investigation of the ditch: anomaly found out by the archaeological research

and female) began to emerge (Figure 3.11). The first corpse (A) was positioned in the central portion of the pit, curled into an almost foetal position and lay transversally across the bottom of the grave. The cranium of corpse A was covered by the right arm of corpse B that lay below victim A and had been deposited along the bottom of the burial. The anthropological analysis confirmed the preliminary data gathered on site, identifying corpse A as being female and corpse B as being male. It was further established that corpse A was Caucasoid, aged between 17 and 22 years, 1.54–1.60 m tall, whereas B was Caucasoid, aged between 15 and 18 years, and 1.71–1.77 m tall.

In addition, the study of the female corpse (A) highlighted the presence of several bone calluses in the left humerus, left radius, left fibula, and a metallic nail in the left femur, compatible with lesions suffered *intra vitam* owing to a road accident. Analysis of the male corpse (B) showed several dental misalignments and incomplete eruption, congruent to the odontological profile of the missing male. Identification of the two adolescents was later confirmed through DNA analysis.

Corpse A showed several sharp force lesions on the spinous process of the 8th and 9th thoracic vertebra, the body of the 2nd and 3rd thoracic vertebra, on the 3rd and 8th right rib, on the distal extremity of the right clavicle, in the subspinous region of the right scapula, and on the distal extremity of the left ulna. The analysis also showed the amputation of the proximal extremity of the 5th right metacarpal bone, suggesting defence lesions. The minimum number of injuries sustained by victim A amounted to 11 (Figure 3.12).

Corpse B presented a fracture of the superior dental arch, of the right mandibular branch, and a linear notch in the bone surface with smooth edges on the right mandibular condyle; several sharp

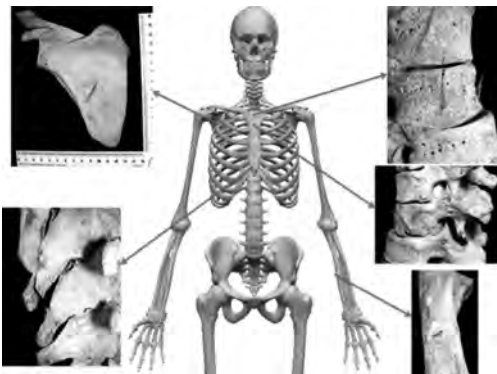


Figure 3.12 Some of the lesions on the female corpse



Figure 3.13 Some of the lesions on the male corpse

force lesions to the left humerus, to the left 4th, 5th, 6th, 7th, and 11th ribs, to the right 11th and 12th rib, and to the 2nd and 3rd lumbar vertebrae; and the amputation of the 5th right metacarpal bone was noted and interpreted as a defence lesion. In total the number of sharp force blows sustained was at least 12 plus the observation of one blunt-force trauma to the jaw (Figure 3.13).

The anthropological and archaeological data were consistent with the details contained in confessions released by the witness. However, during the investigative phases that followed the recovery and the arrest of all the participants in the homicide, the archaeological data regarding details of the chain of the events were confronted with the different versions produced by the accused. As often happens in cases in which there are more than one perpetrator, different levels of responsibility regarding the crime emerged with one participant accusing others of being the material perpetrators and perhaps diminishing his or her role in the event. As a result of the comparison between the data gathered and the declarations made, the witness was finally convicted, along with eight other members of the group, not only of the occultation of the bodies but also of their murder. This case shows how different professional figures can cooperate to improve the quality and quantity of data that can be obtained from skeletonised bodies and the context in which they have been preserved; in detail, an accurate and precise recovery of the two bodies, based on an archaeological approach, enabled anthropologists to perform a complete analysis of the remains with successful identification and assessment of bone lesion. This approach also aided investigators in the reconstruction of the chain of events regarding both the homicide and the burial of the victims.

Conclusion

Owing to the assistance that anthropology and archaeology have been able to provide in the resolution of the cases discussed here and others, in Italy these disciplines are slowly developing both academically and practically. In Milan, where their value has been strongly demonstrated in the courts and by the media, judges and magistrates are slowly coming to realise the importance of their application, both on the crime scene and in the laboratory. This activity has also had reverberations in other parts of Italy, and skeletal cases are slowly receiving proper attention and treatment. However, much work still needs to be done.

In fact, it is not only magistrates, judges, and investigating authorities that need to be “enlightened” but also, if not especially, forensic pathologists. They are the main players in the investigation of human remains, and when human remains are found, a pathologist is almost certainly called in and it is he/she who advises the magistrate on what should be done and which experts to involve. As stated, the pathologist is and should necessarily be called in where human remains are involved. In fact, according to Italian law the pathologist is the only specialist who can certify both death and the

cause of death. However, they are rarely competent in anthropology or archaeology. The reason for this lack resides in the fact that pathologists are not necessarily trained in osteology, and it is therefore of fundamental importance that a forensic anthropologist be consulted in cases involving skeletonised or partly skeletonised remains—which inevitably leads us to the delicate question of the lack of trained personnel (owing to the lack of structured training courses, a problem that is slowly reaching a solution) and the unavoidable appearance of “self-made” anthropologists on the forensic scene. The situation of unqualified personnel trying to make their way in this new discipline is a well-known problem. It is for this reason that teaching and certification are the next important goals of achievement in the sector. This need applies not only to Italian forensic anthropology and archaeology but also to both subjects on a European scale.

Note

- 1 The need for a European association that addresses these types of questions resulted in the establishment of the Forensic Anthropology Society of Europe (FASE). The main goals of FASE, a subsection of the International Academy of Legal Medicine (IALM), are education, harmonisation, and certification, along with the promotion of research (see Delabarde & Baccino, Chapter 4 this volume; Cattaneo & Baccino 2002; Baccino 2005).

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Forensic Anthropology

Perspectives from France

Tania Delabarde and Eric Baccino

In the first edition, Eric Baccino (2009), who is a medical doctor and a professor of legal medicine, highlighted in this chapter the fact that the discipline of forensic anthropology in France was an activity (not an individualised specialty) undertaken mainly by medicolegal doctors to answer demands from the French judicial system. Since 2009, however, there has been a slight but effective change in the status and practice of forensic anthropology in France because of the growing interest of students and professionals from both forensic sciences and the judicial system in this field. The number of university degrees (Masters) proposing a component of forensic anthropology has increased in France since 2009 as well as the number of international and national publications edited by French authors. With the creation of the Forensic Anthropology Society of Europe (FASE) in 2003, workshops in other European countries have promoted the discipline with the training of a great number of participants. Despite the increasing appreciation for the utility of forensic anthropology, there is still a long way to go before the discipline is recognised as a unique academic research field and speciality in France. While biological/physical anthropology is taught in universities, forensic anthropology does not exist as a separate discipline in the academic system. An historical overview will, however, show that biological anthropologists played an important role in research and publications in forensic anthropology but were rarely involved in practical cases.

Historical Overview in France

The man who is considered the father of Physical Anthropology in France, Paul Broca (1824–1880) was also a surgeon and a medical doctor. In addition to his research on bone torsion and brain morphology (in 1875) he played a major role in the foundation of La Société d'Anthropologie de Paris (1850), La revue d'Anthropologie (1872), and L'Ecole d'Anthropologie de Paris (1875). At the end of the 19th century Alphonse Bertillon published anthropometrical methods applied to the identification of criminals (1889) (İşcan & Quatrehomme 1999). Afterward and until the mid-1980s there was an unofficial task repartition between anthropologists who were at the origin of most research articles (Ferembach, Schwidetzky, & Stloukal 1979), and forensic pathologists who tended to concentrate on producing textbooks (with some forensic anthropology content)—for example, Vibert's *Précis de médecine légale* (1863) and, more recently, Dérobert's, *Médecine légale* (1974), which contained two chapters about Identification. These two chapters, called *Os* (“bones”) and *Dents* (“teeth”), explored most of the topics of interest to forensic anthropology: the determination of human and nonhuman skeletal remains, sex,

age, ancestry, stature, postmortem interval, facial reconstruction, photograph superposition, and identification (including from mass disasters). There was no or little mention about techniques employed to recover remains or analysis of bone trauma. This lack differed from the situation in Europe and the United States, where forensic archaeology was first mentioned by İşcan (1988) as “crime scene archaeology” and bone-trauma analysis was a focus in the 1990s (Smith, Berryman, & Symes 1990; Symes, Berryman, & Smith 1998; Galloway et al. 1999). İşcan and Quatrehomme (1999) provide a complete overview of the contributions of French scientists (anthropologists and medical doctors) to various fields of forensic anthropology. They include contributions by Olivier (1960) to general anthropology; Balthazard and Dervieux (1921) to foetal ageing, stature estimation, and microscopic ageing of adult bones; Fully (1956), Manouvrier (1892), and Rollet (1888, in Dérobert 1974) to adult stature and ageing from the ribs end and the sternum; and Dérobert (1974) to ageing from cranial suture closure and for dental charting and ageing.

National Resources and International Exchanges

In 1988 Eric Baccino, an author of this chapter, became the first French member of the American Academy of Forensic Sciences (AAFS), joined later by many French colleagues. This development gave French practitioners the opportunity to attend the forensic anthropology section of the annual AAFS meeting, which is one of the most active professional associations, with sometimes more than 100 presentations given in this section. The same year (1988), the Brest Bone Collection (BBC) was started in Brest (Brittany, France) and later continued in Montpellier (France). Developed initially from hospital and forensic autopsy cases of known age, sex, ancestry, and stature, it was restricted to forensic cases after 1994, when bioethics laws were issued in France, making collection of body parts from cadavers impossible. Today the BBC has more than 400 individuals with pubic symphyses, fourth ribs, medial clavicles, iliac crests, and teeth. This collection is used for training French students individually or in groups, for research purposes, and for students attending the European Workshop on Forensic Anthropology. It is the only Western European modern bone collection dedicated to ageing criteria (Baccino et al. 1999). Colleagues from the U.S., including Douglas Ubelaker, Judy Suchey, Norman Sauer, and others, have played a major role in developing and delivering what is the only training program in forensic anthropology in continental Europe. In 2002 the International Association of Forensic Sciences (IAFS), which meets every three years, held its meeting in France. During this time France was the second-highest publishing nation behind the U.S. in forensic anthropology, but neither medical doctors nor anthropologists had intended to create a national society or section in forensic anthropology. During the International Academy of Legal Medicine (IALM) meeting in Milan in 2003 FASE was officially created, giving the French an opportunity to join a group dedicated to forensic anthropology at the European level. Logically, the organisation of the European Workshops on forensic anthropology was transferred to FASE, which organised workshops in Europe (Milan 2004; Budapest 2006; Madrid 2008; Copenhagen 2010; Madeira 2011; Istanbul 2012; Colombo 2013; Heidelberg 2013; Zagreb 2014; Dubai 2015). To date, FASE has almost 200 members, including medical doctors, anthropologists, radiologists, and odontologists. In 2014 FASE finalised a certification process entitled FASE Certification for Practicing Forensic Anthropologist (C-FASE). At a national level forensic anthropology is present in the program of the monthly meeting of the Société Française de Médecine Légale. However, the main event for French anthropologists remains the annual one-day meeting on forensic anthropology organised by Gérald Quatrehomme in Nice, which also welcomes colleagues from Europe and abroad.

The Current Situation of Forensic Anthropology in France

Between 2009 and early 2015 the evolution of forensic anthropology in France has been illustrated by three key developments: (1) the growing number of forensic practitioners (pathologists, anthropologists, and odontologists) who conduct skeletal remains examination and/or academic research in forensic anthropology and/or subdisciplines; (2) the increasing number of university degrees that offer a component of forensic anthropology; and (3) the increasing number of publications (scientific articles and books) edited internationally (in English) and nationally (in French).

Forensic Anthropology Activities: Who, Where, and What

In the first edition of this chapter, Baccino outlined the French judicial system and the preponderant role of judges who are in charge of the investigation and the selection of relevant experts. Forensic pathologists and odontologists are mainly requested by judges in France to perform skeletal examination in forensic institutes—because from the judiciary point of view, forensic anthropology is just one (small) aspect of medicolegal activities, and there is no admissibility procedure in court such as in the Daubert rulings (United States Supreme Court in *Daubert v. Merrell Dow Pharmaceuticals, Inc.* 1993). Recently, however, some anthropologists (with a physical/biological anthropology background) have started to collaborate with forensic institutes and are more often involved in routine cases. The contribution of biological anthropologists to legal issues is related to their academic background, comprising extensive knowledge of osteology, ability to determine biological profile, analysis of skeletal traumatic injuries, and recovery techniques (since archaeology is part of their training). Furthermore, input at the scene has been extensively demonstrated in other countries, where forensic archaeology techniques have been developed and now commonly used, especially in mass disaster contexts (Dirkmaat & Adovasio 1997; Haglund & Sorg 2002; Bernardi & Fondebrider 2007; Dirkmaat et al. 2008; Tuller, Hofmeister, & Daley 2008; Blau & Sterenberg 2015). In France, the police and gendarmerie have local teams trained in forensic sciences, crime laboratories, and disaster victim identification (DVI) teams: Unité Gendarmerie d'Identification de Victimes de Catastrophes (UGIVC) created in 1992 and Unité Police d'Identification de Victimes de Catastrophes (UPIVC) created in 2000 that jointly operated as Unité Nationale d'Identification de Victimes de Catastrophe (UNIVC), but the National Crime Laboratory of Gendarmerie has a specific unit with an archaeologist, anthropologist, and odontologist who contribute to national and international operations (Schuliar et al. 2015). Some French anthropologists occasionally participate in the scene recovery (Adalian et al. 2002); however, since 2010, Tania Delabarde, an author of this chapter, who is working in two forensic institutes (Strasbourg and Paris), is regularly requested by judges to assist police and gendarmerie forensic teams with the recovery of skeletonised bodies from various contexts (for example, surface scatters, exhumations, fire scenes, riverine areas). The participation of the forensic anthropologist at the scene positively demonstrated the value of professional recovery of skeletal remains; detailed information is provided that may be pertinent to reconstructing the events surrounding death, including postmortem interval, body disposal and placement at the scene, and geological and environmental evidence (Adalian et al. 2002; Delabarde & Ludes 2014). At the scene, the anthropologist works with the forensic and investigation police or gendarmerie team in coordination with the forensic pathologist. As in the mortuary, the multidisciplinary approach facilitates the detailed gathering of all pertinent information that may be useful for determining the identification of the victim and/or establishing the cause and manner of death.

A proper recovery at the scene also improves the quality of the postmortem examination: the completeness of the skeleton is essential for developing an accurate biological profile and analysing trauma. Taphonomic information is key to the analysis of bone defects, because “they should be excluded as taphonomic in nature before they can be considered to have occurred in the perimortem interval” (Dirkmaat et al. 2008). The first emblematic collaboration between forensic anthropologists and pathologists in the mortuary occurred in the early 1980s at the Memphis Medical Examiner’s Office in Tennessee. The published results of this collaboration greatly exemplified the contribution of both practitioners to detailed bone trauma analysis and has undeniably amplified the perspectives and recognition of forensic anthropology beyond a laboratory-based discipline with a focus on biological profile (Smith, Berryman, & Symes 1990; Symes, Berryman, & Smith 1998; Galloway et al. 1999; Dirkmaat 2012). Even if the number of unidentified skeletons is small in most forensic institutes, in urban forensic centres the case load is on the rise; solitude, especially of the elderly, and population mobility within an open European space attractive to illegal immigrants are the two main economic and social reasons (for instance, Cattaneo et al. 2000). Therefore, in cases of unidentified migrants and isolated persons traditional scientific methods of identification such as DNA and odontology are limited. This worldwide situation has motivated forensic anthropologists to develop new methods of identification with large reference databases to trigger identification of unknown bodies with software such as 3DID (Slice & Ross 2009) and Fordisc (Ousley & Jantz 2012). From the recovery of human remains to the identification of an unknown body, anthropologists can greatly contribute to the forensic investigation. However, we must underline the need for extensive training and experience both in the field and in the mortuary to work professionally in legal contexts. The lack of such training and experience is another reason why there are few anthropologists involved in forensic cases in France: a career in biological/physical anthropology in the French academic system does not offer the prerequisites requested in a legal context; the very few anthropologists working in forensic cases today in France have been trained and gained the relevant practical experience abroad.

Academic Structures

In 2015 there is still no French university that offers specific graduate or postgraduate courses in forensic anthropology. However, a growing number of institutions (including the Universities of Bordeaux, Marseille, Nancy, Paris, and Toulouse) are proposing different university degrees (for example, Masters) with forensic anthropology lectures. It is now also possible (although not that common) to prepare a Ph.D. in anthropology with a forensic focus. The idea of a European university degree in forensic anthropology has been discussed by the universities mentioned previously in collaboration with the Universities of Milan, Coimbra, and Bruxelles. The first step for the recognition of forensic anthropology as a discipline in France is to develop rigorous academic and scientific foundations. Consequently, there is a need to generate academic/research positions that would ensure the creation of focused university degrees and student postgraduate formation. But the problem lies in the discipline itself. Although in many contexts forensic archaeology and anthropology are well established and practiced (Groen, Márquez-Grant, & Janaway 2015), this is not the case in France. As stated by İşcan nearly 30 years ago (but still pertinent today in France), the common source of many of the problems within forensic anthropology in France is related to a lack of definition of the still nascent field. The role of the forensic anthropologist had “yet to be fully understood and routinely accepted by both the anthropological community and the medicolegal system” (İşcan 1988: 222). However, in the last decade (2000–2010), the increasing appreciation for the utility of forensic anthropology and archaeology strengthens collaboration between the two disciplines.

Research Activities and Publications

Since the early 1990s the dominant theme in French forensic anthropology publications has been ageing methods (Table 4.1). In the 1980s Baccino published a histological and chest plate X-ray ageing (Baccino et al. 1989). One of the most significant French contributions to ageing mature adult cadavers is the dental method developed by the odontologist Henri Lamendin (1988) (which is also a component of the “two-step procedure” [TSP]). Lamendin’s technique was further developed by forensic pathologists (Lamendin et al. 1992) and validated at the international level (Prince & Ubelaker 2002), where it became one of the most widely used techniques worldwide owing to its excellent simplicity/accuracy ratio (Baccino & Schmitt 2006). Other adult age-estimation techniques include those developed by Rougé-Maillart from the forensic unit in Angers on the auricular surface and acetabulum (Rougé-Maillart et al. 2004, 2007, 2009) and more recently by Saint-Martin from the forensic unit in Tours using fusion of the distal femur and tibia epiphyses (Saint-Martin et al. 2013, 2015).

In Nice, the forensic team, led by Gerald Quatrehomme, who has greatly contributed to the development of forensic anthropology in France, worked on various subjects, including facial reconstruction, restoration techniques, femur sexual determination, and bone trauma analysis (including burned remains) (Quatrehomme et al. 1995; Grévin et al. 1998; Alunni-Perret, Staccini, & Quatrehomme 2003; Quatrehomme 2015).

The Institute of Legal medicine in Strasbourg developed genetic analysis of degraded DNA extracted from human bone, tooth, and hair as well as toxicology methods using bone material and decomposed remains (Ludes et al. 1994; Keyser-Tracqui, Crubézy, & Ludes 2003; Keyser-Tracqui & Ludes 2005; Petkovski et al. 2005; Ludes 2014); finite element modelling of human head injuries (Raul et al. 2006, 2008); histological bone techniques (Cannet et al. 2011); and, more recently, forensic anthropology (Delabarde et al. 2013; Delabarde & Ludes 2014).

The Toulouse forensic team has developed the application of radiological studies to various forensic anthropology questions (Telmon et al. 2005; Dédouit et al. 2007, 2008; Barrier et al. 2009). The forensic institute in Marseille contributed with new methods for age estimation of foetal and immature skeletal remains (Adalian et al. 2002; Piercecchi-Marti et al. 2002). The Lille forensic team developed various researches within forensic entomology and taphonomy

Table 4.1 French forensic anthropology publications concerned with ageing methods

<i>Ageing Methods</i>	<i>References</i>
Suchey Brooks System (SBS system)	Baccino & Schmitt 2006
Three-dimensional CT scan development	Pasquier et al. 1999; Telmon et al. 2005
Işcan’s fourth rib-based method evaluation and simplification	Martrille et al. 2003
X-rays of laryngeal cartilage	de la Grandmaison, Banasr, & Durigon 2003
Pelvic bone (auricular surface, acetabulum)	Rougé-Maillart et al. 2004, 2007, 2009; Schmitt et al. 2002
The multifactorial approach with the Two-Step Procedure (TSP)	Baccino et al. 1999
Histological age on ribs	Cannet et al. 2011
Femur and tibia epiphysis	Saint-Martin et al. 2013, 2015
Lamendin (dental technique)	Lamendin et al. 1992
Foetal age at death	Adalian et al. 2002; Piercecchi-Marti et al. 2002
Dental age in children	Urzel & Bruzek 2013

(Hédouin et al. 1999; Charabidze et al. 2014; Colard et al. 2015). The laboratory of biological anthropology from the University of Bordeaux developed methods for estimating sex based on pelvic bones and, more recently, on facial reconstruction and dental age estimation (Bruzek 2002; Guyomarc'h et al. 2012; Urzel & Bruzek 2013). Forensic institutes at Garches and Versailles worked on various subjects, including age estimation, bone trauma analysis, and historical cases (de la Grandmaison, Banasr, & Durigon 2003; Charlier et al. 2008, 2010). The Crime Laboratory of the French Gendarmerie published several articles about mass disasters and cadaver recovery techniques (Schuliar et al. 1996, 1998, 1999). Finally, the recent publication in French of two books dedicated to forensic anthropology illustrates the significant interest and development of this field undeniably related to legal medicine but following the international evolution to an autonomous discipline in forensic sciences (Delabarde & Ludes 2014; Quatrehomme 2015).

This overview demonstrates the evolution and dynamism of forensic anthropology in France, where multidisciplinary teams of forensic practitioners (pathologists, odontologists, radiologists, geneticists, toxicologists, histologists, and entomologists) working in collaboration with anthropologists have greatly contributed to the development of various fields of the discipline, including biological profile, bone trauma analysis, and taphonomy. The development of scientific validated methods and studies is one essential step to ensure the place and recognition of forensic anthropology as a forensic science.

Conclusion

Since 1990 forensic anthropology in France has undergone spectacular changes. The number of people trained in forensic anthropology has dramatically increased, as have the number of practitioners and the interest of students, who more regularly attend conferences and undertake doctoral research as well as publish articles. A French disaster victim identification (DVI) team (which acknowledges the role of the forensic anthropologist) was created in 2000 and has become very active at home and abroad. A boost in international collaboration is another characteristic of the last two decades (1995–2015) and has resulted in the creation of FASE, through which French forensic anthropologists (medical doctors more than anthropologists and odontologists) seem to thrive, with a Certification for Practicing Forensic Anthropologist (C-FASE) process ongoing since 2014. The number of anthropologists who routinely work on forensic cases is, however, very limited in France, and most of the activity in forensic anthropology remains in the research field. Since the origin of physical anthropology in France more than one and a half centuries ago anthropologists and medicolegal doctors (along with odontologists and other practitioners) have all participated actively in the scientific development of forensic anthropology, from the first step of its evolution from an applied field within forensic medicine to a robust dynamic scientific discipline.

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A History of Forensic Anthropology in Spain

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Forensic anthropology has developed in different ways across the world in response to country-specific criteria for approaches to forensic investigations, the role that the forensic anthropologist plays in these investigations, and the level of experience and/or the type of training system implemented.¹ In some countries, particularly in the United States, forensic anthropology has developed under forensic science as a subdiscipline of physical anthropology for the purpose of resolving criminal cases and is practiced by physical or biological anthropologists who specialize in the forensic field. Their research and techniques are applied to the identification of human remains in the legal sphere, where assessing sex, age, ancestry, and stature is essential to arrive at a biological profile of the individual in question (Stewart 1979; Krogman & İşcan 1986; Hunter 1996; Ubelaker 1999).

In some European countries, however, what is now described as forensic anthropology has been linked to forensic medicine, the specialized branch of medicine in the service of law, which incorporates the study of living and dead individuals, taking knowledge from scientific disciplines other than medicine. In such cases, forensic anthropology has developed, in practice, as a subdiscipline of legal and forensic medicine, and for this reason forensic doctors with training in physical anthropology frequently carry out forensic anthropological examinations (Gulec & İşcan 1994; İşcan & Quatrehomme 1999; Baccino et al. 2004; Prieto 2007; see also Cattaneo, Gibelli, & Salsarola, Chapter 3 this volume; and Delabarde & Baccino, Chapter 4).

In the following sections the historic and current roles played by forensic anthropology within the Spanish medical legal system are explained in terms of organizations, teaching, and research.

Historical Roots: Anthropology and Legal Medicine in Spain

Classical Period

Traditionally, forensic anthropology in Spain has focused on the identification both of living persons and of human remains based on reconstruction and/or comparison of the biological features observed in the skeleton. In Spain the problems of identification encountered in the legal sphere when one is dealing with living subjects and the deceased have always been associated with legal and forensic medicine (Reverte Coma 1991; Sánchez Sánchez 1996; Prieto 2001; Etxeberria 2004), as one of the topics in texts written by leading classic Spanish authors.² Historical roots of Spanish forensic anthropology date back to the mid-19th century under the

influence of two principal events: (1) the constitution of the Société d'anthropologie de Paris by Professor Paul Broca and (2) the development of modern legal medicine, which was greatly influenced by anthropology. Doctors and naturalists have had a significant influence on the development of anthropology in Spain. One outstanding figure is Dr. Pedro González de Velasco, an anatomist, founder of the Spanish Anthropological Society in 1865 and the Anthropological Museum of Madrid in 1875. It was at this time that the first magazines of anthropology, such as *Anthropological Magazine* (1874) and *Modern Anthropology* (1883), appeared (Reverte Coma 1991).

In 1883 the Anthropology and Ethnography sections of the Anthropological Museum were created, followed in 1892 by the appointment of Professor Manuel Antón y Ferrándiz as the first Chair of Anthropology in the Faculty of Sciences at the Central University of Madrid. In 1910 Ferrándiz was named first director of the Museum of Anthropology, Ethnography, and Prehistory. Other significant events include the publication in 1883 of the Cephalic Index of Spain by Dr. Federico Olóriz Aguilera, Chair of Anatomy at the University of Madrid (1894), and the creation of the Craniological Museum, which amassed a total of 2,500 skulls, 2,220 of which were identified individuals and came from donated bodies for research to the Department of Anatomy while Olóriz was chair (Gómez Ocaña 1913). Significant research undertaken by Olóriz includes his publication on stature in Spain (1896). Unfortunately, the lack of collaboration in collecting data from certain Spanish regions resulted in Olóriz giving up this project. His interest in identification techniques turned to fingerprinting, and he was one of the developers of the so-called monodigital system, or Spanish system (1908, 1909, 1910, 1911).

At the end of the 19th and the beginning of the 20th centuries, publications of other illustrious founders of Spanish anthropology, such as Telesforo de Aranzadi, Chair of Anthropology at the University of Barcelona, and Luis de Hoyos Sáinz (Professor of Physiology at the Teacher Training College), including their texts on anthropometry and ethnography, stand out (Hoyos Sáinz 1899, 1939; Hoyos Sáinz & Aranzadi 1913; Aranzadi & Hoyos Sáinz 1917). In the same period anthropology played a leading role in three fields of legal medicine: (1) analyzing the relationship between human physical features and criminal conduct (so-called criminal anthropology); (2) establishing the identity of the living, in particular that of delinquents, with the purpose of augmenting police identification through somatometry or Judicial Anthropometry; and (3) establishing the identity of a corpse, particularly from decayed, mutilated, burnt, and/or skeletonized bodies, from which it is necessary to establish a biological profile (sex, age, stature, and so on).

Criminal anthropology was made famous by the work of the Italian criminologist and physician Cesare Lombroso (1835–1909), who considered the delinquent to be an abnormal subspecies of the human race. For Lombroso a criminal developed innate conduct that represented a regression to previous evolutionary states and that could be recognized owing to a physical series of stigmas or anomalies, such as cranial and face asymmetry, small brow, protruding superciliary arcs, mandibular prognathism, an irregular implantation of the hair and teeth, and what he considered the most atavistic characteristic of criminals: a pit in the middle of the occipital. From the psychological point of view the primitive instincts with congenital incapacity to resist the forces of evil are predominant (Lombroso 1897).³ In Spain one of this perspective's more outstanding representatives was Rafael Salillas (1888, 1908). Other famous psychiatrists of the time also incorporated anthropological theories in their interventions in the courts. Doctors Ángel Pulido Fernández, José María Esquerdo Zaragoza, Luis Simarro Lacabra, and Jaime Vera Lopez often took part in judicial processes by presenting scientific valuations of criminal behaviors to the courts (Fernández 1991).

The anthropometric method, presented by the French police officer and biometric researcher Alphonse Bertillon (1853–1914) in the medical Congress of Rome of 1882 (Barahona Holgado

1908), aimed at identifying criminal recidivists using the almost absolute fixedness of the human skeleton in adult individuals, the interindividual variability of the skeleton measurements, and their simplicity and precision in the living. This method resulted in a practical, simple, and exact classification and was adopted quickly by Spain, contributing to the diffusion works of such Spanish physical anthropologists as Álvarez Taladriz, García Plaza, Alonso, and Aranzadi (Lecha Martínez 1912). The later development of fingerprinting, following the works of Vucetich and especially Olóriz in Spain, suggested the end of Bertillon's anthropometric identification techniques. However, somatometric techniques have again returned in the attempted identification of offenders through images caught by video cameras (for example, Porter & Doran 2000; Ventura et al. 2004).

A significant figure in the history of legal medicine in Spain is Dr. Pedro Mata Fontanet who in 1843 established the first Chair in Legal Medicine at the University of Madrid. To Dr. Mata we owe the creation in 1862 of a body of state doctors reporting to the Ministry of Justice, at the service of courts and tribunals, named the National Forensic Physicians Corps. Following the introduction of the *Criminal Indictment Act* in 1882, the title and functions of forensic doctors were officially recognized: "each court of first instance will have a doctor in charge of assisting the legal authorities in all cases or actions where their participation is necessary or advisable throughout the judicial district" (*Criminal Indictment Act* 1997: 249). Summing up, we can say that forensic doctors are the official advisors or experts in medical and biology matters for the Spanish courts and tribunals. However, the legal authorities have other official institutions that act as advisors in legal medical matters, including the National Institute of Toxicology and Forensic Sciences, governed by the Ministry of Justice, and other independent bodies such as the University Legal Medicine schools, professional medical associations, and the Royal Academy of Medicine. Within this context, anthropology is recognized as one of the main subjects of forensic medicine. On the 1915 list of official exam questions for access to the Forensic Physician Corp, 28 subjects were anthropology related, referring to anthropometry, craniometry, and skeletal characteristics of sex and age or dental evolution (Vibert 1916).

The work of such Spanish anthropologists as Olóriz, Salillas, and Aranzadi are referred to in legal medicine texts of the time (Barahona Holgado 1908; Lecha Marzo 1917; Piga y Pascual 1928), and the anthropological techniques are described in those same texts with respect to cadaver identification. In them are anthropometric references and descriptions on the estimation of stature according to the tables of Orfila, Rollet, and Manouvrier); sex; age (ossification points, obliteration of the sutures, laryngeal ossification, state of the teeth) (Peiró & Rodrigo 1844; Barahona Holgado 1908; Lecha Martínez 1912; Piga y Pascual 1928); particular signs of identity (old fractures, occupational malformations, stigmas, and skeletal X-rays) (Barahona Holgado 1908); and dental analysis (Piga y Pascual 1928). Some authors, such as Lecha Marzo, warn of the importance of microscopic bone analysis in time-since-death estimation and the age of death from the studies developed by Tirelli (Lecha Marzo 1917). The teachings of Maestre (Ballesteros 1913), first director of the Institute of Legal Medicine, Toxicology, and Psychiatry of Spain, created in 1914, and Piga y Pascual (1928, 1935), successor of Maestre in the Legal Medicine Chair of Madrid, are particularly complete with respect to aspects of corpse identification and, although for the most part they present data from works elaborated by other authors, contribute valuable elements of their own personal experience.

The period between the second half of the 19th century and the Spanish Civil War (1936–1939) is known as the Silver Age of Spanish culture and science. During this time institutions such as the Ateneo de Madrid and particularly the Institución Libre de Enseñanza, enjoyed great influence on scientific and cultural environments. The Institución Libre de Enseñanza was founded in 1876 by a group of university professors (including Francisco Giner de los

Ríos, Gumersindo de Azcárate, and Nicolás Salmerón) who separated from the university to defend academic freedom. The Institución, with which the majority of the best Spanish scientists of the moment collaborated, marked a significant time in the development of Spanish scientific culture. One of its main outcomes was the creation of the Junta para la Ampliación de Estudios, in charge of the creation of the National Institute of Physical-Natural Sciences, to which was added, among other institutions, the Museum of Anthropology. The main purpose of this museum was to introduce to Spain pedagogical and scientific theories that were being developed internationally. Unfortunately the civil war resulted in the destruction of this institution and with it the incipient scientific system that had begun to develop in Spain (Otero Carvajal 2001).

Modern Period

While forensic anthropology was rapidly developing outside Spain, especially in post-World War II United States under the direction of Drs. Ales Hrdlička, Wilton Marion Krogman, Ellis R. Kerley, and T. D. Stewart, relatively little progress was made in this field in Spain. Although some investigations involving the study of skeletal remains with forensic aims were undertaken by such people as Dr. Blas Aznar González, who was a driving force in the development of the field of criminology in Spain (Aznar 1931), and the already mentioned Dr. Tomás Maestre (Aznar & Maestre 1945), the texts of renowned authors such as Drs. Royo-Villanova Morales (1952), López Gómez (1967), and Gisbert Calabuig (1985), along with other scientific publications related to the study of human remains, continued making exclusive reference to the most classic authors of the discipline and to outdated knowledge.⁴

It was not until the early 1980s that a new “modern period” began for Spanish forensic anthropology. The point of reference can be located in the creation of the Laboratory of Anthropology Forense and Paleopatología at the Legal Medicine School of Madrid by Dr. José M. Reverte Coma (Reverte Coma 1997).

Through Dr. Reverte and the publication of his book *Forensic Anthropology* (Reverte Coma 1991)—the first book published in Spain on forensic anthropology—the techniques and knowledge developed by the American forensic anthropologists spread into Spanish legal medicine at a time when the structure of legal medicine in Spain was being modernized. Forensic anthropology was added to the curriculum of legal medicine and employed successively in daily forensic medical practice.

In 1984 legal and forensic medicine was officially recognized as a medical speciality in Spain. Today, through a system called MIR (Resident Intern Doctor), a single exam gives access to any of the state posts offered for all medical specialities. For legal and forensic medicine, training is carried out at the legal medicine schools governed by university medicine faculties. At present the legal and forensic medicine speciality is offered in Madrid (Complutense University) and in Granada. Successful students can opt for one of three paths: (1) taking the state exam for the Forensic Physician Corps (FPC), for which the speciality is not an indispensable requirement; (2) obtaining university professorship, which is separate from normal forensic practice; or (3) entering the private advisory sector.

The official organizational structure of forensic medicine in Spain has led to a general isolation of forensic doctors in professional and scientific terms and a complete separation (save in exceptional cases) of official forensic practice (governed by the FPC) from the university mandate in legal and forensic medicine teaching (and theoretically in research). Forensic medical work until now had been performed directly in legal spheres, in court buildings lacking adequate medical or scientific infrastructure and equipment, with scant means, and in an individualistic and

personal manner, without any specialization. Only the leading regional capitals, such as Madrid and Barcelona, boast forensic medical clinics and forensic institutes. At the clinics specialist forensic doctors perform examinations of live subjects in areas such as forensic psychiatry, traumatology (body damage evaluation), gynaecology, and others. The forensic institutes meanwhile deal with legal autopsy of corpses in their judicial district and are simply official mortuaries. Since the late 1980s the Forensic Institute (FI) in Madrid has gradually developed diverse services related to corpse investigation. Thus forensic pathology, toxicology, anthropology, dentistry, and radiology services have been introduced, being the first in their respective specialities to be implemented among the collective of Spanish forensic doctors.

In 1985 Spanish legislation, through the Organic Judicial Powers Act, recognized the need to transform the organizational system of forensic medicine by proposing the creation of so-called Legal Medicine Institutes. The aim of these institutes is to promote the modernization of forensic medicine and to foster teamwork and specialization in adequately equipped centers. This reform is currently at the stage of introducing nationwide Legal Medicine Institutes. The Spanish state is divided into autonomous regions, the majority of which, following devolution by the central authorities, hold legal justice powers, making the regions responsible for innovating the Institutes. The Legal Medicine Institutes, therefore, are being founded as technical bodies that centralize forensic medical expertise to tap its legal advisory capacity.

The Institutes are structured into services and departments, which include all the forensic doctors of a given autonomous region. Their mission is the same as the mandate held until now in a personal and individual manner by all forensic practitioners—namely, to assist the courts and tribunals through expert medical tests. This mandate has increased to include other responsibilities, such as forensic medicine teaching and research, the latter in coordination with the Universities and the National Toxicology Institute. Forensic anthropology forms part of the Institute's Forensic Pathology service, charged with legal medical investigation in all cases of violent or suspected criminal death occurring in their judicial district, as well as corpse and human remains identification. The future Madrid LMI will have a forensic anthropology department inside the Forensic Pathology Service. Its mission will be the identification of living and deceased subjects, as well as the forensic study of remains to identify the cause and circumstances of death.

Although the Spanish Ministry of Education and Science follows the international UNESCO International Standard Classification of Education (ISCED) considers forensic anthropology as a subdiscipline of physical anthropology in the life sciences field, as I stated earlier, legal case resolution in medical and biology matters in Spain has always been the remit of forensic medicine. The problems of identification when one is dealing with living subjects and corpses in the legal sphere have always been associated with legal and forensic medicine (Reverte Coma 1991; Sánchez Sánchez 1996; Prieto 2001; Etxeberría 2004). Inside the Spanish legal medicine system, forensic anthropology is considered a special branch of forensic sciences whose purpose is legal medical study of badly preserved corpses with the aim of identifying them and establishing the cause and circumstances of death.

At present, forensic anthropology is practiced mainly by forensic doctors with specialized knowledge in physical anthropology who are based in legal medicine centers (forensic institutes and university departments). They are considered specialists able to carry out forensic medical consultation in diverse cases of legal interest relating to both living subjects (identification, age estimation in undocumented youths, and so on) and cadavers. In the examination of human remains the objectives are to establish the physical features and personal characteristics that enable identification, as well as the possible cause and circumstances of death (Prieto 2001). These two elements are fundamental in resolving any death case within a legal context and

constitute indisputable objectives of any medicolegal autopsy (as stipulated by Spanish criminal law), whatever the condition of the corpse. The European Union (EU) recognizes the same fundamental elements in Recommendation Number 99 (3) of the Council of Ministers of Member States for Harmonisation of Medico-Legal Autopsies (1999), which states in its Principles and Rules relating to medicolegal autopsy procedures: “Autopsies should be carried out in all obvious or suspected unnatural death, even where there is a delay between causative events and death, in particular . . . unidentified or skeletonized bodies” (Council of Europe Committee of Ministers 1999: 3).

Forensic anthropologists are being incorporated in many cases routinely undertaken in forensic institutes.⁵ They contribute to diagnosis of cause and circumstances of death and complement the work of the forensic pathologist when they are dealing with fresh corpses on which a conventional autopsy is practiced. The forensic anthropologist is particularly useful in providing complementary analyses of perimortem injuries to skeletonized remains (see Clement, Chapter 24 this volume) and in supplying valuable additional data on the characteristics of wounds and the objects or weapons responsible for them (blunt trauma, sharp force, or gunshot wounds). The fact that forensic anthropological assessments are performed in these centers, where conventional autopsies are carried out daily, serves to provide unequaled experience in the diagnosis of trauma when one is studying skeletonized remains and provides a personal perspective different from that of forensic pathologists, who are not trained in the analysis of skeletal structures and their interpretation. Meanwhile, the links between these forensic centers and the universities have enabled practice, teaching, and analysis to develop unavoidably hand in hand.

There are a total of nine laboratories: four in Madrid, two in Valencia, and one each in Catalonia, the Basque Country, and Andalucía. The total annual number of forensic anthropology cases studied at the nine Spanish labs is about 200. This figure is probably far smaller than the number of cases objectively requiring study, as observed in other countries (Cattaneo & Baccino 2002). To give an example, at the Madrid FI approximately 2,500 corpses are received annually, with only 40 requiring the services of a forensic anthropologist. Installation of the Legal Medicine Institutes will enable objective and homogeneous study criteria to be introduced. This change will eliminate the current situation, whereby the forensic practitioner in charge of the case is the only person who decides if examination is necessary based solely on his or her experience. Regardless of the preservation (complete or partial), cases are remitted to the anthropology department for the conventional autopsy in the evaluation of skeletal injuries.

Investigating the Missing in Spain

In addition to contributing to common criminal cases within the medical legal structure, forensic anthropology also plays a role in the recovery and identification of human remains related to the Spanish Civil War (1936–1939) (Etxeberria 2004; Ríos Frutos 2012; Congram 2013; Congram, Passalacqua, & Ríos 2014; Ferlini 2014).

During the Civil War and the first 10 years after General Franco’s dictatorship instauration more than 180,000 persons died off the battlefields, most of them victims of extrajudicial, summary, or arbitrary executions, but also in prisons or as the result of bombings (Juliá 1999). Around 49,000 persons suffered reprisals in the Republican side and 130,000 in zones under control of the military supporting the coup and later on during the dictatorship in almost the whole Spanish territory (Espinosa 2009). Thousands of dead people were officially registered under the cause of death of “war edict imposition,” but a much higher number of cases were not registered. These people were detained, killed, and missing up to now; most of them were buried in mass graves located in open fields or in cemeteries.

Exhumations of so-called triumphants (that is, those individuals fighting on the Nationalists' side) began very early in the aftermath of the war with the official support of the new government. After the war a law was passed in 1940 granting the exhumation of corpses of people killed by the "reds" (that is, the Republicans). This law provided instructions for the dead bodies to be buried in cemeteries exempted from taxes in consideration of their patriotic death (*Ministerio de la Gobernación, Orden de 1 de Mayo de 1940 "sobre exhumaciones e inhumaciones de cadáveres de asesinados por los rojos"*). As a result, thousands of dead bodies belonging to the Nationalists' side were exhumed and delivered to their relatives for mourning and a proper destination.

Between 1940 and 1959 a huge monument in the form of a mausoleum was erected by General Franco with the intention of being remembered by future generations. The mausoleum (which currently holds the dictator's tomb) houses thousands of dead bodies, around 34,000 from both sides, which were transferred, registered, and stored in tagged wooden boxes in several crypts. A recent forensic inspection of the crypts ordered by the Spanish government in 2011 showed the collapse of boxes and a mess of wood and bone, making the individualization of corpses an extremely complex task (<http://www.memoriahistorica.gob.es/es-es/vallecaidos/Documents/informeforensevalledeloscaidos.pdf> accessed January 29, 2016).

In the 1970s the exhumations of General Franco regime's victims began. The initiative was driven by relatives of the missing and undertaken privately in a rudimentary way without any kind of scientific methodology. With the exception of photographs taken by the families during the work, no records of the exhumations were kept. Unfortunately the political situation in the first years after the return of democracy to Spain and especially the attempted coup in 1983 stalled those efforts, and exhumations were abandoned.

It was not until 2000 that the first "scientific" exhumation was undertaken (Silva 2006), in the village of Priaranza del Bierzo (León). For the first time, forensic methodology was implemented, including archaeology, anthropology, and genetics. The case was a milestone in the process of mass grave exhumations in Spain and boosted the establishment of the Asociación para la Recuperación de la Memoria Histórica (ARMH), an entity working intensively on the restitution of the Spanish missing to their relatives.

The absence of public policies and state support for the process of historical memory in Spain has been and is currently the rule, as highlighted by international organizations and institutions of human rights (Amnesty International 2013; United Nations 2014). In 2007 a law recognizing the rights of those who suffered persecution and violence during the Civil War and the dictatorship, the so-called Historical Memory Law (*Ley de Memoria Histórica*) was passed (*Ley 52/2007, de 26 de diciembre, "por la que se reconocen y amplían derechos y se establecen medidas en favor de quienes padecieron persecución o violencia durante la Guerra Civil y la Dictadura"*). The law provided two main tools regarding the location and identification of the missing: (1) a multidisciplinary protocol for scientific tasks (Ministerio de la Presidencia. Orden PRE/2568/2011, de 26 de septiembre, *por la que se publica el Acuerdo del Consejo de Ministros de 23 de septiembre de 2011, por el que se ordena la publicación en el Boletín Oficial del Estado del Protocolo de actuación en exhumaciones de víctimas de la Guerra Civil y la Dictadura*) and (2) the mapping of graves (http://mapadefosas.mjusticia.es/exovi_externo/CargarInformacion.htm). A special office was set up to deal with families and associations, and a program to grant funds for exhumations was approved. However, all work related to the location, recovery, and examination of human remains is entirely the responsibility of the relatives' associations. Managing the process, asking for permission from local authorities or property owners, dealing with the historical investigation, and archaeological prospection and recovery of dead bodies are carried out by them with the unselfish assistance of volunteers and some experts in different fields (history, anthropology, sociology, and forensic sciences).

The absence of legal and financial support contrasts with the involvement of the Spanish State in searching and recovering the bodies of the Blue Division volunteers, the battalion sent by Franco to buttress Nazi troops during World War II. However, the lack of state policies determines the absence of a common framework, resulting in (1) nonstandardized quality in the procedures and professional qualification of those involved in the process; (2) lack of coordination regarding the criteria in the management of cases (for example, prioritizing exhumations) and scientific activity; (3) absence of a unique database to centralize information; and (4) lack of judicial tutelage (such as from forensic institutes) to give the necessary legal guarantee to the process, supporting the legality of identifications and assigning resources.

In 2011 a protocol for a procedural and methodological guide to exhumations was approved by the Presidential Office. This protocol provides key recommendations for the different steps of the process: preliminary investigation, archaeological intervention, forensic investigation, reports, and final destination of human remains. A map of grave locations was published on the website of the Ministry of Justice, but since 2011 the special office was closed, and the map has not been updated. Consequently, there are now no official figures on the number of excavated graves and bodies recovered and identified.

According to the information gathered by the Sociedad de Ciencias Aranzadi (Francisco Etxeberria, pers. comm.), the most active organization in the process, a total of 278 graves had been exhumed by the end of 2011 and more than 5,000 bodies exhumed.

There is a great variability in the kind of burial, from individual graves usually showing remains in the worst state of preservation (sometimes no more than fragments of bone and buckles or rubber soles are found) to, more rarely, graves containing dozens of bodies, demanding a more complex archaeological approach. The third kind of burial is in prison cemeteries. Bodies are usually buried in single graves, and data about the identity are available in prison registers, although sometimes the graves have been recycled.

Identification of deceased individuals after more than 70 years is not an easy task (for example, Renshaw 2011). Poor preservation, the lack of antemortem data mainly due to the loss of testimonies after such a long time after the events, and the small value of unspecific features are the rule. Most of the cases demand DNA analysis, but the lack of suitable relatives and/or the poor preservation of bone, together with limited funding, make DNA identification unfeasible, and only 10% of cases have been identified with the support of DNA analysis (Francisco Etxeberria, pers. comm.).

In conclusion, Spain has the technical capacity and the appropriate professionals to face the challenge associated with the recovery, identification, and restitution to the families of those whose remains are still forgotten in anonymous graves all around the Spanish territory. However, the issue of the missing in Spain demands a robust state policy of support for the relatives.

Teaching and Research

Forensic anthropology in Spain is largely taught as part of forensic medicine programs but is also taught under criminology and biology programs that include physical anthropology. Over recent years, forensic anthropology has raised its profile, thanks to the boost given to training in both the university and the legal spheres. University training is offered at both undergraduate and postgraduate levels. Some topics included in legal medicine undergraduate study incorporate concepts related to forensic anthropology, such as the study of burnt corpses, identification techniques (including biological profile reconstruction), decomposition and preservation techniques, and responses to mass disasters.

With respect to postgraduate studies, the subject of forensic anthropology is covered in the Legal and Forensic Medicine Specialist Subject under the topic Criminology (rather than Legal and Forensic Medicine), specifically in relation to issues of identification, and in doctorate programs in some medicine and biology faculties. A wide range of basic and advanced courses of 60 to 300 hours in forensic anthropology are available at Spanish universities. The wide variety of training programs in university departments has enhanced research activity over the last years, as illustrated by the increasing number of doctorate works, communications presented in scientific meetings, and articles published in national and international journals.

The creation of the Spanish Association of Forensic Anthropology and Odontology (AEAOF) has played a key role in the development of the disciplines. The association was set up in 2006 and currently has 96 active members. The profile of the affiliates is quite varied, drawing together professionals from different disciplines involved in the management of human remains; most of the associates are medical doctors (56), odontologists (14–16 of whom have a medical degree), and biologists (14), and the rest have backgrounds in archaeology and history, anthropology, criminology, chemistry, and law. Since 2008 AEAOF meets annually, with an average of 100 registrations.

Conclusion

In summary, forensic anthropology in Spain is an activity principally linked to the medical legal system, when it deals with common criminal cases. However, cases related to the missing from the Spanish Civil War (1936–1939) are usually performed outside forensic institutions and bring together a variety of professionals with different backgrounds and qualifications. Forensic anthropology, like forensic archaeology in Spain (Márquez-Grant et al. 2015), is a growing scientific discipline, reflected by the increasing number of specific training courses, texts, and articles published in national and international magazines derived from a larger research and experience. It is clear that forensic anthropological expertise in Spain is needed. With the purpose of obtaining properly trained forensic anthropologists and qualified forensic anthropology laboratories across Europe, the Forensic Anthropology Society of Europe (FASE) launched a certification process in 2014 (see Blau, Chapter 40 this volume). Without doubt, scientific associations such as AEAOF in Spain and FASE at a European level play a major role in the evolution of modern forensic anthropology.

Notes

- 1 Gulec & İşcan 1994; Ubelaker 1996; İşcan & Quatrehomme 1999; İşcan & Olivera 2000; İşcan 1998, 2001; Baccino et al. 2004; Rodríguez 2004; Sanabria 2004; Schiwy-Bochat, Riepert, & Rothschild 2004; Brickley & Ferlini 2007.
- 2 Peiró & Rodrigo 1844; Mata Fontanet 1874; Lecha Martínez 1894; Barahona Holgado 1908; Ballesteros 1913; Piga y Pascual 1928; Aznar & Maestre 1945; Royo-Villanova Morales 1952; López Gómez & Gisbert Calabuig 1967; Gisbert Calabuig 1985.
- 3 Lombrosao's theories are no longer well accepted (Gould 1981).
- 4 Martínez Estrada 1951, 1952; Muñoz Tuero & De Portugal Álvarez 1966; Muñoz Tuero, Moya Pueyo, & Blanco 1972; Muñoz Tuero & Díaz Domínguez 1981; Pérez de Petinto Bertomeu 1952, 1980; Romero Palanco, Torres Ortiz, & Vila Lopez 1980; Villalán Blanco & Buján Varela 1981; Villalán Blanco & Ramos Almazán 1981; Serrano Cepedano 1982.
- 5 A number of laboratories have been promoted by different institutions, including the Ministry of Justice (FDC): Madrid Forensic Institute, National Toxicology Institute, Catalonia Legal Medicine Institute; universities (Legal Medicine faculties): Complutense (Legal Medicine School), Basque Country, Valencia, Alicante, Granada (Anthropology Chair at the Medicine faculty); the Home Office (Forensic Police): National Police.

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The Application of Forensic Anthropology to the Investigation of Cases of Political Violence

Perspectives from South America

Luis Fondebrider

This chapter reflects on the development of forensic anthropology in the investigation of cases of political violence. It seeks to contextualize the boom that has been taking place since 1996,¹ following the beginning of extensive forensic investigations in the Balkans. In addition this chapter confronts the apparent novelty of this application of the discipline with reference to its significant development in the Latin American context, where the Argentine Forensic Anthropology Team (EAAF) has been one of the pioneers in the field through its activities since 1984.²

Although the literature on the origins and the current status of this particular application of forensic anthropology³ has substantially increased since the early 2000s (Doretto & Fondebrider 2001; Haglund 2001, 2002; Haglund, Connor, & Scott 2001; Hunter et al. 2001; Skinner, Alempijevic, & Djuric-Srejac 2003; Fondebrider 2004; Simmons & Haglund 2005; Skinner & Sterenberg 2005; Steadman & Haglund 2005), there is still a lack of understanding about the nature of the work and the contribution made by organizations and individual anthropologists outside the Anglo-Saxon world. As an example: work carried out by the two largest organizations in Latin America, EAAF and Fundación de Antropología Forense de Guatemala, or FAFG (the Guatemalan Forensic Anthropology Foundation), are mentioned as merely early and local developments (Simmons & Haglund 2005) (which in the case of EAAF is not true, since they have been working outside Argentina since 1986), incorrectly described (Klonowski, Drukler, & Sarajilic 2004), or ignored (Hunter 2002). This situation could have resulted from a couple of factors: a lack of knowledge regarding the activities of the discipline in other parts of the world or an almost non-existent bibliography that ignores other experiences and mostly concentrates on Anglo-Saxon activities in the Balkans. Because the Balkans is the only region where the majority of Anglo-Saxon forensic anthropologists have worked, this experience is taken as paramount and as a model to apply—for example, in Iraq, a popular destination for forensic anthropologists (Bernardi & Fondebrider 2007).

Additionally, there is no single criterion for the type of contribution made by forensic anthropology to contexts of political violence, which are therefore designated as “humanitarian,” “human rights,” “war crimes,” or “genocide” investigations, all of which are but incomplete

names that simplify the complexity of the problem. This situation may be due to the fact that most of the practitioners of such name applications do not have a profound and comprehensive insight into what political violence entails, the different local contexts, or the judicial and humanitarian dimensions of the investigations. Finally, such applications of forensic anthropology are new for many professionals, who until 1996 had excavated only individual graves in their own countries. Many such professionals have very little to no knowledge of the human rights situations in the places where have worked—for example, the importance of the relatives of the victims.

Facts and Aspirations

Since the early 1990s a great number of forensic anthropologists of different nationalities have worked in the Balkans, acquiring expertise in exhumation and analysis of skeletal remains, as well as an understanding of the significance of interacting with the victims' relatives. In most cases these scientists have worked daily throughout several months excavating graves and analyzing skeletons. There are others, however, who instead have made only short visits to Bosnia, Croatia, or Kosovo and have subsequently published methodological guidelines on these issues. Unfortunately, some colleagues—reputed as international experts in mass grave excavations, analysis of large collections of skeletons, and communication with victims' relatives—have failed to consider the experiences gained by those who have actively participated in the worldwide development of these applications of forensic anthropology.

The Tribunal for the Former Yugoslavia (ICTY) started its intensive investigations of mass graves in Bosnia, which has been enormously significant from all standpoints.⁴ The collective nature of these contributions is highlighted by the Bosnian example: hundreds of archaeologists and anthropologists have worked long hours excavating graves and analyzing remains. A great number of these professionals, particularly those from countries lacking experience in this kind of massive investigation, had to start from the basics. They had never seen a real mass grave before or, in the best of cases, had exhumed only individual graves associated with domestic crimes. Some had a Masters Degree in Forensic Archaeology but were not prepared for fieldwork. Very seldom had they worked with contemporary skeletons, or they were used to perimortem injuries caused by gunshot or accustomed to interacting with forensic pathologists. However, there were other professionals who arrived in Bosnia, and later in Croatia and Kosovo, with experience in cases of this kind. These were professionals (particularly those from the United States) who had worked in criminal contexts or in the recovery of missing American citizens in wars and professionals (from Argentina, Guatemala, and Colombia) for whom working in mass graves and analyzing remains were ordinary rather than exceptional cases.

A good example of the lack of acknowledgment of the origins of the application of forensic anthropology to the investigation of political cases and the nature of the collective contributions is the subject of the protocols used for field and laboratory work and the collection of antemortem data. The majority of organizations mentioned in this chapter has been involved in the development of protocols and have always clearly attributed such protocols to a specific organization. The protocol documents are the result of collective contributions from many anthropologists involved in this work since the mid-1980s. In developing protocols practitioners rely on models *already created* that are modified and adapted for particular contexts.

It is important to present a fair and balanced description of how forensic anthropology started to be applied to investigations of political violence and what the contribution made by each organization has been. The fact that there are almost no scientific papers published by researchers outside the United States and the United Kingdom does not mean that there are

no such researchers or that they should be ignored or mentioned only casually when discussing this issue.⁵ For example, to disregard the fact that the EAAF has worked in over 35 countries, that it has its own laboratory where dozens of remains are analyzed every year, that since 1992 it has been one of the points of reference for the United Nations in these kinds of investigations, that it has contributed to the training of other teams and professionals in no less than seven countries, and that it has kept almost daily contact with the victims' relatives for 30 years does not help to ensure an evenly balanced exchange among the parties involved. Furthermore, to ignore the fact that the FAFG is an organization staffed by a large number of full-time anthropologists, equipped with their own laboratory and over 20 years of experience in excavating highly complicated mass graves and analyzing hundreds of skeletons per year (Steadman & Haglund 2005; www.eaaf.org; www.friendsoffafg.org/) does not help advance our discipline. It also denies the significant contributions made to acknowledging the role of the victims' families as true protagonists rather than as mere secondary actors.

At the same time, one should mention that the two major organizations in Latin America, as well as other individual anthropologists, do not publish enough papers describing all the experiences accumulated. This is a weakness that has to be challenged. It is not a question of drawing attention to personalities, or of drawing a dividing line between Europeans and Americans, on the one hand, and Latin American professionals, on the other, but of joining efforts, acknowledging professional weaknesses or deficiencies, enhancing capabilities, and ultimately contributing to the development and improvement of this specific application of forensic anthropology.

A Briefing on History: The Latin American Context

Figures are tangible evidence and also hard to dispute. To mention only the best-known cases: more than 200,000 people disappeared and/or were murdered in Guatemala between 1960 and 1996; 15,000 in Argentina between 1976 and 1983; 70,000 in El Salvador between 1981 and 1991; 70,000 in Peru between 1980 and 2000; 3,000 in Chile between 1973 and 1989; and thousands in Colombia, an estimate that increases daily. One should keep in mind that these figures refer to real human beings with first and last names, with families and friends still longing to know what has happened to them and, if applicable, demanding to know where their remains are, who killed them, and that justice be brought to those responsible for the crimes.

What was the prevailing *modus operandi*? It mainly involved (1) the victim's illegal detention, immediate extrajudicial killing, and disappearance of his/her body; (2) the victim's kidnapping, transfer to a legal or clandestine detention center, torture, extrajudicial killing, and disappearance of his/her body; or (3) a confrontation between state security forces and a guerrilla group, resulting in the robbery and disappearance of dead guerrillas' remains.

What happened to the remains? The bodies were buried in official cemeteries as John Does; buried in clandestine cemeteries without any identification on the grave, or on crop lands, in military compounds, ravines, and so on; thrown into dried-up water wells; thrown into the sea or volcanoes from airplanes; burnt; or destroyed with explosives or chemicals. More often than not the State was the main perpetrator (with the exception of Colombia and Peru). This fact resulted in families and the community as a whole being terrorized: families were unable to ascertain the fate of their loved ones and failed to obtain a response from the state to their claims for truth, justice, and reparation.

When Dr. Clyde Snow arrived in Argentina in 1984 as part of a scientific delegation organized by the American Association for the Advancement of Science (AAAS), he knew nothing of this situation. He disinterestedly traveled to Argentina to help victims' family members to look for and identify their loved ones' remains and consequently became the pioneer of the application

of forensic anthropology to the investigation of cases of political violence. From this initial trip onward Dr. Snow, imbued with the spirit, repeatedly visited several countries, training young scientists, building a bridge between scientists and the victims' relatives, and raising awareness among public authorities that there should not be any gap between these parties (Snow 1984a, b; Joyce & Stover 1991).

At that time it was most unusual to talk about forensic anthropology in Latin America; indeed, the discipline was unknown to judges and prosecutors. Forensic physicians were acquainted with some general notions from legal medicine publications, which used to include a small section with tables from European publications from the end of the 19th century. Physical anthropologists, in contrast, were better positioned to make anthropological analyses of skeletons but were only seldom consulted by authorities, and there was little interest in incorporating them into forensic circles.⁶ The picture for remains recovery was even worse, since this task was left in the hands of the police, fire fighters, or gravediggers.

To draw a complete picture of this time one must describe the political context. The same countries that had undergone political violence, causing massive human rights violations, were gradually returning to democracy. Transition to democracy was a complex process, during which those responsible for "the disappearances" were free or, in some cases, occupying political positions in the new governments. This situation was the reason why investigations, from their very beginnings, were strongly conditioned by several factors, namely: (1) a strong presence of human rights organizations, particularly those involving victims' relatives;⁷ (2) little or no independence of forensic institutions, very often complicit in the crimes;⁷ (3) lack of information on burial sites; (4) an almost complete lack of interest from the academic world to participate in investigations; (5) after an initial period, a decline of the state's interest in continuing with the investigations; and (6) ensuing decline in the support given by the international community. With the exception of (5) and (6), this was the situation encountered by Dr. Snow at the time of his arrival in Argentina. Consequently he decided to work with a group of anthropology and medical students, who later on were to found EAAF (Joyce & Stover 1991). Snow's pioneering work extended to Chile in 1989 and to Guatemala in 1992, thus contributing to beginning the training process of independent forensic anthropologists in these two countries.

The fact that forensic anthropology in Latin American countries was born out of a dire need to meet the demands of the social sectors hardest hit by violence is one of the most striking differences between the development of forensic anthropology in Latin America and in the United States and Europe. It was not the result of an academic decision or a decision from an anthropology department eager to fulfill its civic responsibility to undertake this task; indeed, the academic community was not interested in the process. Therefore, forensic anthropology in Argentina, Chile, Guatemala, and later in Peru was initially pushed to broaden its traditional role of determining the biological profile of a skeleton for identification purposes; but this was not good enough. There was a need not only to recover bodies following correct procedures but also to respond to issues associated with the political and legal contexts in the places where the work was being performed, to ensure the logistics and security required for each intervention, and, most especially, to establish a relationship with the victims' relatives and their communities. That the victim's relatives, rather than the judge or the forensic anthropologists, are the true protagonists is still hard for most scientists to understand. Given all these considerations, anthropologists had to interact with other actors in the process and broaden their scope of action; for example, establishing ties with the victims' relatives, a task that goes well beyond collecting antemortem data, is a long, slow process that requires a relationship built on mutual trust.

Building an atmosphere of trust is, of course, not a smooth or simple process for the teams involved. We had to learn how to interact with relatives, to understand their doubts, uncertainties,

to respect their need for time. For example, not all family members are always willing to start an investigation; sometimes some of them are afraid of the political consequences. On other occasions the perpetrators still live in the same village, and to ask a relative or a witness to point out the gravesite might put the person in danger. For all these reasons, we think that it is a mistake to see the relatives as simple providers of antemortem data or blood samples for DNA analysis. It is much a more complex procedure entailing hours with the relatives, explaining the process of exhumation, the realistic probability of finding remains, the difficulties of identification, but also to hear their histories, to try to understand, for example, how the disappearance of their loved one has affected the family and changed their lives. All these things are unrelated to the traditional field of forensic anthropology but were important skills we had to learn along the way (Stover & Shigekane 2002; Doretti & Snow 2003; Doretti & Fondebrider 2004).

The other main difference between Latin American and North American and European forensic anthropology organizations is that for the EAAF, and in certain respects also for other Latin American teams, the preliminary investigation of each case is an essential part of the work. The lack of interest of the judiciary to investigate properly, the lack of support from the state, and the reluctance of the perpetrators to provide information require that from the very beginning that we construct our own hypotheses about the location of the remains of the disappeared people. We cannot ask the police or criminal investigators for help. They were in many cases part of the same system. Based on the idea that perpetrators, especially when they are the state, leave traces of their actions in various media, we started searching cemetery records, death certificate archives, court records, intelligence reports produced by the army or the police, and press information, and we interviewed not only relatives of the victims but also witnesses that participated in or saw the killings and burials of the bodies (Snow & Bihurriet 1992; Doretti & Snow 2003; Bernardi & Fondebrider 2007).

Therefore, when extensive investigations started in Bosnia in 1996, under the ICTY, the processes of investigating cases of political violence (including the relationship with the victims' relatives, the exhumation of graves, and the analysis of skeletal remains) were firmly rooted in the work of EAAF in Argentina. In Guatemala many useful experiences were also gained during four years of exhumations of mass graves and analysis of remains. In Colombia individual anthropologists were engaged in the investigation of political cases as well as in ordinary crimes.

The International Context: The Balkans and the Rest of the World

Dr. Snow worked in isolation for several years, since very few colleagues from the United States joined his efforts. In Europe only a few forensic pathologists lent their support following requests from Amnesty International to investigate cases of torture or death in custody in the countries where such crimes were reported. It was not until the ICTY's investigations that anthropologists became more interested in the forensic application of their field.

Thus one must begin the history of the application of forensic anthropology to the investigation of political violence by mentioning the work of the American Association for the Advancement of Science (AAAS) that in 1984 engaged a group of American scientists, among them Dr. Clyde Snow, to go to Argentina, after which the AAAS helped to start the process in Guatemala. Before 1996, when the work in Bosnia started, there were two organizations working at the international level: the EAAF and the Physicians for Human Rights (PHR). The EAAF⁸, created in 1984 after Snow's visit, began in 1986 to participate in forensic investigations in other countries that, after periods of violence, were starting to analyze their past. So, in those 12 years before the work in Bosnia, EAAF had been working already in Argentina, Bolivia, Brazil, Colombia, Croatia, Chile, El Salvador, Ethiopia, Guatemala, Iraq, the Philippines, Romania, and South Africa.

PHR, founded in 1986 with a wider objective, also developed forensic anthropology through its forensic program, directed initially by Dr. Robert Kirshner and later by Dr. William Haglund. Mr. Eric Stover participated in the original delegation of the AAAS to Argentina and played a major role in this process as executive director of PHR until his retirement in 1995. Until 1996 PHR conducted forensic missions to Croatia, Mexico, Guatemala, Honduras, and Rwanda. Instead of counting on its own team of forensic anthropologists, the forensic program of PHR is presided over by a forensic specialist (until recently, Dr. W. Haglund), who recruits anthropologists and other professionals from different countries whenever they are assigned a specific mission. Once the mission is finished, each specialist returns to his/her country of residence. The longest and most significant project for PHR was in the Balkans, beginning in 1996, and then in Cyprus, beginning in 1999 (<http://physiciansforhumanrights.org/>). For specific missions, such as those in Iraq (1992) and Croatia (1993 and 1996), EAAF as well as colleagues from the Guatemalan and Chilean teams were invited to participate by PHR, the coordinating organization.

In 1996 PHR was commissioned by the ICTY for the Balkans mission to conduct the first mass exhumations in Bosnia. Again it recruited a large group of experts from different countries giving many international anthropologists the opportunity to participate in this kind of work for first time. For most of the anthropologists who traveled to Croatia and Bosnia in those years (1996 and 1997), this was their first experience with a mass grave and with analyzing the skeletal remains of different populations. Many of the pathologists, radiologists, and crime-scene investigators who were part of the teams in those years had never investigated the kinds of cases in which the state was responsible for the killing of large numbers of people. It was not a typical mass disaster, such as an airplane crash. In this case the perpetrators went free, the bodies hidden in mass graves, and thousands of families were involved. Very few of those scientists recognized that they were unprepared for such a different task. In contrast to the experience in Latin America, these first years had a very technical profile, almost without contact between forensic specialists and families, quite the opposite of what Snow had promoted since 1984.

Sometime later the Tribunal decided to hire its own forensic specialist, José Pablo Baraybar from Peru, who opened up the path for another important group of anthropologists, mainly from Latin America, the United States, and the United Kingdom, to work in this field. Also in the Balkans, in 1996, the International Commission on Missing Persons (ICMP) was created, with a strong emphasis on the use of DNA analysis to identify remains. A few years later ICMP also began to hire anthropologists for the recovery of remains from mass graves and their analysis. During some periods the ICTY, PHR, and ICMP worked at the same time in Bosnia. Some of the most interesting articles about the exhumation of mass graves and anthropological analyses were produced by anthropologists who worked for ICTY and later for ICMP (for example, Haglund 2002; Komar 2003; Skinner, Alempijevic, & Djuric-Srejc 2003; Skinner & Sterenberg 2005; Baraybar & Marek 2006; Tuller & Duric 2006; Tuller, Hofmeister, & Daley 2008). In 2002 the United Nations Mission in Kosovo (UNMIK) created the Office on Missing Persons and Forensics (OMPF) within the Department of Justice, with the objective of determining the whereabouts of missing persons, identifying their remains, and returning them to the families. The OMPF was also assigned to establish a medical examiner's office to provide medico-legal forensic examinations according to international standards and to build local institutional capacity to carry out this work.⁹

Finally, in 2001, INFORCE was created. This organization is staffed mostly by English scientists who have been trained in forensic anthropology and archaeology and who gained practical experience in the Balkans between 1996 and 2001 working for PHR, ICTY, or ICMP. To date INFORCE as an institution has worked in the Balkans, Cyprus, and Iraq, and one of its

members participated in a mission to the Democratic Republic of Congo in 2003, under the coordination of EAAF. In addition, many anthropologists, although not members of any of the previously mentioned organizations, have worked for them in the Balkans, providing input from their countries of origin.

The U.S. Department of Defense Joint POW/MIA Accounting Command deserves a special mention. Even though it cannot be regarded as a typical organization engaged in the kinds of cases discussed here, it has gained broad experience in the recovery and analysis of remains of American citizens disappeared in war, particularly in Southeast Asia.

The preceding brief description illustrates that, with the exception of the EAAF and PHR, the other organizations outlined have focused their activities in the Balkans. Consequently the great majority of forensic anthropologists who have been working for the last 10 years in applying their disciplines to cases of political violence have done so almost exclusively in this region of the world. Only in exceptional cases have these scientists been faced with circumstances in other countries.¹⁰ Thus many publications on the application of forensic anthropology to political violence are biased owing to the fact that the authors' experience in this area is an exception rather than a rule.

There were several negative experiences in the Balkans, including a profusion of local and international agencies involved in the task that disagreed about methodologies and that applied different work protocols. Lack of coordination resulted, in many occasions, in problems with the identification of the remains and the re-analysis of bodies—which, in turn, created uncertainty among the relatives about the process. As a consequence the International Committee of the Red Cross (ICRC) launched The Missing project (www.icrc.org/eng/resources/documents/publication/p0897.htm). This important initiative promotes *the right to know* of the relatives of the missing around the world, as well as raising the profile of legal, humanitarian, psychological, and scientific aspects of the work. This initiative involved an important effort to draw lessons from experiences gained in the Balkans and other parts of the world, such as Latin America, where science has been used to investigate cases of missing people.

The Current Situation in Latin America

In Latin America forensic anthropology may be applied to three types of cases: (1) domestic crimes; (2) mass disasters (aircraft accidents, earthquakes, car bombs, and so on); and (3) political violence (kidnapping/disappearance of persons and executions). The first two scenarios involve forensic anthropologists working for an official institution (for example, medico-legal services, judicial police, offices of prosecutors, and/or scientific police). Argentina, Colombia, Costa Rica, Cuba, Chile, Mexico, Peru, Puerto Rico, Uruguay, and Venezuela are some of the Latin American countries that have incorporated forensic anthropologists in at least one of the services mentioned here. In general, they focus on the analysis of remains rather than on their recovery, but they have undoubtedly acquired important case-based knowledge.

The third type of case has been largely left in the hands of nongovernment organizations, with a few exceptions, such as Peru very recently. In addition to the EAAF and FAFG there are other organizations that investigate political violence in Latin America, including the Guatemalan organization Centro de Antropología Forense y Ciencias Aplicadas, or CAFCA (Center for Forensic Anthropology and Applied Sciences); the Equipo Peruano de Antropología Forense, or EPAF (Peruvian Forensic Anthropology Team); and the Centro Andino de Investigaciones Antropológico Forenses, or CENIA (Andean Center for Forensic Anthropology Research). Similar activities are undertaken by the Equipo Forense Especializado (Specialized Forensic Team) in the Legal Medicine Institute in Peru, also under the purview

of the Public Ministry. In Colombia these activities are performed by the Legal Medicine Institute and the prosecutor's office, with their own anthropologists, and recently an independent organization was formed called Equipo Colombiano Interdisciplinario de Trabajo Forense y Asistencia Psicosocial, or EQUITAS (Colombian Interdisciplinary Team for Forensic Work and Psychosocial Services).

Why are most of the initiatives from private and not state-run organizations? There are countless reasons to account for this peculiar feature, but two stand out: first, there is the relatives' lack of trust in public agencies to conduct this kind of investigation, despite the new democratic wind blowing in the region; and, second, there is the state's lack of interest in digging deep into the past.

Conclusion

This chapter has briefly described how forensic anthropology first began to be applied in 1984 to investigations into political violence in Latin America and has highlighted differences between investigations undertaken in Latin America and those conducted in the Balkans from 1996 onward. Differences in development and experience between Latin American and European and U.S. scientists result from a series of factors:

- 1 There are disappeared people and mass graves containing their remains throughout Latin America, Africa, the Middle East, and Asia. Also, the rate of criminal cases (including those requiring analysis of skeletal remains) is high in several countries. This situation means that forensic anthropologies have the possibility to have a permanent and full-time job in official and non-official organizations, to obtain experience with domestic cases, and to develop new field and laboratory population standards.
- 2 There are practically no mass graves or large numbers of remains to be identified in the United States or Europe (with the exception of Spain and countries in the east and WWII graves, particularly in Germany and Austria). The United States, in turn, has a high rate of domestic crimes and, since September 2001, cases related to terrorism, many of which require the analysis of remains. In Europe, particularly in the northern countries, the rate is very low. Consequently there are limited jobs for forensic anthropologists in Europe. Most of the cases involving skeletal remains are analyzed by forensic pathologists, and the exhumations are done by the police or personnel from a criminalistic field.
- 3 Latin American forensic anthropology organizations specializing in political cases have focused closely on their relationship with the victims' relatives. For European and U.S. organizations and anthropologists, this aspect has been just one among many others, often left to the responsibility of the United Nations or other organizations, so as to focus exclusively on technical issues.
- 4 Compared to the United States the United Kingdom offers relatively few training courses in forensic anthropology. There are even fewer training courses available in Latin America.
- 5 Forensic anthropologists in Latin America have a strong empirical knowledge, based on vast experience, but only a few have a Ph.D. In developed countries, the situation is just the opposite.

Cooperation under equal conditions is absolutely desirable. In fact, the differences listed above should not divide forensic anthropologists working in this field of application but on the contrary should enrich our task, by fostering a balanced and open dialogue with a view to rendering a better service to the victims' relatives, doing justice and preventing impunity.

Notes

- 1 In spite of the fact that specific forensic investigations began in the Balkans in 1992 with the United Nations appointed Commission of Experts, assisted by Physicians for Human Rights (PHR), extensive investigations did not start until 1996, when the International Criminal Tribunal for the Former Yugoslavia (ICTY) commissioned PHR to conduct the forensic exhumations resulting in the contracting of large numbers of scientists.
- 2 EAAF is a nongovernment, independent organization created in 1984. To date, the EAAF has carried out forensic missions in Angola, Argentina, Bolivia, Brazil, Colombia, Côte d'Ivoire, Cyprus, Chile, Democratic Republic of the Congo, El Salvador, Ethiopia, Guatemala, Honduras, Indonesia, Kenya, Mexico, Morocco, Namibia, Panama, Paraguay, Philippines, Romania, Sierra Leone, South Africa, Sudan, Togo, Uruguay, Venezuela, and Zimbabwe. In addition the EAAF has participated as a member of international teams in missions in Bosnia, Croatia, Georgia/Abkazia, Haiti, Iraq, Kosovo, Peru, Philippines, and Timor-Leste.
- 3 The term *forensic anthropology* is used in its widest sense, comprising the activities of both archaeologists and anthropologists who are concerned with the investigation of cases of criminal and political violence.
- 4 Fondebrider, author of this chapter, as a member of EAAF participated in some of its investigation stages from 1993 through 2000.
- 5 The group of forensic anthropologists engaged in investigations of this kind is a small one, and we all know one another very well. Therefore, we know what other colleagues have done, where they work, and for whom they have worked. The volume and extent of the experience gathered can be very simply evaluated by looking at the reports issued by each organization, at least those who produce a report every year.
- 6 In this brief summary I should mention the pioneering work of Dr. José Vicente Rodríguez from Colombia in the training of young generations of forensic anthropologists in his country.
- 7 In most Latin American countries forensic experts form part of (1) the judicial system, (2) the prosecutor's office, and (3) the security forces.
- 8 The EAAF is based in Argentina, and despite the fact that the organization has a branch office in New York, it is still, on some occasions, denied a status as an international organization. It appears as if only those based in the United States or Western Europe may be called "international."
- 9 Also it should be mentioned that apart from the organizations mentioned, local governments in Bosnia, Croatia, and Republika Srpska exhumed graves, in some cases, with advice or participation from foreign scientists.
- 10 One of the exceptions is the participation of several forensic anthropologists since 2001 in investigations in East Timor, under the direction of the United Nations Serious Crimes Investigation Unit (SCIU).

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The Origin and Development of Forensic Anthropology and Archaeology in Colombia

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Forensic anthropology and forensic archaeology in Colombia are recent disciplines going back no more than 25 years; they have been developed from the same educational tradition as cultural anthropology by anthropologists who have gained experience in judicial investigations and medicolegal autopsies from the daily casework load.

This situation differs from that in North America and Europe, where forensic anthropology and archaeology have strong academic foundations and a culture of research practice, as well as educational programs in forensic anthropology and archaeology (Dirkmaat et al. 2008; Dirkmaat & Cabo 2012). The Colombian context also differs from the dynamics that led to the development of these disciplines in other South and Central American countries, which occurred in post-conflict societies through nongovernmental organizations and was supported by the initiatives of missing persons' relatives seeking to obtain evidence of human rights violations perpetrated by past dictatorial regimes (Doretti & Fondebrider 2001; Salado & Fondebrider 2008: 214).

By contrast, in Colombia these disciplines have been prompted by the medico-legal system and law enforcement institutions owing to different intrinsic and extrinsic factors, such as the escalation of homicidal violence, the political negotiations for the demobilization of paramilitary groups, the international cooperation agreements for the support of antidrug policies, and, last but not least, the social movements supporting the search for missing persons over the backdrop of a civil war that has been ongoing for over 60 years.

The Colombian civil war, which represents one of the longest-lasting current armed conflicts (Fisas 2013), has seen the involvement of multiple and heterogeneous armed groups, including guerrillas, paramilitary organizations, government armed forces, and criminal organizations, some of them related to drug trafficking. It has had a cruel effect on Colombia's civilian population; out of the 220,000 casualties of this war, 81.5% have been civilians, and only 18.5% have been directly involved in the armed conflict (Centro Nacional De Memoria Histórica 2013a: 32).

Forensic anthropology and archaeology advances cannot be detached from this context. Consequently, this chapter assesses the origins and development of these disciplines within the background of the historical and structural violence that has shaped Colombian society. Three periods are proposed to understand the development and changing goals of the disciplines. Finally, the predicted trends and challenges are outlined, based on the experience gained and lessons learned over the past 25 years.

Origins: Institutionalization of Forensic Anthropology and Archaeology in Colombia

This chapter proposes that in Colombia forensic anthropology and archaeology originated between the mid-1980s and the mid-1990s, when the Laboratory of Physical Anthropology of the National University of Colombia, under the direction of Dr. José Vicente Rodríguez (a physical anthropologist who undertook training in Russia), started to provide assistance to the judicial system with the identification of the great number of dismembered, skeletonized, or extremely altered bodies (for example, burnt) that began to appear all over the country (Rodríguez 1996: 91; 2004: 33–34).

Within the Colombian academic community of physical anthropologists, Dr. Rodríguez can be considered the first scholar who started and then continued to apply human skeletal biology research to criminal investigations. The human remains were usually brought to the Physical Anthropology Laboratory for biological profile estimation (sex, ancestry, biological age, and stature) and facial reconstructions, and in some circumstances he and the graduate students provided support for the exhumations of clandestine graves (for instance, the Justice Palace and Siriri Operation cases described in Rodríguez 2004: 215–38).

Cases requested for consultation were related not only to political violence but also to criminal activities. Aspects of this forensic analysis were related to investigations of alleged executions, selective assassinations or enforced disappearances linked to the counterinsurgent action undertaken by the government armed forces or the paramilitary groups against left-wing political leaders, or to the civilian population that was occupying a territory controlled by the opponent armed group (Cubides 2005; Centro Nacional De Memoria Histórica 2013a: 23–27). Other complex cases analyzed by forensic anthropologists were related to kidnappings and selective assassinations, strategies that were used by the guerrillas to gain control of a territory, and to the production and trade chain of coca and cocaine (Centro Nacional De Memoria Histórica 2013b: 22, 33). Other challenging forensic examinations were linked to deaths caused by hired assassins or terrorist attacks related to the drug trade violence (P. Morales pers. comm. December 30, 2014).

During this early period Colombia was considered one of the five countries in Latin America with the highest rates of homicide; 1991 had the highest number of annual violent deaths recorded in Colombian history: 28,284 (Villaveces 2001: 275–77). The abrupt escalation of the rural and urban homicides was associated with multiple factors, including the territorial and military expansion of the guerrillas, and the consolidation of paramilitary groups and their strengthening due to ties with drug trafficking (Gutiérrez & Barón 2006: 289; Centro Nacional De Memoria Histórica 2013a: 50–54).

At this time the medico-legal system had a strong structure, established since the beginning of the 20th century; nonetheless, the medical examiners were not trained in the analysis of skeletonized corpses. Therefore, trauma analysis undertaken following the autopsies performed on bodies in stages of advanced decay or intentionally altered was very general. In many cases the cause and circumstances around the death were usually concluded as “undetermined,” and basic information required for identification was seldom supplied (P. Morales pers. comm. December 30, 2014).

In this period between the late 1980s and early 1990s two events are specifically referred to because of the awareness they raised in the medico-legal system about the importance of the work of the forensic anthropologist, particularly in the identification process and in the association of body parts: the case of the Avianca Boeing 727 bombing, which occurred on November 27, 1989, and claimed the lives of 107 people; and the terrorist car-bombing of the Director of the National Department of Security (DAS) on December 6, 1989, which caused the deaths of 110 people. These two disasters exemplified challenging medico-legal issues at a time when

Colombian society was terrorized as a result of the war between the drug cartels and their confrontation with the state (P. Morales pers. comm. December 30, 2014).

During the early 1990s the escalation of homicidal violence, compounded by technical insufficiency and shortages in qualified personnel, encouraged the medico-legal system to hire anthropologists with experience in physical anthropology and bioarchaeology, a process that this chapter refers to as the institutionalization of the discipline. By this time two difficult issues facing the development of the field became evident: the absence of a graduate program in forensic anthropology and the lack of an academic community or professional association.

In 1990 the National Institution of Legal Medicine and Forensic Sciences (Instituto Nacional de Medicina Legal y Ciencias Forenses—INMLCF), by initiative of the head of the National Coordination of Forensic Pathology, Dr. Mary Luz Morales, officially founded the first laboratory of forensic anthropology based in Bogotá, which hired one anthropologist during its first four years. In 1995 an additional anthropologist was hired, and by the late 1990s three anthropologists were working at this laboratory. In 1994 the Criminalistics Unit of Technical Investigation (CTI), ascribed to the General Attorney's Office, founded a second laboratory, named Laboratory of Specialized Identification (Rodríguez 2004: 34–35). This laboratory included not only anthropologists but also medical examiners, dentists, and morphologists. As part of a law enforcement institution, these anthropologists started to be trained in crime scene analysis and to participate in scene documentation, handling of physical evidence, and the recovery of dead bodies (Fiscalía General de la Nación 2005).

In spite of the institutionalization of forensic anthropology and archaeology in different governmental institutions, the number of available anthropologists with experience in analysis of skeletal remains and bioarchaeology was insufficient given Colombia's high rates of homicides. Therefore it was common that the recovery of remains from clandestine graves was performed by law enforcement officials who had no background in forensic archaeology. Many of the exhumations at this time were performed without following the basic scientific protocols and lacked *in situ* documentation. As a result, large amounts of evidence and contextual information were frequently lost.

Lessons Learned from the Case of Pueblo Bello Massacre

The Pueblo Bello Massacre is a case that exemplifies the irreversible legal and psychosocial negative effects resulting from the deficiency of best forensic practices and the lack of recognition of the need for forensic experts to assist in the search, recovery, and identification of dead bodies within an armed conflict setting.

In January 1990, 43 farm workers were subjected to “forced disappearance” and murdered by a paramilitary group, with the acquiescence of government armed forces. In 2006 the Inter-American Human Rights Court (CIDH) issued a condemnatory verdict against the Colombian state, which said that there were deficient forensic practices employed in the recovery and identification of the victims, as well as psychosocial damages caused by the improper conditions in which the relatives were forced to visually identify the bodies of their beloved ones (Inter-American Court of Human Rights 2006: 27).

The inadequate forensic practices took place during the exhumations performed two months after the massacre. A total of 24 bodies were exhumed without appropriate retrieval procedures and evidence management. Afterward the relatives had to inspect the bodies, some of them still with decomposing soft tissue, in search of evidence such as clothes or belongings that would allow their loved ones to be recognized. Six of these bodies were visually identified by their relatives. The investigations made by the CIDH concluded that this event had negative effects on the mental and physical health of relatives “after they had observed the ‘full details of the horror’ without any type of support” (Inter-American Court of Human Rights 2006: 26).

Following these outrageous events, a third act of victimization occurred: the unidentified bodies were buried in a mass grave in a local cemetery which was under the responsibility of law enforcement officials. As a result these victims were subjected to a second disappearance. In spite of the multiple actions conducted to date, it has not been possible to recover 37 of the deceased victims, and their relatives still feel the anguish of not knowing the fate of their missing loved ones.

This case demonstrates that the failure to include specialized forensic anthropology and archaeology fields in the management of the dead within armed conflicts in a proper and dignified manner can cause irreparable damage to the survivors and can result in penal liabilities for the state. Therefore, the need for protocols for best forensic practices to be evaluated on a permanent basis from an ethical and procedural standpoint is paramount. In addition, there is a need for continuous psychosocial assistance for relatives during the entire process of the search, recovery, examination, identification, and final disposition of the deceased victims.

The Organizations of Families of Victims of Enforced Disappearances and Extrajudicial Executions

Although in Colombia forensic anthropology and archaeology were established within governmental institutions, the disciplines were legitimized as scientific tools to support investigations on human rights violations, largely because of the struggles undertaken since the early 1970s by the families of the missing persons and by human rights organizations, with the purpose of finding loved ones and claiming justice (Centro Nacional De Memoria Histórica 2013b).

By 1989 the Association of Families of Detained and Disappeared Persons (ASFADDES) and the Latin American Federation of Associations of Families of the Detained and Disappeared (FEDEFAM) ensured the visit of the United Nations Working Group on Enforced or Involuntary Disappearances (UNWGEID). One of the recommendations to the Colombian state was the need to criminalize the act of enforced disappearance as an offense under the justice system. A second proposal urged the government to improve its forensic teams, especially those involved in the examination and identification of unidentified bodies.

Latin American forensic anthropology teams, such as the Argentinian Forensic Anthropology Team (EAAF), had set a precedent in applying forensic anthropology to the investigation of human rights violations and identification of the missing persons, and in achieving positive results. By the late 1990s the EAAF already had wide recognition from the families of victims of enforced disappearances in regard to technical and scientific support for the search, recovery, and identification of the bodies of missing persons (Fondebrider 2009). An additional consideration related to the final disposition of the unidentified bodies, which at that time were buried in mass graves in local cemeteries. In this regard, the Working Group on Enforced or Involuntary Disappearances indicated that among these unidentified bodies could be many victims of enforced disappearance; therefore their recommendations argued the need to implement a strategy for the final disposition of the unidentified bodies in order to ensure tracing and future recovery (United Nations Commission on Human Rights [UNCHR], Working Group on Enforced or Involuntary Disappearances [WGEID] 1989: 18, 23).

In 1991 ASFADDES recognized the necessity for forensic anthropologists to obtain qualifications in the analysis of skeletal remains. They invited the EAAF to provide training activities for government officials, lawyers, anthropologists, medical examiners, and other forensic experts in the application of forensic anthropology and archaeology methods for supporting investigations in the search of missing persons. The EAAF also conducted workshops with the families of victims of extrajudicial executions and enforced disappearance for sensitization on the search, analysis, and identification of deceased victims of enforced disappearance in order

to instruct them on what to expect and demand from the judicial and forensic investigations (Equipo Argentino de Antropología Forense 1991).

The Development Period

The second period, between 1996 and 2005, is characterized by three factors: (1) the growth of professional practice; (2) the strengthening of a scientific research community and a greater recognition of the gained experience of the Colombian forensic anthropologists; and, last but not least, (3) acknowledgment from the judicial system of the contributions made by forensic archaeology to the management of the scene and in the recovery of human remains from clandestine graves.

The strengthening of research in the field is associated with the establishment of the first graduate program, Specialization in Forensic Anthropology, launched in 1995 by the Department of Anthropology at the National University of Colombia. It was targeted not only at anthropologists but also at physicians, dentists, and lawyers, and it represents the first attempt at providing specializing professionals in the field (Rodríguez 2004, 2008). This graduate program encouraged scientific research—specifically, topics related to population variability and validation of methods for biological profile estimations. Although seven people completed the course and graduated in 2006, by 2008 the program was closed—because by this stage most people with relevant experience were working for the government, and demand for course applications fell sharply.

In an international setting Colombian forensic anthropologists and archaeologists are being recognized, especially for the experience gained owing to the high casework load in the medico-legal system and participation in criminal investigations of human rights violations. In 1998 a number of organizations, such as the Argentinian Forensic Anthropology Team (EAAF) and the International Criminal Tribunal for the Former Yugoslavia (ICTY), contacted the National Institution of Legal Medicine and Forensic Sciences (Instituto Nacional de Medicina Legal y Ciencias Forenses—INMLCF) and started requesting forensic anthropologists to be part of multinational groups of forensic experts. Since this time Colombian forensic anthropologists have participated as external consultants in international missions for the recovery and analysis of human remains (A. Patiño pers. comm. March 26, 2015).

In addition governmental institutions started to recognize the need for standardizing good practices for the recovery and identification of skeletonized bodies; this awareness correlated with the intensification of the armed conflict and the increasing numbers of missing persons. According to data reported in the National Record of Missing Persons the temporal trend of enforced disappearances displayed a significant growth between 1995 and 2005, which correlates with the increased number of dead bodies recovered by this time from clandestine burials (Ramírez & Segura 2013) (Figure 7.1).

Given this situation, more anthropologists and archaeologists were hired, and new laboratories for forensic anthropology were set up. Throughout the 1990s and until 2005 the CTI established five more laboratories for specialized identification in different countries; as a result the number of hired anthropologists increased from 8 to 25 (Rodríguez 2004: 34–35; Fiscalía General de la Nación 2005).

The main requests that medical examiners and coroners made to forensic anthropologists focused on providing a biological profile in order to narrow down the number of missing persons. Nonetheless, by this period the discipline was not limited to laboratory activity (Rodríguez 2004: 14–17). The practitioners' backgrounds in bioarchaeology added to the training in crime scene analysis and has allowed this discipline to develop a strong approach in forensic archaeology and not be limited to laboratory analysis only. The application of archaeological techniques

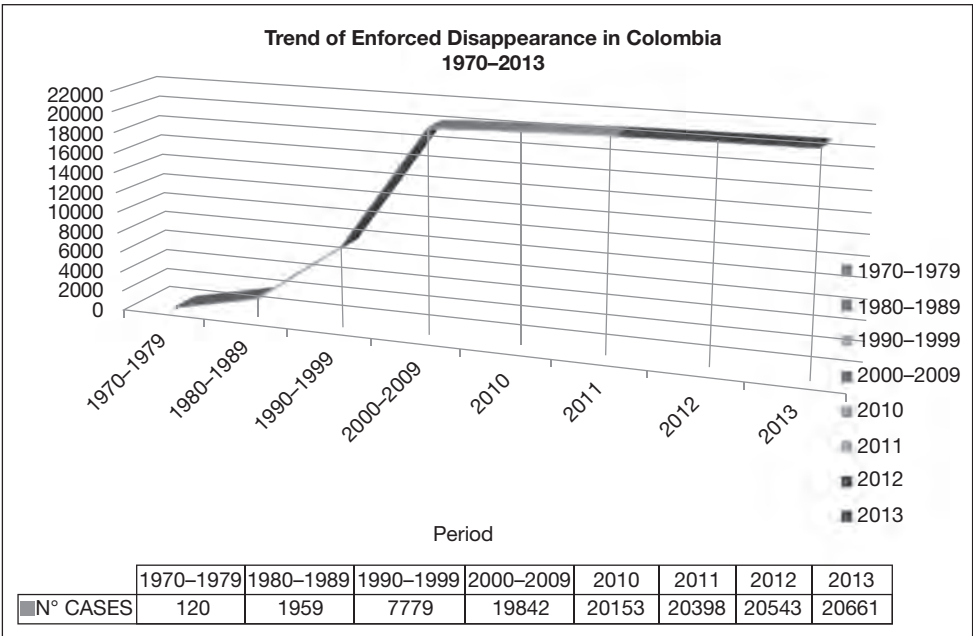


Figure 7.1 Official data of the number of cases of enforced disappearances (National Record of Missing Persons; Ramírez & Segura 2013)



Figure 7.2 Temporary mortuary for examination of the victims of American Airlines Flight 965, which crashed in 1995 at Buga, Colombia (photo from INMLCF archives)

became more frequent for outdoor crime scene documentation and not only in contexts associated with recovering bodies from clandestine burials but also in cases of mass disasters and collective deaths due to armed confrontations.

An example of how anthropologists and archaeologists participated in the management of a mass disaster was American Airlines Flight 965 in 1995, which resulted in the deaths of 159 people when the plane crashed into a mountain in Buga, Colombia (Figure 7.2). Archaeologists and anthropologists from the CTI were engaged in the recovery of the bodies. Additionally, forensic anthropology played a crucial role during the medico-legal examinations, particularly for the association of body parts and individualization and identification of the victims (P. Morales pers. comm. December 30, 2014).

The strengthening of the field became evident with the increasing number of professionals, which correlated with the intensification of the armed conflict and the increasing number of

analyzed cases. Between 1989 and 1994 the Laboratory of Forensic Anthropology of the INMLCF examined 153 human remains, and between 1995 and 2005 it issued 1928 reports. Additionally, between 1997 and 2000 the Laboratory of Specialized Identification of the CTI performed analyses on 720 cases (Rodríguez 2004: 35). By 2005 the forensic anthropology laboratories had analyzed about 3,000 unidentified bodies, most without presumptive identities (Figure 7.3).

Consolidation of a Specific Field of Expertise and the New Challenges

The third period is identified as between 2005 and 2014, during which forensic anthropology and archaeology started to be recognized within the medico-legal academy and in some cases identified as a specific field of expertise. This recognition is demonstrated by the percentage of medico-legal cases in which the participation and experience of forensic anthropologists were required.

From the 26,623 violent deaths recorded in the national medico-legal system in 2013, 5% required forensic anthropological analysis. These cases focused specifically on autopsies in which the bodies had bone trauma and/or the cause of death was not clear, the identification was complex, and/or torture, sexual violence, and/or child abuse was suspected (Instituto Nacional de Medicina Legal y Ciencias Forenses 2011) (Figure 7.4). According to the Forensic Anthropology Laboratory at the INMLCF during this period an expert examined an average of 60 cases per year, a number that could easily reach 80, because complementary reports from additional judicial requirements are not included in the casework load statistics.

Another important aspect related to this period was the development of forensic nongovernmental organizations (NGOs), such as Equipo Colombiano Interdisciplinario de Trabajo Forense y Asistencia Psicosocial (EQUITAS) and Equipo Colombiano de Investigación en Antropología Forense (ECIAF). In 2003 the first of these organizations was funded by the forensic anthropologists Andres Patiño, Dr. Ana María Gomez, and Dr. Karen Burns (EQUITAS 2011). These forensic NGOs were an important milestone for the victims of the conflict, because they represent critical and independent alternatives of forensic scientific support, which can assist families during the judicial investigations and forensic procedures.

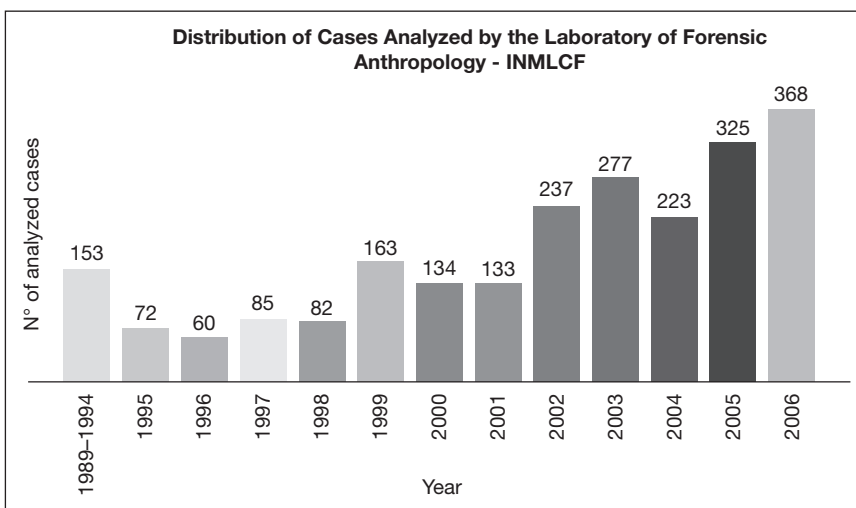


Figure 7.3 Number of cases analyzed by the Laboratory of Forensic Anthropology INMLCF from 1989 to 2006



Figure 7.4 Interdisciplinary forensic approach for the analysis of high-profile cases related to deaths and disappearances within the Colombian armed conflict. Forensic anthropologists have acquired a more comprehensive perspective and experience from working with medical examiners, forensic dentists, ballistics experts, and geneticists, among other forensic experts (photo from INMLCF archives).

External Factors Related to the Establishment of the Field

This chapter recognizes that there was a convergence of multiple factors that led to an upsurge in the thoroughness and legitimacy of Colombian forensic anthropology and archaeology. Extrinsic factors primarily relied on the international economic assistance for supporting anti-drug policies, which greatly affected the field's positioning by facilitating investments on training experts abroad, purchasing equipment, and enhancing standardization and best forensic practices (for example, cooperation program between German and Colombian governments [Deutsche Gesellschaft für Internationale Zusammenarbeit—GIZ N.d.]).

Additionally, the cooperation program reached in 1999 between the United States and the Colombian government, called *Plan Colombia*, also had a direct effect on the strengthening of the field. This agreement aimed to reduce the production and trafficking of illegal drugs and also to fight the drug cartels and left-wing insurgent groups. Besides the resources invested in the Colombian military forces, it also financed the judicial system (Acevedo, Bewley-Taylor, & Youngers 2008), under which projects for the improvement of the medico-legal system were supported.

Over five years the International Criminal Investigative Training Assistance Program of the United States Department of Justice (ICITAP N.d.) supported equipment acquisition for the modernization of the forensic anthropology laboratories and sponsored training activities for forensic experts, with programs specially focused on topics related to the recovery of bodies from clandestine burials and examination of human skeletal remains, including bone trauma analysis.

These international cooperation programs reinforced the professionals' skills and competences and significantly influenced the external perceptions about the expertise of the field.

Internal Factors that Prompted the Consolidation of the Field

The Evolving Principles of Scientific Proof Admissibility

In 2004 the emergence of a new Criminal Law and a Code of Criminal Procedure posed new challenges and influenced the development of the field. Through this law new regulations of the Chain of Custody Procedure were established for the proper handling, documentation, transfer, and disposition of evidence. In addition, the principles of technical and scientific proof admissibility were outlined. The reliability of the forensic anthropology expert was defined as necessarily requiring technical and scientific qualifications, proven knowledge, experience, education, accurate reports, and a degree of acceptance from the scientific principles and methods applied in the analysis (Criminal Law 906 de 2004).

To reach the minimal levels of admissibility, it was established that forensic proof has to encompass at least one of these principles: (1) a tested theory or technique; (2) a theory or technique subject to peer review; (3) an acceptable error rate; and (4) a method with widespread acceptance (Criminal Law 906 de 2004). These principles represented new challenges for the discipline, especially because forensic anthropology analysis and interpretations are based mainly on observation and experience. Additionally, most of the Colombian forensic anthropologists and archaeologists are self-taught and experience-based experts and do not hold a formal education or graduate degrees that could certify them as experts in the field.

However, the principles of proof admissibility have encouraged forensic anthropologists and archaeologists to improve the rigor by which the evidence is described, documented, and interpreted. Additionally, the experience gained from constantly participating in medico-legal autopsies, as well as the continuous trainings and the permanent discussions sustained with multiple forensic experts, have led to a much improved expertise.

The Justice and Peace Law and the Increase of Exhumed Bodies

A second internal situation that strongly influenced the development of the field was the political negotiations that started in 2003 between the Colombian government and paramilitary groups. In 2005 the Colombian government instituted Law 975, or the "Justice and Peace Law" (JyP), which promoted the demobilization of paramilitary groups by establishing an alternative penal sanction. These demobilized groups had to give up all armed activities, be reintegrated into society, and confess to the heinous offenses perpetrated, by which they began confessing a wide array of crimes, such as massacres, homicides, enforced disappearances, forced displacements, kidnappings, sexual violence, and torture, as well as revealing the location of thousands of clandestine graves (Figure 7.5).

By the end of 2014 the number of recovered clandestine burials had increased to 5,693 bodies (Fiscalía General de la Nación 2014a) (Figure 7.6). In 2010 a new policy was enacted that promoted the identification of 22,689 unidentified bodies that had been previously autopsied and buried in official cemeteries as "N.Ns: No Name Bodies" (Inter-Institutional Agreement 001-2010 between the Ministry of Internal Affairs, National Civil Registry, and the INMLCF), some of whom were likely victims of enforced disappearance (D. Ramírez 2015 interview January 15). To achieve their identification, postmortem fingerprints gathered during the first autopsies were analyzed and compared to fingerprints from the National Civil Registry. For 2012, 11,111 positive matches were determined. Since then some of these bodies have been located and exhumed from the local cemeteries. The recovered human remains have been analyzed and compared

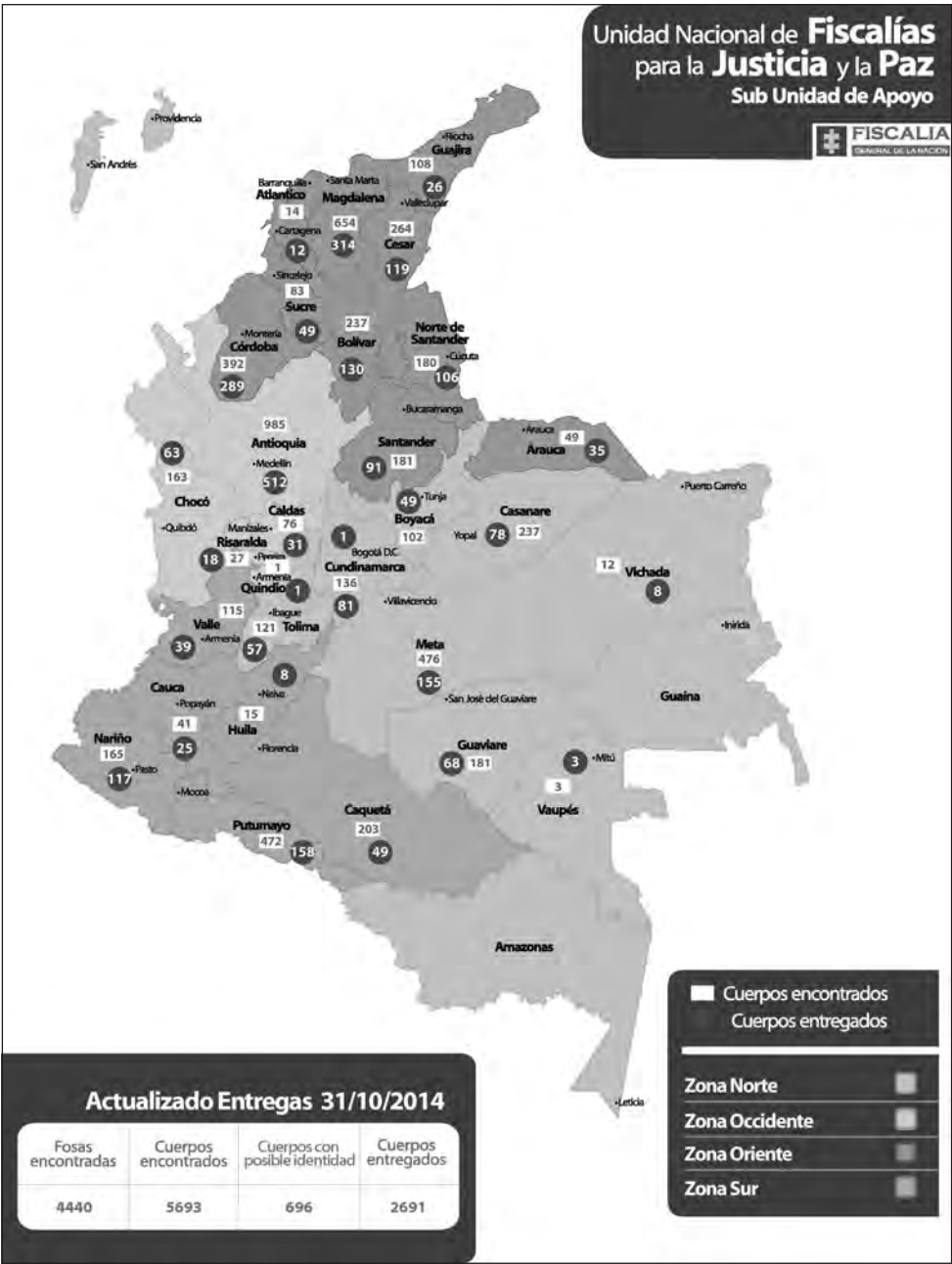


Figure 7.5 Number of bodies exhumed form clandestine graves and cemeteries up to October 31, 2014 (data available from the Exhumation Working Group, Transitional Justice Division of the General Attorney’s Office, formerly named Unit for Justice and Peace–FGN 2014a)



Figure 7.6 Ossuary with commingled human remains located in an official cemetery in Meta, Colombia, where the human remains of persons are buried as unidentified bodies (photo from INMLCF archives)

with the forensic reports of the first autopsies to ensure a positive identification (D. Ramírez interview January 15, 2015). Nonetheless, one of the greatest current problems is the impossibility of locating burials owing to lack of cemetery records.

The great number of recovered bodies from clandestine graves and local cemeteries exceeds the capacity of forensic anthropology and archaeology and poses great challenges and expectations regarding the professional analysis, as well as the identification and return of remains to their families. Although the main objective of investigations carried out under the JyP Law is to identify and return the recovered bodies to their families, considerations of the Committee Against Torture (2010) concluded that most of the missing persons recovered from clandestine burials were tortured before being murdered, as the bodies show signs of having been tied, blindfolded, and dismembered (Figures 7.7 and 7.8). Consequently, examinations undertaken since 2010 included documentation and rigorous interpretations of the findings in relation to signs of sexual violence and torture, so that these cases could later be used in court proceedings.

The Challenging Context of Human Identification within the Armed Conflict Setting

Law enforcement institutions and the medico-legal system statistics, as well as the report issued in 2005 by the High Commissioner for Human Rights in Colombia, stated that more than 60% of the examined bodies remained without a name (United Nations Commission on Human

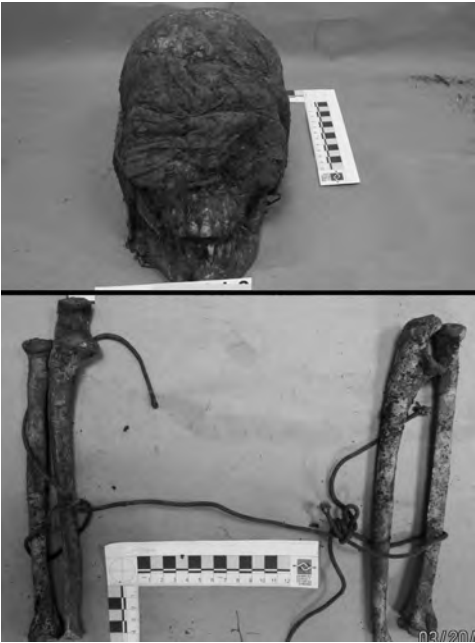


Figure 7.7 This case exemplifies victims of enforced disappearance recovered from clandestine graves, with evidence of this person having been blindfolded and having his arms tied. Regarding the context and the forensic analysis this finding can be correlated with torture (photo from INMLCF archives).



Figure 7.8 Clothing recovered from a clandestine grave, with evidence of cut marks not consistent with the location of the trauma observed in bone (photo from INMLCF archives)

Rights 2006: 13, 16, 69; Rodríguez 2008: 10; United Nations Commission on Human Rights 2011: 12). At this point, for forensic anthropology the high percentage of unidentified bodies was the greatest challenge. One of the factors that directly affected this problem was the lack of a proper conceptualization of the human identification process, which by that period relied exclusively on one method—specifically, genetic analysis—and on the final decision of the coroners (EQUITAS 2011: 4; International Committee of the Red Cross 2011).

Even though the Colombian State recognized the dimension and complexities inherent in the enforced disappearance phenomenon, which caused it to institutionalize different legal instruments (for example, Law 589–2000, Commission for Missing Persons and the National Record of Missing Persons [RND], among others legal instruments), it was not until 2007 that an information technology system was developed to compare in a structured manner the large volume of postmortem information obtained from the forensic examination of bodies, with the antemortem (AM) data of missing persons reported throughout the country (Ramírez & Segura 2013: 479). According to official data 20,944 persons have been victims of enforced disappearance (Ramírez & Segura 2013: 477); however, until 2014 only 2,789 have been identified among the 5,735 bodies recovered from clandestine graves (Fiscalía General de la Nación 2014b) (Figure 7.9).

Since 2010 a committee of forensic experts has been established to track the high number of unidentified bodies. This committee concluded that challenging cases of human identification need to be reconceptualized as an integrated and multidisciplinary process that does not depend solely on genetic analysis and on the coroners' decisions. Instead, the DNA analysis and the judicial investigation should be taken into account when one is analyzing and comparing the AM data (for example, sociodemographic data, physical description, identifying features, medical and dental



Figure 7.9 Clothing, personal belongings, and other evidence recovered from a clandestine grave. This case represents a missing person with signs of having been tied, blindfolded, and dismembered (photo from INMLCF archives).

records, clothing and belongings, testimonies about circumstances, and place of his/her disappearance or death) with the PM data (such as scene documentation and forensic analysis). The analysis of AM and PM data to facilitate either a match or an exclusion ideally should be done by an interdisciplinary group of forensic experts (International Committee of the Red Cross 2011: 1).

Some of the challenges associated with identifying the victims of enforced disappearances in the context of the Colombian conflict involve these:

- 1 The number of missing persons is uncertain and still rising, as the armed conflict continues.
- 2 Security issues: In territories of ongoing conflict the number of missing persons is under-reported. The potential of threats to personal safety affects the witnesses' willingness to provide information.
- 3 Most of the missing persons share similar biological profiles (88.9% males, 11.03% females, between 17 and 35 years old) (Ramírez & Segura 2013: 486).
- 4 Enforced disappearances within endogamous groups (for example, indigenous communities) and cases of various missing persons within the same family, which present difficulties for establishing accurate exclusion in the analytical process of comparing AM and PM data.
- 5 Most of the victims do not have AM medical or dental records.
- 6 Problems with location: Some of the interments of the unidentified bodies buried in local cemeteries cannot be determined. In addition, many of these bodies were disposed of in ossuaries with commingled human remains (Figure 7.10).

The multidisciplinary approach has increased the number of identified bodies from an annual mean of 28 positive identifications to a mean of 117 per year since 2011 (Figure 7.11). Currently the big challenge is to identify the 2,079 bodies that do not have a presumptive identity and out of which only 11% have been positively identified (Figure 7.12).

Another change adopted in the identification process was brought about by the need for direct communication between the forensic experts and the families. Since 2011 the process of having the families of missing persons accompanied by a forensic expert was implemented. Supportive bonds started to be built by keeping the families updated about the results of the forensic analysis, specifically on information related not only to the identification process but also to sensitive results related to the cause, manner, and circumstances of death of the victims. Principles of impartiality

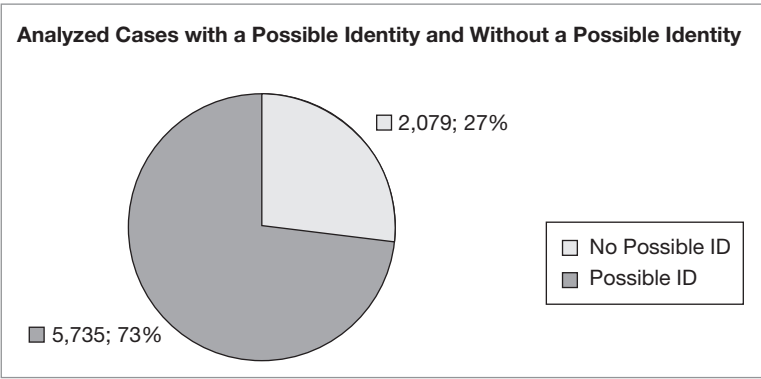


Figure 7.10 Percentage of cases analyzed by the INMLCF and CTI forensic laboratories 2009–2014. The cases were classified according to having or not having a possible identity (statistics provided by the Exhumation Unit, Transitional Justice Division [FGN] 2014b).

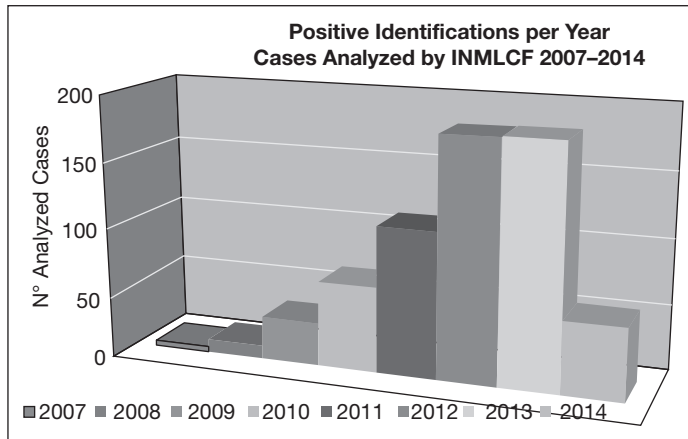


Figure 7.11 Number of cases identified by the INMLCF between 2007 and 2014. These cases correspond exclusively to the bodies recovered from exhumations undertaken by the Unit of Justice and Peace Law Division from the General Attorney's Office.

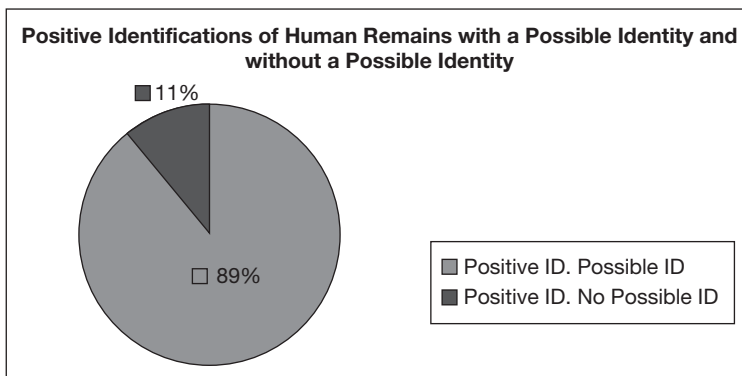


Figure 7.12 Percentage of cases identified by the INMLCF 2007–2014. These cases correspond exclusively to analyses carried out on bodies exhumed.

and providing dignity to victims are prioritized, as well as avoiding situations that promote false expectations and a subsequent revictimization. Through this integrated identification process, which has humanitarian, legal, and scientific implications, forensic anthropology and archaeology have contributed to reconstructing the truth, dignifying the memory of the victims, and minimizing the negative effects that these events have had on the mental well-being of the survivors of Colombian conflict.

The Challenges of Second Autopsies

The investigation of one of the heaviest burdens in the history of the state policies, which is related to the extrajudicial executions and disappearances of civilians, has posed additional

challenges to the field. These victims were usually rural people, who after being executed, were presented by the state armed forces as members of guerrilla or paramilitary groups who died in combat. The media called such deaths “false positives” (Centro Nacional De Memoria Histórica 2013b: 27–28).

The upsurge of extrajudicial executions was encouraged by counterinsurgency policies that offered perks and economic benefits for increasing the number of casualties of illegal armed groups (Centro Nacional De Memoria Histórica 2013b: 393–408). Therefore, a body-count was used to estimate the effectiveness of military strategy and to legitimize the upholding of armed confrontations.

By assuming that the deaths occurred during military operations, a character of legality was accepted; therefore, medico-legal autopsies did not seek to provide forensic evidence to clarify the circumstances of the deaths. In some cases only external examinations were performed. In other instances it was a general medical practitioner with no forensic expertise who performed the autopsy with the sole purpose of legally certifying death. Thus many of these victims ended up being buried as unidentified bodies in cemeteries far away from their places of origin. This situation prevented the identification of the victims, obstructed the criminal investigations, and aggravated the anguish of the missing persons’ families, who had no information about their whereabouts (UNCHR 2010: 5, 2013: 15).

Since 2010, when judicial investigations of the “false positives” began to affect the discipline, the number of second autopsies of alleged extrajudicial killings significantly increased. The judicial appeals requested:

- 1 Identification of the bodies that were subjected to medico-legal autopsies and not identified at the time, and
- 2 Provision of a second expert opinion to clarify the cause, manner, and circumstances associated with the death.

The second aim has posed a major challenge for the field. Forensic anthropologists as part of an interdisciplinary team of forensic experts must evaluate all available evidence, such as the documentation of the scene, the autopsy, and other previous forensic reports, injury patterns, and chain of custody, among other elements. From this evidence a contextual analysis of the human remains and other evidence has to be made in order to issue a second expert opinion for either supporting or denying that the deceased individual was related to an armed confrontation.

One of the contributions that forensic anthropology has made to these kinds of investigation is related to skeletal trauma analysis. Consistencies or discrepancies are determined in correlation with the scene, previous forensic reports, and versions of the witnesses and/or of the suspected perpetrators. The experience that forensic anthropologists have acquired in the morgue, particularly from working with medical examiners on cases of “fresh bodies” analysis and in the field, has been fundamental. This experience has allowed forensic anthropologists to have a more comprehensive perspective on the injury patterns expected during an armed confrontation.

Depending on the particularities of each case, the challenge is unique. The goal is to transcend isolated analysis and evolve toward integrated interpretations between the physical evidence and the contextual information, in order to contribute with scientific foundations to the criminal prosecutions of alleged extrajudicial executions and to the analysis of macro-criminality patterns within the Colombian history of violence.

Conclusions

In the context where deaths occur as a result of political and criminal violence the objectives and challenges of Colombian forensic anthropology and forensic archaeology professionals have not always been the same. Depending on the mechanisms of victimization perpetrated against civilians, as well as the national and international junctures, the fields of forensic anthropology and forensic archaeology have had to face new challenges and goals.

Significant contributions to criminal prosecution have been made, especially by revealing evidence about torture, sexual violence, and extrajudicial executions. In fact, in the armed conflict and other situations of violence, these disciplines have already proven to be a useful auxiliary tool for reconstructing history and for providing evidence for criminal prosecutions. In the Latin American context, Colombian forensic anthropologists and archaeologists have positioned themselves as forensic experts with a broad background and experience.

This chapter highlights the conditions that, in the Colombian context, have encouraged the development of forensic anthropology and forensic archaeology up until their establishment as one of the biggest forensic anthropologist and archaeologist communities in Latin America:

- A long-term armed conflict wherein enforced disappearance was one of the control mechanisms imposed by the armed groups;
- High numbers of homicidal deaths related not only to the armed conflict but also to criminal violence;
- During the origins of the disciplines, their relationship with the physical anthropology academy;
- Being disciplines with a broad approach, including laboratory and field-based expertise;
- Integration of the disciplines with a medico-legal system that has a long-standing tradition since the beginning of the 20th century;
- Having a multidisciplinary approach and broad experience gained from working with medical examiners and other forensic experts during autopsies undertaken on recently deceased and decomposed bodies;
- Challenging cases, regarding not only identification of the human remains of victims of the armed conflict but also participation in autopsies related to criminal prosecutions of sexual violence, torture, and extrajudicial executions; and
- A humanitarian approach, which entails supporting the families of victims of enforced disappearances throughout the process of determination of cause, manner, circumstances of death, identification, and returning victims to their families.

Although forensic anthropology and archaeology in Colombia are now established disciplines and their contributions have been recognized, these disciplines have clearly faced many challenges. One of them is the need to develop formal training and postgraduate academic programs in forensic anthropology. The objectives of such postgraduate programs should focus on the improvement of the expertise of field practitioners and the promotion of research within the forensic field.

An additional challenge is the disciplines' need to contribute to the reinterpretation of Colombia's violent past by placing the forensic analysis of specific cases into a historical framework. In other words, we propose that Colombian forensic anthropology and archaeology should take on a new, large-scale scope in order to provide information on temporal and spatial dynamics of violence. Therefore the goals of this discipline should include not only the investigation of clandestine graves and recovery of unidentified bodies and identification of human remains but also the development of strategies that could provide an account of the different modalities of violence committed during the armed conflict and in other situations of violence.

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Historical Development of Forensic Anthropology

Perspectives from the United States

Douglas H. Ubelaker

Much of the intellectual growth of forensic anthropology in the past several decades can be traced to initiatives within the United States. Key themes within this development are significant early involvement of anthropologists in high-profile cases, a research focus on problems centered in forensic anthropology, organizational advances, and the formation of relevant graduate programs. This chapter reviews that history with an emphasis on these themes.

Although the academic roots of forensic anthropology in the United States extend into Europe, they originate in North America with early anatomists and physicians who applied their knowledge to medico-legal issues. Some of these applications were serendipitous when major crimes and court trials happened to occur in the vicinity where the experts worked. In other cases, research interests in skeletal anatomy and human variation led anthropologists into the forensic arena.

The Parkman Trial

The Parkman trial that took place in Boston stands out as an early benchmark (Snow 1973; Stewart 1979a, b). In 1849 Dr. George Parkman, a prominent local physician, was killed by Harvard professor and chemist John W. Webster. The murder took place at Harvard Medical School in a building constructed on land that Parkman had donated to the university. In addition to his philanthropy Parkman had made loans to faculty members, including Webster. When Webster failed to make proper payment on his loan, Parkman began to apply pressure. Ultimately Webster invited Parkman to his university laboratory, allegedly to make a payment, but instead Webster killed Parkman. In an effort to conceal the crime Webster dismembered the body, attempted to burn the dismembered parts in the building furnace, and dispatched the bulk of the remains in the sewage system associated with his laboratory. Thanks to the efforts of a suspicious janitor and the local authorities, the remains were discovered.

In the trial Harvard professors Oliver Wendell Holmes (1809–1894) and Jeffries Wyman (1814–1874) testified on anatomical issues of the recovered remains, bringing local public attention to the applied aspects of anatomy studies. At the time Holmes was the initial appointee to the Parkman Professorship of Anatomy at Harvard, a position established by the university to recognize Parkman for his generous donation.

Wyman had graduated from medical school at Harvard and subsequently (1843) held the Harvard position of Hersey Professor of Anatomy. After the Parkman trial in 1866 Wyman became

the first curator of Harvard's Peabody Museum of American Archaeology and Ethnology and was recognized as a leading physical anthropologist of the time for his research on the skeletal anatomy of gorillas and humans, as well as on human remains recovered archaeologically from shell mounds in Florida (Hrdlička 1919). At the Webster trial Wyman testified that cremated fragments found within the furnace were consistent with an origin from the same individual as the remains recovered from the laboratory sewage system. The verdict was guilty, and Webster was put to death by hanging.

Thomas Dwight (1843–1911)

At the time of the high-profile Parkman trial Thomas Dwight was a child living in Boston. Likely influenced by discussions of the trial testimony and anatomical topics, Dwight developed an interest in medico-legal applications of anatomy and 29 years after the trial (1878) published a historically important essay: "The Identification of the Human Skeleton: A Medico-Legal Study." The essay won an award from the Massachusetts Medical Society and launched Dwight's career focusing on these issues. Dwight succeeded Holmes in holding the Parkman Professorship of Anatomy at Harvard. He followed up his landmark 1878 study with separate investigations of sex and age variation of the sternum (1881, 1890a), age changes in cranial suture closure (1890b), stature estimation from skeletal elements (1894a), the role of variation in skeletal interpretation (1894b), and sex differences in the size of bone articular surfaces (1905). Along the way he also apparently participated in forensic cases (Stewart 1979a; Warren 1911). Dwight's early contributions were sufficiently important for T. D. Stewart (1979a: xii) to designate him "the father of forensic anthropology in the United States."

George A. Dorsey (1868–1931)

As an anthropology student at Harvard, George Dorsey was influenced by Dwight's research on skeletal variation and forensic applications (Stewart 1979a). While still a graduate student he conducted archaeological excavations at Ancon, Peru, and assembled an archaeological exhibit for the 1893 World's Columbian Exposition in Chicago. In 1894 he received Harvard's first Ph.D. in anthropology, with a dissertation focusing on the Ancon material. From 1895–1896 Dorsey was an instructor at Harvard University. He subsequently (1898) became Curator at the Field Columbian Museum in Chicago and conducted his own research on sex variation of the heads of the femur and humerus (Dorsey 1897) and general bone identification, age, sex, and ancestry determination (Dorsey 1899). During his career Dorsey held professorships in comparative anatomy at Northwestern University Dental School and in anthropology at the University of Chicago, and he was also a founding member of the American Association of Physical Anthropologists.

Dorsey offered testimony in the high-profile Chicago trial of a local sausage maker, Adolph Luetgert, accused of murdering his wife Louisa and disposing of her remains in a vat at the sausage factory. Dorsey opined on small bone fragments that had been recovered at the scene. Although challenged by other experts, his testimony received extensive favorable media coverage in this high-profile trial. Subsequently, however, he shifted his interests toward ethnology, travel, and government service.

H. H. Wilder (1864–1928) and Paul Stevenson (1890–1971)

Harris Hawthorne Wilder began his career as a European-trained zoologist but developed a research interest in forensic anthropology while a professor at Smith College in Massachusetts

(Stewart 1982a, b). After graduating from Amherst College in Massachusetts in 1886, he studied zoology in Germany, receiving his doctorate there. He began his long career at Smith College in 1892. Wilder's interests included forensic aspects of dermatoglyphics and techniques of facial reproduction, improving on methodology he had been exposed to in Germany. In 1918 he coauthored a book on personal identification (Wilder & Wentworth 1918).

Wilder's career overlapped that of Paul Stevenson, an American anatomist who spent much of his career outside the United States. His one major publication from the United States offered detailed information on the age progression of epiphyseal union (Stevenson 1924). Although this information is of limited use today, because his study did not separate the sexes, historically the publication represents a key development in demonstrating the variation in the timing of union with detailed data.

Earnest A. Hooton (1887–1954) and Aleš Hrdlička (1869–1943)

Hooton and Hrdlička are widely recognized as key figures in the development of American physical anthropology. Earnest Hooton was a faculty member at Harvard University from 1913 to 1954. His major research interests included the skeletal biology of past peoples, race and human variation, and the relationship between body form and behavior—particularly that of criminals. Through his position at Harvard, Hooton trained many physical anthropologists who went on to make major contributions to forensic anthropology (including W. W. Howells, C. E. Snow, S. L. Washburn, and J. L. Angel, among others). Although active in forensic applications (Stewart 1979a), Hooton published relatively little on the subject (Hooton 1943).

Aleš Hrdlička immigrated to the United States with his family from Bohemia (now the Czech Republic) in 1881. He later acquired a medical degree and became interested in legal medicine, including the possible biological basis of insanity and criminal behavior. His research included anthropometry and its application to medicine and prehistoric populations. In 1902 Hrdlička began his 40-year career at the Smithsonian Institution in Washington, D.C.; during this time he assembled large collections of human remains that enabled much research in skeletal biology and forensic anthropology.

After founding the *American Journal of Physical Anthropology* in 1918 and the American Association of Physical Anthropologists, Hrdlička investigated a variety of anthropological topics, such as the peopling of the New World, human origins, and forensic anthropology. His many publications included forensic topics (see all Hrdlička references in Ubelaker 1999) and the 1939 edition of *Practical Anthropometry*, which presented a major section for forensic anthropology topics.

As early as 1896 Hrdlička presented court testimony on issues of epilepsy and insanity in a jury trial (Ubelaker 1999). Subsequently, forensic activities included analyses of human remains in Argentina and Peru (1910), studies of ancestry issues in litigation involving Chippewa Indian status in Minnesota (1915 to 1920), and a comparison of a skull recovered in Arizona with photographs and stereoscopic photographs of a missing person (1932). By 1936 his expertise was recognized by the Federal Bureau of Investigation (FBI), and he subsequently reported on evidence submitted by them. The record indicates he reported on at least nine cases over his career, but the actual number was probably much greater.

The Modern Era

In 1939 Wilton M. Krogman (1903–1987) published his *Guide to the Identification of Human Skeletal Material*, launching what many consider to be the modern era of forensic anthropology in the United States. During a seven-year academic appointment at (Case) Western Reserve

Medical School, Krogman had worked closely with T. Wingate Todd (1885–1938), who had published key articles on age changes in the pubic bone (1920–1921), the clavicular epiphysis (Todd & D’Errico 1928), and the cranial sutures (Todd & Lyon 1924–1925). Krogman’s book was published the same year as a revised edition of Hrdlička’s *Practical Anthropometry*, but the guide’s enhanced importance relates to its stand-alone emphasis on forensic applications and its publication in the FBI’s law-enforcement-oriented periodical. It rapidly became the authoritative work in forensic anthropology and was widely utilized (Stewart 1979a).

Although much of Krogman’s research focused on growth and development, he went on to publish other important forensic contributions (1943, 1946, 1949), including his key text, *The Human Skeleton in Forensic Medicine* (1962). Krogman’s book was widely utilized by those involved in identifying remains for the military, such as H. L. Shapiro (1902–1990) in Europe and Charles E. Snow (1910–1967), Mildred Trotter (1899–1991), and T. Dale Stewart (1901–1997) in Hawaii. The extensive identification effort by these individuals and others elucidated the shortcomings of Krogman’s book and led to important research aimed at improving methodology such as Trotter’s work on stature (Trotter & Gleser 1952) and Stewart’s approach to age changes (McKern & Stewart 1957). The military identification effort not only provided those involved with extensive experience in identification but also led to key publications, such as Stewart’s edited volume on mass disaster investigation (1970).

Smithsonian Collaboration with the FBI

Following Hrdlička’s retirement in 1942 consultation with the FBI continued at the Smithsonian Institution with Hrdlička’s successor, T. Dale Stewart. Like Hrdlička, Stewart had a medical degree. He served as an assistant to Hrdlička for many years but seemingly remained unaware of most of Hrdlička’s forensic consultation (Stewart 1979a; Ubelaker 1999, 2000a, b). Stewart immediately began working on FBI cases when he became curator in 1942. By 1969 he had reported on at least 254 cases, including 169 at the request of the FBI, and he had testified in court at least seven times.

With this casework experience Stewart recognized the need for research aimed specifically at improving methodology in forensic applications. His classic 1957 publication with Thomas McKern (1920–1974), *Skeletal Age Changes in Young American Males*, resulted directly from his experience identifying remains for the military in Hawaii. Stewart recognized that methodology at the time, including that summarized in Krogman’s book, was primarily based on anatomical collections such as those developed by Todd in Ohio. These collections represented primarily the elderly, and thus methodology was limited for age changes and other factors in the young. Working with the remains of young men killed in the Korean Conflict, Stewart and his colleagues assembled data from this important age group and revisited existing methodology.

Stewart also became a champion of problem-oriented research aimed at improving methodology. Examples include his research on issues relating to race (Stewart 1944, 1962), identification of cultural attributes on the skeleton (Stewart 1937, 1939, 1941, 1950; Stewart & Titterton 1944, 1946), age changes (Stewart 1953a, 1954a, 1957, 1958; McKern & Stewart 1957), sex estimation (Stewart 1954b), distinguishing human from nonhuman remains (Stewart 1959, 1961), historical issues (Stewart 1978, 1979c, 1982a, b), anatomical aspects of facial reproduction (Stewart 1983), and objectivity in casework (Stewart 1984). Much of this is summarized in synthetic works (Stewart 1948, 1951, 1953b, 1954c, 1968, 1970, 1972, 1973, 1979a, b, 1980; Stewart & Trotter 1954, 1955), including his own classic 1979 text, *Essentials of Forensic Anthropology*.

In 1962 Stewart accepted an appointment as Director of the United States National Museum, and J. Lawrence Angel (1915–1986) assumed casework responsibility for the FBI and others. British-born Angel had received his Ph.D. at Harvard working closely with Hooton and Clyde Kluckhohn (1905–1960). Although his dissertation and major research had focused on anatomical issues and human remains from the Near East, his interests shifted toward forensic applications when he left Jefferson Medical College in Philadelphia and joined the Smithsonian Institution in 1962. Assuming the forensic caseload from Stewart, he reported on approximately 565 cases for the FBI and others before his death in 1986. In about 1977 Angel took sabbatical leave, and Douglas H. Ubelaker assumed the Smithsonian Institution forensic consultation for the FBI, and he continued in that role until 2013, having reported on over 970 cases for the FBI and others.

Organizational Advances

In 1972 physical anthropologists launched their own section of the American Academy of Forensic Sciences. Before that time, participating anthropologists held membership in the Pathology-Biology or General sections, but formation of the new section galvanized the participation of physical anthropologists at such meetings. The initial formation of 14 founding members grew steadily to a 2015 membership of 507. The annual meeting is well-attended, usually with over two days of scientific papers and posters on a variety of subjects relating to the field. The meeting also has stimulated interaction of anthropologists with others in forensic science through Academy-wide committee appointments and attendance at simultaneous and joint academic sessions. For many years the section carried the title Physical Anthropology, but recently the name was changed to Anthropology to recognize important contributions in archaeology and other subdisciplines.

Ellis R. Kerley (1924–1998) provided leadership in the formation of the section and also in the establishment of the American Board of Forensic Anthropology (ABFA) in 1977/1978. The ABFA provides certification for forensic anthropologists and has grown from an initial enrollment of 22; 102 diplomates have been certified by 2015. The ABFA is important historically in providing recognition to its diplomates and offering the legal system a list of professionals deemed to be qualified by their peers.

Educational Advances

Historically, training in forensic anthropology in the United States has shifted from medical schools to departments of anthropology. Whereas the pioneers in the field largely held medical degrees with specialties in anatomy, all current ABFA certified forensic anthropologists hold degrees from academic departments of anthropology and related disciplines. This development reflects the increasing complexity and specialization of American science, as well as the nature of the development of forensic anthropology. Forensic anthropologists uniquely bring knowledge of archaeological techniques, taphonomic changes, and human variation to their casework—knowledge acquired in graduate school rather than medical school. Historically, several learning institutions have been particularly instrumental in training forensic anthropologists. In the early days Harvard played a key role, although forensic anthropology assumed a role secondary to the more general field of physical anthropology. Hooton trained many students, and many of them later became involved in forensic applications (for example, J. Lawrence Angel).

In more recent years a variety of universities have trained forensic anthropologists, but special mention is due the University of Kansas in the 1960s and 1970s. William M. Bass III joined the

faculty there in 1960, soon to be joined by Ellis R. Kerley and Thomas McKern. Bass brought extensive experience working with archaeologically recovered remains, as well as having completed a dissertation at the University of Pennsylvania under the direction of Wilton Krogman and T. D. Stewart, among others. As noted, Kerley was especially active in the American Academy of Forensic Sciences and had pioneered research in microscopic approaches to the estimation of age at death in adults. Thomas McKern had worked closely with T. D. Stewart of the Smithsonian Institution on the analysis of the age at death data from the Korean War dead (McKern & Stewart 1957). Until the trio departed the university in the early 1970s for other positions they had assembled a formidable teaching team that trained many of the forensic anthropologists practicing today. Bass left Kansas for the University of Tennessee, where he founded another major training program in forensic anthropology and organized a long-term research project to study human postmortem change.

Currently, training for forensic anthropologists in the United States is available at a variety of levels in graduate programs within universities. The nucleus of this activity continues to be the department of anthropology or its equivalent, but, increasingly, training incorporates coursework in related areas of forensic science, law, statistics, anatomy, and other key areas. Workshops and internships supplement this formal training in important ways by providing practical experience.

Recent years have witnessed a quantum leap in student interest in forensic anthropology within the United States. Likely fueled by media presentations of forensic themes, growing numbers of new students are attracted to the field allowing graduate admissions committees to be increasingly selective. The result seems to be a cohort of young forensic anthropologists who are ever more intelligent, focused, well-trained, and capable.

Research Advances

Stimulated by the growing focus on forensic anthropology in graduate programs, increased experience in casework, and enhanced communication and publication outlets forensic anthropologists are undertaking research in a range of key areas. Parts of these advances are fueled by new technology and awareness of the applications of existing technology to problems in forensic anthropology. Molecular analysis (see Baker, Chapter 28 this volume), radiocarbon analysis (see Forbes & Nugent, Chapter 16), sophisticated computer technology, analysis using the scanning electron microscope and mass spectrometer, and a variety of other approaches are finding their way into anthropological research. Much of this research is problem driven; work on forensic cases encounters previously unrecognized problems that require resolution. Research answers can be found in other university departments or with the colleague at another institution who is doing work in a relevant area.

Significant research advances are enabled by computer technology and the enlarged databases that are now possible to assemble. Work in forensic research laboratories in the United States currently takes full advantage of this and other technologies to address a variety of research problems. Although large databases have been constructed using samples from the United States, growing awareness of the importance of human variation has stimulated the inclusion of worldwide perspective on such important issues as ancestry, sexual dimorphism, and the timing of age changes. Greater awareness of secular change in the United States populations has tempered interpretation of older databases and led to the formation of more contemporary ones as exemplified by the computerized FORDISC system for the assessment of ancestry, sex, and living stature (Jantz & Moore-Jansen 1988; Jantz & Ousley 1993).

Collections of well-documented human remains play key roles in the development of the scientific methodology of forensic anthropology. Permanent collections not only allow

new research but also permit previously published techniques to be reexamined with fresh perspective. On the positive side, global interest in forensic anthropology has stimulated the formation of new collections, many originating from parts of the world and populations previously not well represented (Ubelaker 2014).

In the United States, however, concerns expressed by aboriginal peoples, political developments, and legislation have limited access to remains relating to American Indians. Although state laws and policies vary considerably (Ubelaker & Grant 1989), two federal laws (the National Museum of the American Indian Act passed in 1989 and the Native American Graves Protection and Repatriation Act passed in 1990) specifically target collections of human remains and call for research to determine if those being curated can be linked to existing American Indian groups (Buikstra 2006). Although these laws and associated policy have resulted in reduced access to some collections, they have also stimulated considerable research.

Every year at the annual meeting of the American Academy of Forensic Sciences (AAFS) scientists present new research in the Anthropology Section. These presentations show the myriad of topics explored in the field of forensic anthropology. The recent meeting in Orlando, Florida (February 2015), included taphonomy and postmortem interval; reanalysis of techniques in identification; new methods in the estimation of age, sex, and ancestry; the application of theory; trauma reconstruction; and in 2015 AAFS included sessions taking a multidisciplinary approach to identification.

Forensic anthropology's first and foremost objective is individuation and identification. Several scientists reanalyzed techniques often used today in stature estimation (Baker & Christensen 2015; Christensen 2015), stature estimation when ancestry is unknown (Hatzia, Ousley, & Cabo 2015), and the assessment of age in elderly populations (Cappella et al. 2015). New approaches in the estimation of age in adults (Brown 2015; Liversidge & Manica 2015; Parr, Passalacqua, & Skorpinski 2015; Shirley & Dudzik 2015) and subadults (Lottering et al. 2015; Schaefer & Hackman 2015), sex estimation (Kruger, L'Abbe, & Stull 2015; Meeusen, Christensen, & Hefner 2015; Rozendaal & Peckmann 2015), and evaluation of ancestry (Hefner et al. 2015; Jantz, Ousley, & Hefner 2015; Liebenberg, L'Abbe, & Stull 2015; Meeusen, Christensen, & Hefner 2015) were introduced. Advances in 3D modeling of fragmented remains (Mahfouz et al. 2015) and isotopic analysis (Bartelink et al. 2015; Chesson et al. 2015; Tipple et al. 2015; Warner et al. 2015) were also included.

Trauma interpretation remains a significant issue in research (for example, Bird & Soler 2015; Collini et al. 2015; Fenton et al. 2015; Hentschel & Wescott 2015; Isa et al. 2015; Khalil, Raymond, & Miller 2015; Lopez & Steadman 2015; Spatola 2015; Vollner et al. 2015; Williams 2015), particularly in relation to child abuse cases (Garvin & Symes 2015; Love & Soto Martinez 2015; McCormick & Love 2015; Vogelsberg et al. 2015). The application of theory in forensic anthropology (Boyd & Boyd 2015; Johnston & Schweikart 2015) and avoiding bias (Warren 2015; Winburn 2015) were also research themes at the AAFS 2015 meeting, as well as how they relate to forensic anthropology expert testimony (Lesciotto 2015). Using archaeological techniques to locate and recover human remains (Congram, Green, & Tuller 2015; Norton, Ford, & Cheetham 2015); decomposition (Dabbs, Connor, & Bytheway 2015; Klein 2015; Passalacqua & Megyesi 2015); taphonomy interpretation (Wescott 2015); and the estimation of postmortem interval (Boyd, Baden, & Boyd 2015; Hale & Ross 2015) continue to be subjects of research. Mitochondrial DNA mutations in age-at-death estimations (Zapico & Ubelaker 2015) and identification using radiographs of the proximal femur (Maxwell, Ross, & Lanfear 2015) were introduced. These approaches show the variability and development of forensic anthropology even though not all these methods will prove to be acceptable as they are tested over time.

The diversity of these research topics and the new concepts and methodology they represent reflect the growth and intensity of forensic anthropology in the United States. The field has changed immensely since its foundation in the 19th century, but it continues to evolve.

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Forensic Anthropology

Canadian Content and Contributions

Mark Skinner and Kristina Bowie

“The downside is you cannot make a living in Canada in the ultraspecialized field of forensic anthropology,” he adds. “There just aren’t enough homicides,” says Dr. Melbye.

(Belford 2003: B11)

Despite Dr. Melbye’s assertion, forensic anthropology has emerged in Canada as an increasingly important applied science at the core of societal concerns with public safety. Canadian citizens express dismay at horrendous homicides in Montreal, Toronto, and Vancouver that erode the confidence with which we can turn our children out to play. Our job as forensic anthropologists is to try to restore harmony to our society by improving the ability to prosecute criminals and to identify their victims. The point of reviewing the historical trajectory of our discipline must surely be to determine if we are doing the job.

The focus of this chapter is deliberately parochial: an evaluation of the contribution that individual Canadian forensic anthropologists have made and are currently making to death investigation. We are still a small community of scholars with local concerns but who conduct their business within an intellectual nexus shared internationally with forensic scientists facing a common problem.

In this chapter we first define Canadian content with an emphasis on our contributions to forensic osteology and fieldwork locally and internationally. Then we identify the intellectual lineages of anatomists and biological anthropologists who chose in their careers to engage themselves and their students in specific forensic anthropological concerns with victim identification, elapsed time since death, circumstances of recent deaths, and recovering physical evidence of perpetrator behaviors. Next we examine how and to what extent legal jurisdictions have reached out to academic expertise in our communities in death investigation. We critically evaluate the content of publications by Canadians in forensic anthropology and archaeology over a span of several decades. Finally we review centers of training in forensic anthropology as they have proliferated recently across Canada. The results of our review are mixed; Canadian contributions to forensic osteology, to the investigation of mass graves internationally, and to forensic taphonomy have been considerable and yet remain insufficiently focused on research initiatives and ongoing, core involvement at crime scenes and in the analysis of human tissues and associated evidence.

For the purposes of this chapter¹ forensic anthropology embraces the following concerns:

- 1 archaeology (landscape assessment, GIS, search and recovery techniques, evidence continuity, and conservation);
- 2 biological anthropology, including osteology (age at death, sex, ancestry, stature, individualization), circumstances of death (tool marks, peri- and postmortem trauma, body disposal), taphonomy, time since death, archaeometry (including bone biology);
- 3 social anthropology: material culture and practices, human rights, law; and
- 4 molecular forensic DNA.

As the discipline of forensic anthropology has matured in Canada, collaboration has increased among specialists such that reports and published articles are multiauthored and combine disciplines, making it more difficult to isolate forensic anthropology from closely allied sciences that address identification of historic individuals. For example, John Mayhall, a dental anthropologist, assisted with the DNA-based identification of a 13-month-old infant from the Titanic disaster (1912) buried in Nova Scotia by identifying dental fragments (Titley et al. 2004). Tanya Peckmann (1998) has termed the positive identification of historical personages using customary forensic techniques “*applied forensic osteology*.” Elliott Leyton’s enormously influential and reissued study (2003) of the cultural settings of serial homicide, *Hunting Humans*, should remind us that there is such a thing as “cultural forensic anthropology” and that discovering new ways to find and to understand perpetrators may be more of a contribution to society than a discovery of a new way to locate buried bodies or sex the radius. However, in our opinion, such important contributions do not qualify as forensic anthropology, *sensu stricto*.

Canadian Content

To a significant degree forensic anthropology in Canada differs from that in the United States. Fundamentally, the demand is less due to our lower crime rates. The historical emphasis in America on the determination of ancestry of victim (Ousley & Jantz 1998) and perpetrator has been less frequently relevant in our experience both in Canada and internationally, although this situation may change with increasing immigration. Similarly, the frequency of gunshot wounds in American forensic cases is not observed in Canada; but, alarmingly, this is changing with the recent flow of handguns across our common border. Other distinctions are due to the fact that decay rates slow with higher latitudes and prolonged winters such that we observe soft-tissue tags on some bodies even after many years. Many parts of rural Canada are heavily forested with significant predators, such as coyote, cougar, and bear, that prey on and scavenge remains. Therefore, for a variety of reasons, the demands of Canadian forensic casework are somewhat different from those in the United States.

We have chosen to emphasize Canadian content rather than simply requiring that the practitioners be Canadian. Consequently, this review includes high-profile Canadian cases to which American forensic anthropologists, some of them trained in Canada, contribute their expertise. Similarly, there are several young Canadians whose first-class training in osteology has enabled them to find employment and conduct forensic casework elsewhere in the world.

To discuss forensic anthropology as solely Canadian is parochial; forensic science has no such political boundaries. Expertise is what counts, which is why some of Canada’s high-profile cases have had significant input from Americans. For example, Steven Symes (Mercyhurst Archaeological Institute, Pennsylvania) was involved in the Paul Bernardo Case (1995) and in the Reynolds Case (1997), both of which required his expertise in tool-mark analysis (Steven Symes pers. comm.

2001). Likewise, Jon Nordby from Final Analysis Forensics (Washington State) worked on the “parking garage homicide” for the Hamilton–Wentworth Police (Jon Nordby pers. comm. 2006).

Constructing a “History” of Forensic Anthropology in Canada

The history of Canadian forensic anthropology is best addressed by identifying the intellectual lineages of teachers and students who have conducted casework and advanced the discipline through teaching, research, and publications. Finding the links to scholars in nations other than Canada is part of this enquiry. Another factor is to define which casework is relevant to the history of the discipline in Canada: casework may involve determining whether recovered bones are animal or of heritage significance (as required by law in Canada); a World War II unidentified death may now be considered merely of historical interest but most certainly was considered of immediate forensic interest by earlier generations of forensic anthropologists and still is to the Nation and victim’s relatives. A current problem in Canada is the investigation of bodies of persons killed in airplane accidents up to half a century ago, whose skeletal remains are now exposed by melting snow cover, subjecting them to potential theft and disturbance. The bottom line is that, if there are people who are concerned with the personal identification of deceased individuals and the determination of how they died, no matter how long ago, and if this determination draws on forensic science, then this is forensic casework. Evaluation of ancient remains, which are protected by law in Canada, may involve “forensic” techniques, including archaeology, anthropology, and DNA analysis (Dudar, Waye, & Saunders 2003). However, this chapter does not include discussions of routine examination of unknown ancient remains for repatriation.

Historical Foundations of Forensic Anthropology in Canada

Canada inherited the legal and scientific traditions of Europe, particularly France and the United Kingdom. Consequently, there are many cases of human remains recovered in the 19th and 20th centuries in Canada that relied on familiar techniques of identification performed by anatomists, many of whom shared the contemporary concerns of anthropology with understanding skeletal variation and ancestry. Thus Dr. William Dunlop, educated in Edinburgh in the 1820s, provided the first identifications in forensic medicine in Ontario (Lucas 1996). Just as medically trained experts dealt with bones, police investigators—not archaeologists—dealt with graves and their contents. In another Ontario case from 1897 Detective Murray delicately reexhumed an abortive grave intended for Emma Orr, whose remains were found interred elsewhere and was able to find a well-preserved boot print in the compressed earth. The body in the actual grave was detected by “touch-probing” with a gentleman’s walking stick (Campbell 1970). Even our modern concerns with taphonomy (see Nawrocki, Chapter 25 this volume) and scavenging are clearly nothing new. In the first years of the 20th century wolf-scavenged remains and fragments of clothing of several children from a Native family in Saskatchewan were collected by a police officer and transported over 1,000 miles to Edmonton, where the children’s father was charged with desertion (Young 1968: 75).

Alphonse Bertillon is considered the father of criminal identification. In the final decades of the 19th century he developed an anthropometric system for recording the body segments of criminals in Paris as a remarkably successful means of identifying repeat offenders. The year 1896 saw the heyday of “Bertillonage” and the zenith of the contribution that anthropology was to make to forensic science for nearly a century. However, Bertillon’s system for measuring body segments was flawed, because of lack of independence between measured body parts. This lack prevented the accurate multiplication of separate probabilities, a realization that prompted

reliance on the newly discovered uniqueness of fingerprints as a means of identifying victims and perpetrators. Canada moved in 1897 to introduce Bertillonage into its prison systems, just as it was being abandoned elsewhere (Campbell 1970). British police introduced Bertillonage only in 1895 in a deliberately abbreviated form, substituting dactyloscopy of all 10 digits. As is sadly typical of many, even recent, forensic investigations in Canada, police in the late 19th century took upon themselves the technical role of the anthropologist:

Inspector Stark, of the local detective Department, yesterday received from Chicago a complete set of instruments to be used in the Bertillon system of recording criminals. Instruments finely made [in Paris] consist of large and small calipers for measurement of the body, head, fingers, feet, arms and ears. Inspector Stark gave a brief explanation of the workings of the system yesterday using Crown Attorney Curry as an object lesson. Mr. Curry's measurements, however, were not recorded.

(Campbell 1970: 126)

Fingerprinting was adopted in Canada only in 1908 (*ibid.*).

The first city in North America to establish a criminalistics laboratory was Montreal in 1914. It was run by a physician, while medically trained individuals analyzed human remains (Nafte 2000). Anthropology as a distinct discipline concerned, in part, with human remains identification did not emerge in North America until the 1930s with the founding of the American Association of Physical Anthropologists (AAPA) in alliance with the American Association of Anatomists (Boaz & Spencer 1981). A charter member of AAPA was J. C. Boileau Grant from the University of Toronto, where the Grant Anatomy Collection now serves as a valuable resource in current use for osteological research with forensic relevance (Bedford et al. 1993; Kurki 2005). A request in 1921 for Grant to examine a skull found in basement construction in The Pas, Manitoba, is the earliest such request for assistance from an anatomist with anthropological interests (Albanese 2006a).

Grant was asked to examine a skeleton in 1956, alleged to be that of Tom Thomson, one of Canada's most famous northern wilderness painters, who had died under suspicious circumstances in 1917. Local friends of the artist rejected the explanation that he simply fell out of his canoe and drowned; they also averred that his body was not removed from the temporary grave on Canoe Lake in southern Ontario and that the family got the wrong body or none at all. In 1956 deliberate exhumation at Canoe Lake of a skeleton complete with an alleged bullet hole excited considerable interest. The thoughtful consideration then given to site formation processes is impressive:

Old hazel nuts and rotted vegetation were found with the bones. Had the grave been shallower one might assume rodents had found their way to the coffin and the remains.

(Sharpe 1970: 36)

The care taken in 1956 by Dr. Noble Sharpe, Medical Director of the Ontario Attorney General's Laboratory, in showing that the skeleton was not that of Tom Thomson is impressive still today. He personally assisted with the exhumation, noting surface topography, plant cover, burial depth, artifact type, and preservation. He sifted the sand, maintained a chain of custody, and performed both a radiological examination with an expert and a differential diagnosis with a neuropathologist of the alleged bullet hole compared to surgical trephination. He also obtained opinions from Grant as to age, sex, race, height, and probable time of death and/or

burial, conducted photographic superimposition, evaluated the dentition, and finally assessed burial site transformation processes.

A 1953 case in British Columbia elicited a similarly high quality of investigation involving anthropological expertise. Known as the Babes in the Wood Case, two children's skeletons were discovered in Stanley Park (Vancouver) along with a lather's hatchet, which had been used to kill them. A sample of vegetation taken from above the bodies yielded 5½ years of alternating layers of deciduous leaves and pine needles, placing the deaths somewhere around 1947. These skeletons have never been identified, despite years of examination. In 1961 Mrs. Ena von Engel-Baiersdorf sculpted likenesses of the children based on the skulls in a very early example of forensic facial reproduction. She was "an artist trained in physical anthropology at the Vienna Natural History Museum" (Stainsby 1961: 59).

The Rise of Forensic Anthropology as an Academic Discipline in Canada

While specific histories of physical anthropology in Canada simply note that forensics was being done by the 1990s (Meiklejohn 1997) or do not mention it at all (Melbye & Meiklejohn 1992), the foundations for forensic casework and research were being created in Canada by the first generation of physical anthropologists. It was shortly after the Second World War that anatomy and physical anthropology were recognized to be separate and diverging disciplines with an enduring bond sustained by forensic osteology. J. C. Boileau Grant, who has been described as a physical anthropologist in all but name (Jerkic 2001), contributed significantly to the future of forensic anthropology in Canada by nurturing the osteological interests of James E. Anderson (1926–1995). Anderson became the intellectual bridge between the two disciplines. Although medically trained, receiving his degree from Toronto in 1953, Anderson became a lecturer in Anatomy in 1956 but then, significantly, was appointed in 1958 as an assistant professor of physical anthropology, Canada's first, and trained many of the prominent osteologists who currently conduct forensic work in Canada (Melbye 1995; Jerkic 2001). Anderson's *The Human Skeleton: A Manual for Archaeologists* (1969) provides particularly useful descriptions of dental morphology. Its impact on Canadian osteology can be compared to that of Don Brothwell's *Digging Up Bones* (1963), which influenced a whole generation of skeletal biologists in Britain.

In Western Canada a second intellectual lineage of forensic anthropologists was created by the arrival of Thomas W. McKern at Simon Fraser University, British Columbia, in 1971. McKern (1920–1974) received his Ph.D. from Berkeley in 1954 under the tutelage of Theodore McCown (Steele 1975) and was greatly influenced by T. Dale Stewart, with whom he wrote the classic study of skeletal age changes of identified U.S. soldiers killed in the Pacific (McKern & Stewart 1957). McKern taught Gentry Steele, a young osteologist who studied at the University of Alberta (1971–1978), where he undertook the occasional forensic case for the Medical Examiner's Office. In the late 1970s Steele gave a workshop on forensic anthropology to the Royal Canadian Mounted Police (RCMP) in Fort Wainwright (Alaska); Steele's influence may well have prepared the ground for Owen Beattie, his successor in physical anthropology at the University of Alberta.

According to Professor Steele, who took classes from McKern before he came to Canada, McKern had contacted the RCMP in British Columbia offering to undertake forensic casework, but there is no indication he had done so before his untimely death in 1974. Nevertheless, when Mark Skinner arrived in January 1976 as McKern's successor at Simon Fraser University, the local police simply expected him to provide what McKern had offered; which he did despite being completely inexperienced in the area. Significantly, a new graduate student at Simon Fraser University, Owen Beattie, soon stepped in to teach all McKern's graduate and undergraduate classes (including osteology). Beattie harvested anatomical specimens from the University

of British Columbia. These were curated by Carlos Germann and became the Germann Public Symphysis Collection at Simon Fraser University (subsequently studied by Nancy Lovell in 1989).² Professor Beattie went on to the University of Alberta to conduct enormously publicized exhumations of members of the Franklin Expedition and is routinely involved in Canadian and international forensic cases.

Forensic Anthropology: Current Practices

The modern period of forensic anthropology, according to some, begins with the creation of the Physical Anthropology Section of the American Academy of Forensic Sciences in 1972. Involved were Ellis Kerley (1924–1998) and Clyde Snow (1928–2014), each of whom played key roles in making forensic anthropology international. In 1977 the American Board of Forensic Anthropology (ABFA) was created to certify Diplomates with particular expertise. Skinner was the first Canadian to become a board-certified Diplomate in 1982, followed by Jerry Melbye in 1997.

We prefer to define maturation of the discipline by the ability of the legal fraternity in Canada to call on professional expertise in forensic anthropology to support either side in an adversarial court system; that is, both the Crown and the Defense can evaluate the forensic evidence with confidence. Canadian anthropologists played a modest role in the investigation of the murder in 1984 of Christine Jessop. Guy Paul Morin was wrongfully convicted in 1992 for this crime and was exonerated only in 1995, almost 10 years after he was first arrested (King 1998). In 1990, as part of the legal run-up to the trial in 1991, Kathryn Gruspier, then a doctoral candidate, appeared for the Crown; Jerry Melbye, Ph.D., testified for the Defense at the Preliminary Hearing, while Gruspier appeared at the trial itself on behalf of the Defense. On June 7, 2006, two doctorally qualified forensic anthropologists (Lazenby and Skinner) appeared in the Supreme Court in British Columbia to testify as expert witnesses for the Crown and for the Defense, respectively, in a high-profile serial homicide case (Robert William Pickton). As far as we are aware, these are the only two cases in Canadian legal history in which both Prosecution and Defense counsel availed themselves of expertise in forensic anthropology. In 2002 Melbye gave a paper entitled “The Rise of a New Academic Discipline in Forensic Science,” which marks a disciplinary self-awareness of the vigorous growth of our activities in the preceding decade.

Geography and Casework

Canada is divided into 10 provinces and three territories, the majority of which have a Coroner’s system (see Ranson, Chapter 44 this volume). Only Alberta, Manitoba, Nova Scotia, and Newfoundland have a Medical Examiner’s system. In the latter system practitioners must be medically qualified, whereas in the former practitioners have varied backgrounds that typically involve police work. There seems to be no logic to the varied relationships between these jurisdictional systems and forensic anthropologists. Theoretically, of course, crime scenes are the responsibility of the police (city, provincial, and national police services exist), whereas bodies are handled by the coroner or medical examiner. In that both human remains and their surrounds usually contain evidence of circumstances of death and individuals must also be identified, there is no national consensus as to how best to involve the broad skills of the archaeologist and the anthropologist. Sad to say, in our opinion, neither the many RCMP crime labs across Canada nor the major provincial crime labs in Ontario (Centre of Forensic Science) and Quebec (Laboratoire de Sciences Judiciaires et de Médecine Légale du Québec) have full-time forensic anthropologists on staff. Presumably it is even now more cost effective to involve anthropologists

on an as-needed basis. However the Toronto Forensic Pathology Unit of the Office of the Chief Coroner routinely provides office space and a lot of casework to a local anthropologist.

In the following section we have deliberately chosen to name Canadian forensic anthropologists and archaeologists. In so doing we acknowledge the choice of the lone scholar to volunteer to the community his or her forensic expertise, despite little or no remuneration and with little in the way of career advancement.

For the purpose of death investigation Alberta is divided into northern and southern territories, each of which has identified a Consultant Forensic Anthropologist to undertake cases (in Edmonton: Beattie, assisted by Pamel Mayne Correia; in Calgary: Annie Katzenberg). Even more encouraging is the situation in Nova Scotia, which, perhaps significantly, like Alberta has a Medical Examiner's system, where Tanya Peckmann has been appointed officially as the Provincial Forensic Anthropologist—Canada's first to our knowledge. Her mandated examination of all bones found in the province is conducted in the Medical Examiner's facilities. In Saskatchewan Ernest Walker was appointed in 2000 as a supernumerary Special Constable with the RCMP and conducts all their forensic anthropological casework. In British Columbia allocation of casework appears to be in a state of flux. Corporal Diane Cockle with the RCMP, trained as both an archaeologist and anthropologist, performed virtually all fieldwork and examination of skeletal remains in the southern part of this province from 2004 to 2006, and Richard Lazenby at University of Northern British Columbia remains extremely busy with casework in the north of British Columbia. Skinner is involved with casework internationally, while he and his graduate students receive forensic cases regularly from the Office of the Chief Coroner. Lynne Bell, now in the School of Criminology at Simon Fraser University, is part of the team helping to create a new Centre for Forensic Research.

In Manitoba Chris Meikeljohn (the University of Winnipeg) has been a Consulting Forensic Osteologist since 1980. In central Ontario Kathy Gruspier assists the Toronto Forensic Pathology Unit, which is housed in the same complex as the Centre of Forensic Science for Ontario. With the appointment of John Albanese to the University of Windsor in 2003 additional casework to that already done by Michael Spence at the University of Western Ontario is being conducted. Spence has undertaken casework since 1979, working for at least nine municipal police departments. In Northern Ontario, where a Department of Forensic Science was created in 2004, Scott Fairgrieve and Tracy Oost conduct casework. In Eastern Ontario Jerry Cybulski and Janet Young (The Canadian Museum of Civilization, Ottawa) have conducted casework since 1974. Shelley Saunders (McMaster University) provides similar expertise in southern Ontario. Tracy Rogers, recently appointed at the University of Toronto, Mississauga, is Canada's first tenure-track professor in forensic anthropology. Clearly, Ontario has a wealth of expertise compared to the rest of Canada. A few cases have been conducted in Newfoundland by Sunny Jerkic (Memorial University). Prince Edward Island, New Brunswick, the Yukon, Northwest Territories, and Nunavut do not apparently have resident forensic anthropological expertise.

Quebec appears to be a special case. All forensic anthropological consulting is conducted by Kathy Reichs³ (University of Northern Carolina at Charlotte). Consultation is undertaken during her periodic visits to Montreal, where she examines remains at Laboratoire de Sciences Judiciaires et de Médecine Légale du Québec.

Database of Individuals Involved in Forensic Anthropology

Potential participants in this history were asked for their curriculum vitae as well as their views on the history of forensic anthropology in Canada. They were also asked to provide names of other Canadian practitioners unknown to us. The total number of respondents included in this

chapter is 48, including 24 in academic posts, 13 students, 4 in museum posts, and 7 in other posts (for example, working for police or intergovernmental organization). The gender ratio of this sample is 29 females:19 males.

Reported Case Loads

Only a few forensic anthropologists routinely report the size and nature of their casework as part of their professional practice⁴ in papers, publications, or on their CVs. Some practitioners (for example, Skinner) report every consultation, including nonhuman animal bones and heritage cases and, as well, differentiate recent human cases by manner of death, while others consider that only recent human cases need be counted. Consequently, one suspects that the caseloads reported in Table 9.1 are not truly comparable. Note that Table 9.1 does not include mass grave work yet does include forensic entomology.

As unreliable as the numbers in the table may be, there clearly are two centers of activity in Canada: Ontario and the West. Ontario has its own provincial police force and contains the Centre of Forensic Science. Two factors may explain the large amount of casework in British Columbia and Alberta: the legacy of Tom McKern, who directly or indirectly influenced Beattie and Skinner; also, major policing in the Western provinces is done by our national police force

Table 9.1 Domestic casework (as of June 1, 2006)

Name	Job	Total/Comments
Albanese	academic	occasional
Beattie	academic	236 + 13 court appearances
Cockle	police/student	89 (60 nonhuman, 15 heritage [i.e., archaeological], 4 accidents/suicides, 10 homicides)
Curtin*	academic (USA)	sporadic over 22 years, 9 in last 3 years
Cybulski	museum	105 + 2 court appearances
Dupras*	academic (USA)	25
Fairgrieve	academic	76 + 4 court appearances
Gruspier	professional consultant	>477 (+ 10 court appearances)
Heathcote*	academic (USA)	4
Hillier	student	2 homicide excavations
Jerkic	academic	23
Katzenberg	academic	43
Komar	academic (USA)	12 + 3 court appearances (242 + 9 in USA)
Lazenby	academic	>50 (31 human, 8 homicides) + 1 court appearance
Meiklejohn	academic	144
Melbye	academic (Can/USA)	69 (Katzmarzyk 2001)
Oost	academic	10 (many entomological)
Peckmann	academic	>20
Pietrusewsky*	academic (USA)	30
Rogers	academic	68 + 4 court appearances
Saunders	academic	3–4 per year since the late 1980s
Skinner	academic	358 (144 forensic, 56 homicides) + 13 court appearances
Spence	academic	65 (24 recent, 20 in field) + 3 court appearances
Stratton	academic	21
Wilson	academic	4

*Canada-trained but not resident

(RCMP). The Canadian respondents to our enquiry report working on some 1,872 cases, of which about one-third relate to recent bodies. How significant are these numbers? In 1996 Beattie reported that less than 2% of Medical Examiner cases in Alberta involved the assistance of a forensic anthropologist. In 2000 Gruspier observed that, for the period 1974 to 1998, anthropological cases at the Toronto Forensic Pathology Unit represented between 1.3% and 3% of autopsies (Gruspier & Chiasson 2000: 2). These authors remark that “the actual number of anthropological cases being done by an anthropologist in the office is approximately one-third of the 20 to 40 cases which come in per year” (ibid.); in other words, pathologists and odontologists are contributing their expertise to cases that could also include an anthropologist. Interestingly, there is no trend at the Toronto Forensic Pathology Unit for an increase in the number of anthropological cases for the period 1974 to 1998; this situation is unlike the general tendency, Canada-wide, for anthropological casework to have increased dramatically over the past decades. This subject needs better evaluation.

In addition, many Canadian forensic anthropologists work internationally, typically on mass graves and mass disasters. It is difficult to assess the exact number of cases undertaken by single practitioners, because bodies are typically processed by teams. Nevertheless, Table 9.2 gives some

Table 9.2 International casework

<i>Name</i>	<i>Job</i>	<i>Operational Theatre(s)</i>	<i>Notes</i>
Bassendale	ICMP ¹	Bosnia	student at Lukavac
Beattie	mostly PHR ²	Cyprus, Somalia, Rwanda, Abkhazia/Georgia	
Cockle	RCMP	Thailand Tsunami	
Congram	ICTY, RCLO	Bosnia, Croatia, Iraq, Kosovo, Costa Rica	professional and student
Fernandez	ICTY, ³ ICMP, UNV ⁴	Bosnia, East Timor	court appearance
Gruspier	ICTY, UNTAET ⁵	Kosovo, East Timor, Cambodia	anthropologist
Katzmarzyk	ICTY, OMPF, ⁶ ICMP	Bosnia	manager Lukavac
Komar	ICTY, ICMP, PHR, RCLO ⁷	Bosnia, Kosovo, Iraq	
Kosalka	ICMP, Kenyon ⁸	Thailand, WTC, Bosnia	student
Lazenby	consultant	Guatemala	initiating field school
Melbye	UN Review Panel		ICTY investigations
Mundorff	OCME-NYC ⁹	WTC, Thailand	professional and student
Prevost	ICMP	Bosnia	student at Lukavac
Scott	Kenyon	WTC, New Orleans	student
Skinner	PHR, ICMP	Afghanistan, Bosnia, East Timor, Serbia	seconded to UNHCHR, UNTAET
Skinner, Mark	UNV	East Timor	student
Stratton	PHR	Cyprus	student then

1 International Commission on Missing Persons (Lukavac Re-Association Center)

2 Physicians for Human Rights

3 International Criminal Tribunal for the Former Yugoslavia

4 United Nations Volunteer

5 United Nations Transitional Administration in East Timor

6 Office of Missing Persons and Forensics, United Nations Mission in Kosovo

7 Regional Crimes Liaison Office, Iraq

8 Office of the Chief Medical Examiner, New York City

9 Kenyon International Emergency Services—disaster response

indication of the scale of Canadian involvement in other countries. Clearly most of the Canadian contribution to fieldwork in mass disasters and mass graves internationally is being done by such students and young professionals as Congram, Gruspier, Katzmarzyk, and Mundorff rather than tenured faculty staff.

Temporal Trends in Academic Communication

Our first task was to define Canadian content. Besides students and faculty who work in Canada, we include those Canadians working abroad on a permanent or part-time basis and foreign academics trained or training in Canada. The period under consideration covers 30 years, commencing in 1978 with the first publications on forensic science by a Canadian anthropologist (Michael Wilson) and includes items in press as of June 1, 2006. Publications include peer- and non-peer-reviewed items as well as reports to such major agencies as ICTY, PHR, and ICMP but exclude book reviews (for example, Skinner et al. 2010). We also consider “presentations,” which include all communications ranging from formal symposium lectures to talks to lay audiences. In both publications and presentations, we sought temporal trends in the proportion of forensic communications relative to nonforensic.

The number of publications (as defined previously) per year is shown in Figure 9.1. Excluding those “in press,” in the first 20 years up to 1997, 54 publications appeared—a rate of 2.7 per year. In the following nine years up to 2006, 93 publications appeared—a rate of 10.3 per year. Thus, in the latter third of the review period, the rate of forensic publications in Canada increased by 280%. This number sounds encouraging for the discipline. However, if one compares the number of respondents who supplied CVs (48) with the total number of publications judged to be forensic in content (ca. 147), the average number of publications in forensic anthropology (*sensu lato*) per individual career is only three. Interestingly, during the same two time periods, the average number of different authors/publication in any one year barely changed, from 1.56

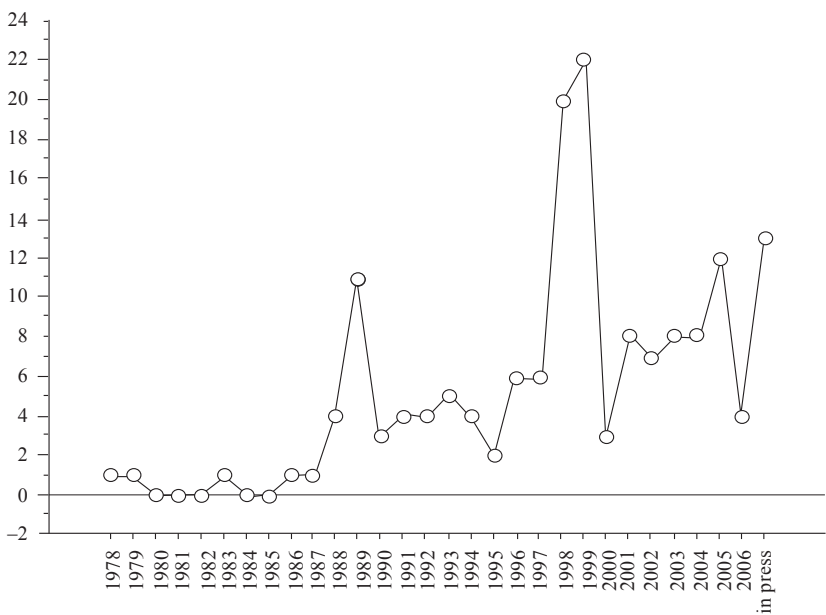


Figure 9.1 Publications with forensic content per year

to 1.62, suggesting no dramatic increase in team efforts. However, note that, in 2006, the ratio of multi-authored publications peaked, indicating the recent replacement of lone efforts with teams of death investigators including anthropologists. Another factor must be the occurrence of large-scale investigations of mass graves confronted by such organizations as Physicians for Human Rights under the direction of William Haglund, who purposefully involved internationals including Canadians, and the effects of the World Trade Center disaster, which, perforce, involved large numbers of various investigators.

Clearly, however, relatively few practitioners listed in Table 9.1 publish their extensive experience, to the detriment of the discipline both in casework and theoretical developments. One must recognize, however, that those whose work has been conducted under the aegis of international criminal courts may be prevented by confidentiality agreements from publishing detailed accounts of their findings.

We also examined the ratio of specifically forensic presentations and publications to an author's general productivity. In both cases about 40% relate to forensic anthropology. It can be concluded that, as we saw in the low average number of career publications in forensic anthropology, for most Canadian biological anthropologists who report any forensic involvement, forensic anthropology remains, if not a sideline, their subordinate calling. Those scholars whose publications are in forensics more often than not include John Albanese, Scott Fairgrieve, Debra Komar, Amy Mundorff, and Tracy Rogers, individuals who have chosen early in their careers to specialize in forensic anthropology.

Characterizing the Recent History of Forensic Anthropology in Canada

History will decide what efforts and which publications by Canadians were most significant for the discipline in the long run. It was teasingly remarked that when, in the 1980s, it became politically difficult in Canada to excavate First Nations' skeletal remains, Jerry Melbye cannily shifted to forensic anthropology (Knight 2006). But, as noted shortly, Melbye was already teaching forensics at the beginning of the decade. The major historical change in reported casework was the deployment of Canadians into foreign locales, mostly in the late 1990s.

Forensic Archaeology

Major publications in forensic archaeology include those by Skinner and Lazenby (1983) and Skinner (1987). Although field practices internationally may have been positively affected by these efforts (Luis Fondebrider & Jon Sterenberg pers. comm. 2006), there is disappointingly little published evidence that forensic archaeology has increased in Canada apart from sporadic cases undertaken by Skinner and Michael Spence (University of Western Ontario). The latter archaeologist has conducted 13 field recoveries of bodies and recent skeletons with surviving soft tissue (Michael Spence, pers. comm. 2007), indicating local acceptance of his expertise. More encouraging is the recent appearance of the first Canadian article on remote sensing of mass graves by means of spectral analysis (Kalascka & Bell 2006) and the first book specifically on forensic archaeology (Dupras et al. 2006), which, given its American debut, may have a higher visibility and influence. "Archaeology" is said to have been performed on the Pickton "pig farm" crime scene in British Columbia in 2002–2004 (Girard 2002), but a full account has yet to be published. The much-publicized use of conveyor belts at this scene was introduced much earlier at the dreadful Hinton Train Collision in 1986 (Stratton & Beattie 1999). Indeed, conveyor belts were also utilized at Ground Zero in New York City 2001. Another indication that, at least in foreign locales, forensic archaeology is becoming more commonplace than it is

in Canada, is shown by Skinner's coauthored publications on guidelines for bioarchaeological monitors of mass grave investigations (2003), on how to allocate different kinds of forensic scientists at mass graves (Skinner & Sterenberg 2005), and a proposed typology of mass graves (Jesee & Skinner 2005).

Forensic Anthropology

A valiant but rather strained effort by Skinner (1988) to apply joint probability theory to skeletal identification has been completely obviated, one notes thankfully, by DNA-based identifications. Our inability to estimate elapsed time since death with any precision prompted us to promote forensic entomology at sites involving skeletons (Skinner et al. 1988); this approach is now routine in Canada thanks to the exemplary efforts of Gail Anderson and her students (reviewed in Anderson 2001). A review of research published from 1989 to 1996 reveals a number of routine articles on skeletal biology applied in a forensic context relieved only by the first articles on diagenetic changes at the histological level (Bell, Cox, & Sealy 1993; Bell, Skinner, & Jones 1996). This period in Canadian forensic anthropology clearly fits within Kuhn's descriptions of scientists' efforts in the midst of a prevailing paradigm: "Mopping up operations are what engage most scientists throughout their careers. They constitute what I am calling here 'normal science'" (1977: 24).

In 1997 things began to change. The impending revolution in identification methodology based on replication of biomolecules from bones was introduced to Canadian forensic anthropology by Yang and associates' (1997) important article on the removal of polymerase chain reaction (PCR) inhibitors. The very influential book on forensic taphonomy by Haglund and Sorg appeared in the same year; as we already noted, Haglund was instrumental in assisting several Canadian forensic anthropologists into international work at that time. Not coincidentally a series of articles by Debra Komar and Owen Beattie appeared around this time describing their field simulations of taphonomic processes at the Ellerslie Research Facility, University of Alberta Farms, Edmonton, Alberta (Komar & Beattie 1998a, b; Komar 1999). A similarly important work by Kathy Reichs, who had started to work on Quebec cases, appeared in 1998. Scott Fairgrieve, drawing on his commitment to forensic casework and teaching at Laurentian University, brought out a book of case studies in 1999, authored largely by Canadians, which showed for the first time the breadth of high-quality work being conducted in Canada.

A new means of tracking individual migration life history from detailed histological bone chemistry analysis was introduced in 2001 by Bell and coworkers. A new work on forensic taphonomy appeared in 2002, edited by Haglund and Sorg, which contained two articles by Canadians. So pervasive was the influence of this volume that, in Serbia at least, the phrase "forensic taphonomy" was substituted by interpreters for "forensic archaeology"—a compliment to the editors that seemed disrespectful to correct.

At this time, bodies of Kosovar Albanians buried in Serbia, including the suburbs of Belgrade, began to be exhumed, as described in several ICMP monitor's reports written by Skinner (for example, 2001). The ensuing years saw the publication of many articles and reports written about mass graves and mass disasters, including the World Trade Center and the 2004 Boxing Day Tsunami (Cockle, Andrews, & Thompson 2005). Fieldwork, concentrating on innovative archaeological techniques, was described in Skinner, Alempijevic, and Djuric-Srejic (2003) and in a series of articles in 2003 by Mundorff and Steadman and in 2004 by Cockle, Andrews, and Thompson (2005). Noteworthy at this time is Debra Komar's critical review (2003) of success in reconstructions of age at death, sex, and stature of victims from Srebrenica, Bosnia, and Herzegovina conducted by anthropologists and pathologists drawn from a variety of countries.

The results were properly sobering. Several articles by Tracy Rogers (2004) and Rogers and Allard (2004) signaled her appointment to the University of Toronto in 2001. Marking the shift from classical to DNA-based identifications, including cold cases, are recent articles by Torwalt and associates (2005) and Katzenberg and colleagues (2005).

Standards and Professionalism

Apart from noting the dramatic increase in peer-reviewed and other publications in recent years in forensic anthropology, another way to examine the increasing professionalism of forensic anthropological practitioners is to examine thesis topics of the highest degree (usually Ph.D.) over time to see whether the practitioner specialized in forensics as a student. The results are shown in Figure 9.2.

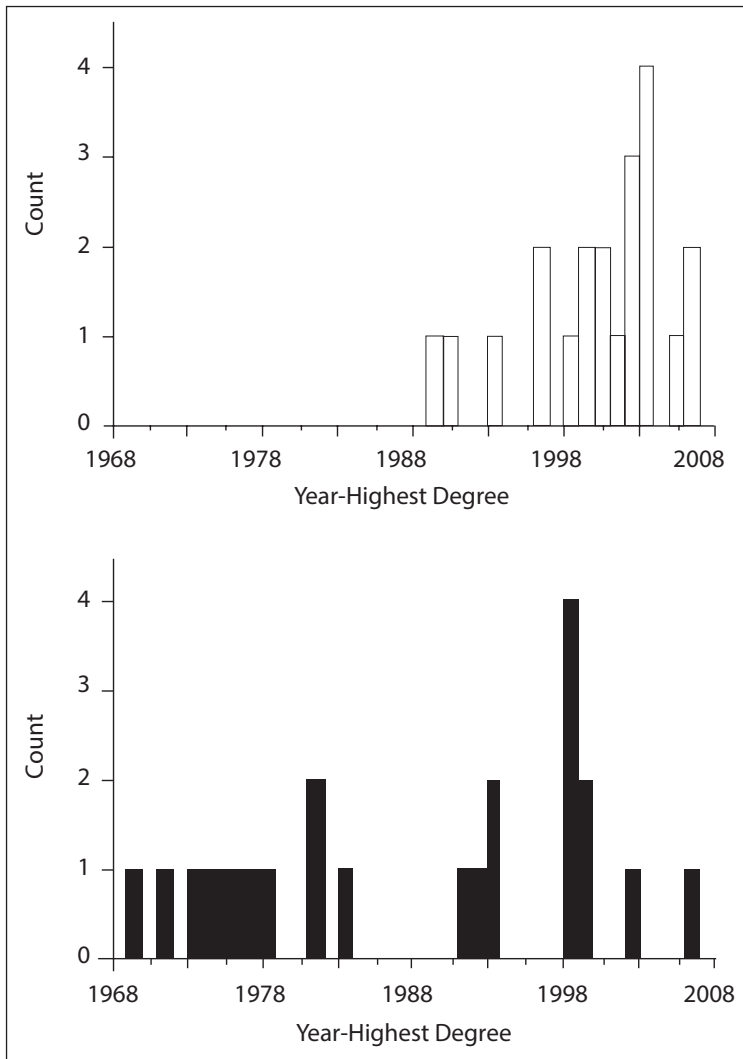


Figure 9.2 Thesis topic of highest degree undertaken by forensic practitioner by year: forensic above, nonforensic below (see text for further details)

In 1989 Sabine Stratton produced the first thesis (Masters level) in Canada with a specific forensic content. The first Canadian doctorate in forensic anthropology was awarded to Debra Komar in 1999; notably, both of these students were at the University of Alberta. Most forensic theses among our respondents are at Masters level, and the majority of these have been awarded outside Canada.

As current Chair of the Anthropology-Medical-Odontology Section (AMO) (created in 1995) of the Canadian Society of Forensic Science, Jerry Cybulski reports that currently there are 95 AMO members, including 16 anthropologists. Four others belong to the Medical Section for unclear reasons (Jerry Cybulski pers. comm. 2007).

Training Opportunities in Canada

Jerry Melbye introduced the first course in forensic anthropology in 1981 at the University of Toronto, followed in 1983 by Mark Skinner, who introduced a course at Simon Fraser University. This course coincided with the publication of the field text for police officers, *Found! Human Remains* (Skinner & Lazenby 1983), which has been used in many course offerings across Canada.

There are dozens of undergraduate students and a handful of graduate students currently enrolled in programs across Canada. Individual courses and/or minors in forensic anthropology are offered at times in a number of Canadian institutions (Table 9.3). Larger programs that emphasize forensic anthropology, often within a forensic science focus, are also available (Table 9.4).

Conclusion

Despite Jerry Melbye’s lament at the beginning of this chapter, there do appear to be many people doing a great deal of forensic anthropology in Canada. It is not all homicides, and it is not all in Canada. Large-scale operations in foreign locales are now dominating expansion of the field in terms of training and publications. Some of our graduates are finding employment in Firearms and Tool Mark Examiners sections of Canada’s provincial and federal crime labs. An emerging career strategy is for completed Masters-degree students to work professionally for several years before returning to academe.

Table 9.3 Some of the Canadian institutions offering individual courses and/or minors in forensic anthropology

Province	University/Other
Newfoundland	Memorial
New Brunswick	St. Thomas—offers a minor
Ontario	Lakehead—several courses
	McMaster
	Trent
	Ontario: Institute of Technology
Manitoba	Manitoba
Saskatchewan	Saskatchewan (plus a 5-day noncredit course)
British Columbia	Simon Fraser
	Victoria

Table 9.4 Larger programs in forensic anthropology offered in Canada

Province	Comment about Courses in Forensic Anthropology
Nova Scotia	In about 1996 Paul Erickson (Saint Mary’s University) introduced basic courses in forensic anthropology, which resulted in 2000 in a formal agreement with the RCMP to offer a stand-alone Forensic Sciences Diploma Program. In 2001, 25 students enrolled (University Affairs January 2001: 7).
Ontario	The University of Toronto has led the way in teaching forensic anthropology. In 1997 Jerry Melbye created a B.Sc. Program in Forensic Science at Mississauga. Tracy Rogers succeeded him in 2001. Under her direction, University of Toronto Mississauga (UTM) has one of the most complete undergraduate forensic anthropology streams in Canada, with an introductory course, a field school emphasizing forensic archaeology, and a full-year case-based class that culminates in a mock trial under the cross-examination of an Ontario Crown Attorney. They also offer a course in the use of demonstrative aids for the presentation of expert testimony in collaboration with Biomedical Communications. Dr. Rogers has been involved in the development of a graduate forensic science program at UTM, which will give students the option of completing a Masters in either Anthropology or Forensic Science, depending on their inclination and long-term goals. She is one of the few people in Canada who teaches forensic anthropology at the graduate level, supervising graduate research in this field (Tracy Rogers personal communication). University of Windsor offers field and lab courses in forensic anthropology and forensic science. Laurentian University has an entire Department of Forensic Science, directed by a forensic anthropologist Scott Fairgrieve. Scott writes: “Yesterday (June 1, 2006) we graduated our first class of the new Hons. B.Sc. in Forensic Science at Laurentian University. There were 12 students graduating with this degree in areas, including Forensic Anthropology, Forensic Analytical Chemistry and Instrumentation, Forensic Psychology, and, as a single specialization, Forensic Science” (Scott Fairgrieve personal communication).
British Columbia	Simon Fraser University Centre for Forensic Research—Simon Fraser University has been a leader in the field of forensic science since the 1970s and was one of the first universities in North America to offer forensic entomology, biological anthropology, and forensic archaeology as a service to the police community. Graduate training at the Masters and Doctorate level is offered. Since this time, Simon Fraser University has been at the forefront of research in these areas and is now developing a Centre for Forensic Research (CFR). The current level of investment in the Centre itself is about \$3.5 million and includes imaging suites, several secure laboratories to process entomological and biological materials safely, and the recent hiring of two new faculty members. Opened in the fall of 2007, the Centre bridges the Departments of Archaeology and School of Criminology and will act as a nucleus for the expansion of research in Forensics between these two departments and others within Simon Fraser University, including botany and molecular biology. The Centre routinely accepts casework but is designed to enhance research capability in these forensic sciences.

The core role of forensic anthropology as an applied science is to identify individuals from detailed knowledge of skeletal anatomy, which can yield reliable indications of age, sex, ancestry, and stature. Such knowledge provides a guide to more reliable means of identification based on such antemortem data as dental and medical records. All such methods have now been surpassed by the enormously more accurate means of DNA-based identifications. Recourse to this method has been routine for about a decade, and one might expect the practice of forensic anthropology to have visibly withered during this time; but, as we have seen, quite the contrary situation is occurring. How can this be? Apart from the increasing numbers of articles, practitioners, and new Ph.D. graduates trained specifically in forensic anthropology, the discipline of forensic anthropology is broadening considerably. How does a science grow? As Kuhn (1977) has shown, one way is to introduce a whole new manner of doing or seeing things. A three-pronged paradigm shift has resulted from (1) the justly famous PCR amplification of remnant degraded DNA (see Baker, Chapter 28 this volume); (2) society's realization that locked in the organic content of our bones and teeth is a unique biochemical record of a person; and (3) even in the absence of objects bearing one's DNA (for example, toothbrushes, cervical smears), there is potentially a complete copy of our DNA shared among close biological relatives. This revolution in identification methodology is implemented on an impressive scale by the International Commission on Missing Persons, which has employed a surprising number of Canadian students both in the excavation and antemortem-postmortem review phases.

Besides noting paradigm shifts, this chapter makes clear that forensic anthropologists are redefining their roles and their discipline to keep it vibrant and relevant. One way has been by broadening scales of inquiry. This broadening is evidenced, on the one hand, by Bell, Cox, and Sealy's analyses of stable isotopes of bone packages within osteons (2001) and Skinner and Dupras's study of variation in location of the neonatal line in dental enamel as a function of gestation length (1993) and, on the other hand, by GIS-based and spectral analyses of remotely sensed images to detect mass graves (Kalascka & Bell 2006). Typically, in the variety of cases worked on by forensic anthropologists, much time elapses between death and discovery. The intervening time creates numerous opportunities for natural postmortem processes such as scavenging, transport, burial, decay, and discovery to affect skeletal integrity, requiring a differential diagnosis to distinguish with confidence relevant and irrelevant aspects of altered bone. Taphonomic studies as undertaken by Komar and Beattie (1998a, b, c) and Komar (1999) are important enrichments of the discipline.

One obvious way to enhance the discipline is to add international casework to domestic. Functionally, most established academic practitioners stay home and students go abroad. At least one professional forensic archaeologist (Congram) has worked internationally for several years before returning to graduate studies. Another way is to broaden our anthropological purview to include human rights issues—for example, Blau and Skinner's deliberate advocacy (2005) to investigate a neglected mass grave in East Timor. Few anthropologists consult for the Defense.⁵

We can ask "does the historical trajectory of the discipline demand deliberate intervention for the good of the subject?" One answer is "yes!" Despite the enthusiasm and inventiveness of its practitioners, forensic anthropology in Canada has some problems. Forensic anthropologists are still not integrated into crime labs, and their involvement is piecemeal and ad hoc. Some provinces have no local expertise, whereas others bestow titles, such as Consulting Forensic Osteologist but provide little casework. There are almost no published accounts of the application of forensic archaeology to actual cases in Canada. With the recent exception of a report by John Albanese (2006b) to the Department of National Defence, there is virtually no link between the Canadian military and academic forensic anthropology. This situation stifles the scope for research and practice on large-scale problems such as international investigations of war crimes. Skeletal and artifactual collections of forensic materials are tiny or lacking completely in most

teaching institutions. Defense counsels seem largely unaware of our expertise. Our contributions to scholarly research are too focused on casework. Moreover, the failure of many of us to publish, whether because of workload, confidentiality clauses, or sloth, is surely one cause.

Our successes center on excellence in casework and court testimony, our international involvement, and the successful deployment of our students into academic and applied posts in Canada and abroad. Fundamentally, we still face the task of changing the perception by the public and by death investigators of our role. We should be much more involved as senior managers in crime scenes and field investigation including mass disasters. We should be much more involved in cases involving fresh bodies and soft tissue. We should be seen as first responders.

Notes

- 1 Our chapter is based on curricula vitae received by June 2006.
- 2 Skinner recalls that only Owen, who had been taught how to use the McKern-Stewart symphyseal phase casts by McKern himself, felt competent in their usage; Skinner certainly did not.
- 3 Kathy Reichs is also an accomplished novelist specializing in forensic mysteries.
- 4 The two Canadians (Skinner at Simon Fraser University and Melbye, now at the University of Texas) are Diplomates of the American Board of Forensic Anthropology and thus required to submit annual tallies of casework.
- 5 To date, only Gruspier and Skinner are known to have done so.

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The Development and Current State of Forensic Anthropology

An Australian Perspective

Denise Donlon

The history of forensic anthropology in Australia is very closely linked to the history of physical anthropology and anatomy. In this chapter I concentrate on the early practitioners who made a major contribution to the field. This perspective investigates possible reasons why the discipline of forensic anthropology was so slow to develop in Australia. As with any discipline that deals with human remains ethical issues are important in the history and the current practice of the discipline. These issues are discussed particularly in light of the use of collections of Aboriginal skeletal remains.

The last 20 years have seen significant advances in the field. Thus new developments in the discipline, such as advances in education and training, are briefly discussed, and the roles of various forensic societies and associations in the development of forensic anthropology are also examined. Employment of forensic anthropologists is outlined, along with examples of court cases in which forensic anthropologists acted as expert witnesses.

Forensic anthropology is sometimes confused with or overlaps with closely related disciplines such as archaeology and osteology. Forensic archaeology is concerned mainly with the search for and the recovery of remains. This chapter concentrates on forensic anthropology rather than archaeology, because the latter discipline is young and was recently covered by Blau (2004; Blau & Sterenberg 2015). *Forensic osteology* is used here to mean the same thing as *forensic anthropology*.

Early Practitioners: The Anatomists

Practitioners of forensic anthropology in the six Australian states and territories were initially found in university departments of anatomy. In the state of New South Wales (NSW), for example, the coroner and the police always called on the services of the Professor of Anatomy at The University of Sydney to give advice on the identification of skeletonised remains. A famous example was the Pyjama Girl case. Found in 1934, a girl's body had been partially buried, charred, and dressed in yellow silk pyjamas and remained unidentified for 10 years (Coleman 1978). During that time her remains were examined in detail by Professor Arthur Burkitt, Challis Professor of Anatomy from 1925 to 1954. This examination included the description of some bones, X-rays, and also detailed anthropometric investigation of her facial features,

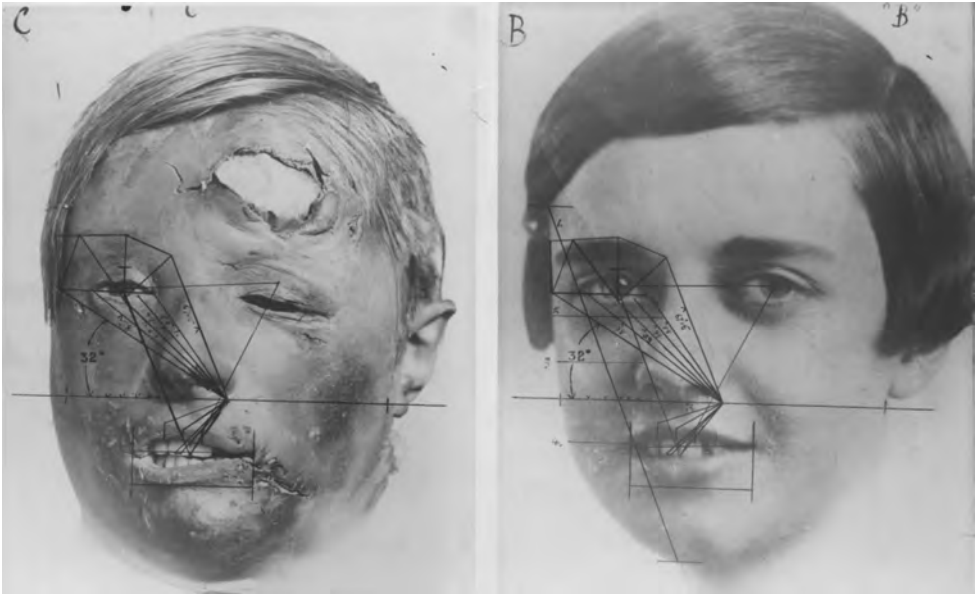


Figure 10.1 Early facial comparison by Professor A. Burkitt: the Pyjama Girl (*left*) and Philomena Morgan, a suspected victim (*right*) (photographs used with permission of the Shellshear Museum)

which were compared with those of suspected victims (Figure 10.1).¹ The Pyjama Girl was preserved in formalin and placed on display in The University of Sydney's Department of Anatomy museum in an attempt to identify her. In 1944 the Pyjama Girl was formally identified using dental records as Linda Agostini, and her husband was found guilty of manslaughter.

Probably the most outstanding pioneer in forensic anthropology in Australia was Neil Macintosh, Challis Professor of Anatomy at The University of Sydney from 1955 until 1973 (Figure 10.2). Macintosh had broad interests, which included general anatomy and the anthropology of the Australian Aborigines (Macintosh 1949, 1952, 1965; Larnach & Macintosh 1966, 1967). He was on good terms with Police Commissioners and heads of the Criminal Investigation Bureau (CIB) (of which he was an honorary consultant) in NSW from the 1950s through to the 1970s (Elkin 1978), providing them with advice on identification of skeletal remains as well as on methods of recovering remains from burials (N. W. G. Macintosh 1972). The police brought skeletal remains directly to the university, and pathologists from the Sydney City Morgue would ask for his advice on cases that were skeletonised or decomposed. Working alongside Macintosh during the 1960s and 1970s were Dr. Len Freedman (Senior Lecturer) and Mr. Stan Larnach (Curator of the Shellshear Museum). Their work involved the anatomy and anthropology of Aboriginal remains from the east coast of NSW (Freedman 1964; Larnach & Freedman 1964; Larnach & Macintosh 1966, 1967, 1970, 1971; Macintosh & Larnach 1973; Larnach 1974). Forensic anthropology consultation and research continues today at The University of Sydney by the author (a physical anthropologist) and students in the Shellshear Museum (Chiu & Donlon 2000; Croker & Donlon 2006; Robinson et al. 2006).

Practitioners such as Macintosh were in constant communication with international scholars working in the area of forensic anthropology. For example, Macintosh was particularly



Figure 10.2 Professor N. W. G. Macintosh, a pioneer in Australian forensic anthropology (photograph taken in 1955 and used with permission of Mrs. N. W. G. Macintosh)

friendly with American anthropologists T. D. (Dale) Stewart and W. W. (Bill) Howells. In 1972 T. D. Stewart was invited to Australia to participate in the Grafton Elliot Smith Centenary Celebration (Stewart 1974). At this conference a paper on forensic anthropology was given by Godfrey Oettle (a NSW forensic pathologist) and Stan Larnach (Oettle & Larnach 1974). This may have been the first conference paper given in Australia that refers directly to forensic anthropology. Stewart then travelled around Australia with the help of Macintosh, visiting the police in Canberra and in Adelaide (Macintosh 1972).

The 1960s and 1970s saw international visitors to Australia whose aim was to examine the Aboriginal collections and whose publications are now used in forensic anthropological work. The visiting anthropologists included Ales Hrdlička, Eugene Giles (Giles & Elliot 1962), William Howells (1973), and Michael Pietrusewsky (1990). However, their interests were not so much in forensic anthropology as in biological anthropology, human evolution, and dispersal. Macintosh, Larnach, and Freedman were motivated by Giles and Elliot's paper and Howells's work on racial identification to apply similar methods to the collection of Aboriginal remains, specifically those from the east coast of New South Wales (NSW) (Macintosh & Larnach 1973).

In these early days personnel in other Australian anatomy departments also gave opinions on cases involving skeletonised remains. There were those who took a particular interest in forensic anthropology (although it may not have been called that at the time). At The University of Queensland, Dr. Walter Wood (Senior Lecturer in Anatomy), acted as a consultant for the Queensland Government Forensic Pathology Unit assisting with the identification of unknown skeletonised human remains from 1972 until 2001. Wood analysed Aboriginal skeletal remains from the Broadbeach burial ground (Wood 1968, 1998; Smith, Brown, & Wood 1981) and was also involved with the identification of WWII Australian servicemen in Papua New Guinea while working there as a medical practitioner. In addition, he wrote a chapter on forensic osteology in a legal book concerned with the role of the expert witness (Wood 1993; Wood, Briggs, & Donlon 2002).

In Victoria medical practitioners involved in forensic anthropology include Dr. W. H. Mollison, who was the Coroner's Surgeon and Lecturer in Forensic Medicine and Anatomy at The

University of Melbourne from 1893 until 1943. In the 1930s Frederick Wood-Jones, Professor of Anatomy at The University of Melbourne, had a particular interest in skeletal remains. In 1945 Dr. Les Ray joined the Department of Anatomy at The University of Melbourne and also provided forensic advice to the police and Coroner (Ray 1959). From the mid-1970s until the early 1990s advice on forensic cases was provided very much on an ad hoc basis by such people as Dr. Geoff Kenny (Senior Lecturer in Anatomy and curator of the Anatomy Museum at The University of Melbourne), as well as Associate Professor Chris Briggs (Lecturer in Anatomy, The University of Melbourne). From 1995 until 2005 Briggs provided a 24 hour, on-call consultancy service until Dr. Soren Blau began in 2005 in a fulltime position at the Victorian Institute of Forensic Medicine, where her role is concerned with both domestic cases and disaster victim identification (Blau 2006). In the 2000s Dr. Catherine Bennett, a physical anthropologist in the Department of Epidemiology, also provided advice on the identification of Aboriginal and non-Aboriginal remains (Bennett 1995).

In South Australia much of the early skeletal identification was undertaken by Frederick Wood-Jones (1931) and A.A. Abbie (1976), Professors of Anatomy at The University of Adelaide and also physical anthropologists. More recently, Maciej Henneberg (Wood-Jones Professor of Anatomy and Physical Anthropology at The University of Adelaide) and Dr. Ellie Simpson (Forensic Science, SA) provided forensic anthropology services. Henneberg was involved in a number of criminal cases, including the high-profile Falconio murder case (*R. v. Murdoch* [2005]) and Snowtown murders (Stephan & Henneberg 2006). Similarly, Dr. Carl Stephan (Lecturer in Anatomy at The University of Queensland) was involved in cases of CCTV comparisons for the FBI, South Australian and NSW police. Stephan and Henneberg, along with others, have published extensively on facial approximation (Stephan & Henneberg 2001, 2004; Henneberg, Stephan, & Simpson 2003; Stephan, Henneberg, & Simpson 2003; Stephan et al. 2005a, b).

Before the 1980s the majority of work in Western Australia (WA) was performed by David Allbrook, Professor of Anatomy at The University of Western Australia (Allbrook 1961). Allbrook was followed by Dr. Len Freedman, who provided a free service to the Coroner, WA Police, and pathologists in the 1980s. In the early 1990s Freedman passed the responsibility for forensic and coronal work to his student, Dr. Alanah Buck, now the fulltime forensic anthropologist at the Department of Health's PathWest Centre (Buck et al. 2000).

In the Australian Commonwealth Territory (ACT) there was no medical school until very recently and relatively little demand for an anthropologist owing to the small population (approximately 300,000). Consultation on cases was done by the late Dr. Alan Thorne and Dr. Marc Oxenham, both of the Australian National University. In the smallest state, Tasmania, there has never been an in-house forensic anthropologist, probably because of the small population. Many of the cases in the Northern Territory involve the separation of ancient Aboriginal remains from recent Aboriginal and non-Aboriginal remains. In the 1970s Thorne identified Aboriginal remains from under the old casino in Darwin (Cantwell 2000). In the mid-2000s identification of Aboriginal remains was undertaken by Dr. Ken Mulvaney, an archaeologist with the Aboriginal Areas Protection Authority (Ken Mulvaney pers. comm. 2006).

Reasons for the Slow Development

The slow development of forensic anthropology in Australia is probably the result of a number of factors: the small population and low homicide rate in Australia, the nonrepatriation of the war dead, and a lack of population-specific skeletal collections, as well as difficult ethical issues involved in dealing with human remains.

Small Caseloads

As a result of the small population in Australia relatively few cases require a forensic anthropologist. The homicide rate in Australia is low compared with other countries, especially the United States (US). There are around 350 homicides per year in Australia with only 1 in 50 buried (Blau 2004). This means that for each state/territory (of which there are 6) there are about 50 homicides per year and roughly 1 buried body per state per year. In New South Wales, which has the greatest population, approximately 10 skeletonised human cases are examined by a forensic anthropologist each year (Donlon 2003).

The War Dead

Another factor in the slow development may relate to the Australian protocols for identification and burial of the war dead, which, until recently, meant that the identification and burial of any skeletonised remains were always made off-shore. Until the Vietnam War, all Australian servicemen and women were buried in the theatre of war in which they died. Thus approximately 102,239 Australians from World Wars I and II and the Korean War are buried, mainly in war graves, in Belgium, Crete, Egypt, France, Indonesia, Korea, Malaysia, Papua New Guinea, Thailand, Singapore, Solomon Islands, Turkey, and the United Kingdom (www.awm.gov.au/research/infosheets/war_casualties.asp). This situation is quite different from that of the United States, where the mission was, and continues to be, to repatriate all the war dead to the United States (Holland, Byrd, & Sava 2008). In the United States, unlike in Australia, the skeletonised remains are examined by physical anthropologists for the purpose of identification, but, in addition, much research has been carried out on those remains since they are of known age, ancestry, sex, and stature, thus providing an excellent source of data for forensic research (for example, McKern & Stewart 1957; Trotter & Gleser 1958). Although the protocols for identification and burial of the war dead have changed in Australia (see Cox, Loe, & Jones, Chapter 39 this volume), there have not been (and will probably never be) the numbers of skeletal remains examined to allow for the generation of large databases.

The Importance of Skeletal Collections and Ethical Issues

As pointed out by Walker (2000), dealing with human remains often involves a conflict among beliefs, usually religious, over the proper treatment of the dead and the value that scientists place on the data that might be collected from human remains. Such conflicts have arisen in Australia with the collection and use of Aboriginal skeletal remains for research, as well as, more recently, with coroner's cases.

In Australia there is an almost total lack of collections of Australians of European and Asian origin—the two major population groups in Australia. Thus practitioners must rely on research done in the United States or Europe, which is not always relevant to the extremely heterogenous Australian population. Although there are still large collections of Aboriginal skeletal remains in Australia, accessing them for research is problematic (Donlon 1994), and most institutions are in the process of repatriating ancestral remains. Australian anthropologists have utilised research undertaken on collections in Australia and Europe. Focus, however, has been on collections from the United States, because they include large collections of Caucasoids (for example, Terry collection in Washington, D.C., 108 Part One: History of the Disciplines and Hamann-Todd collection at the Cleveland Museum of Natural History) (İşcan 1988).

Of significant importance to forensic anthropology has been the research done on Australian Aboriginal collections. These collections resulted mainly from the discovery of remains by members of the public but also by archaeological excavation. Those reported to the police initially became forensic cases and then later were sent to state museums with smaller collections being housed in universities. Such collections were investigated by various anthropologists and anatomists for their doctoral research² and specific research papers (for example, early researchers/anatomists mentioned here and some relevant to forensic anthropology).³

At the same time as interest was growing in forensic anthropology in the 1980s and 1990s Aboriginal skeletal remains, which had typically been the source of much research, were becoming increasingly unavailable. This situation was a result of efforts by Aboriginal communities to have remains repatriated to the appropriate communities (Donlon 1994). State museums and universities around Australia drew up policies for the management of Aboriginal remains held in these institutions. All these policies restricted access to remains for research. More recently, research in physical anthropology that is useful for forensic work has moved toward using published data (Wright 1992; Pardoe 1999). Particularly useful publications around this time were manuals written for the identification of Aboriginal versus non-Aboriginal remains (Thorne & Ross 1986; Hope & Littleton 1995).

Professional associations such as the Australian Archaeological Association (AAA) and the Australian and New Zealand Forensic Science Society (ANZFSS) have codes of ethics for use by researchers. The AAA's code of ethics deals specifically with Aboriginal remains. It states: "Members acknowledge the special importance to Indigenous peoples of ancestral remains and objects and sites associate with such remains. Members will treat such remains with respect" (www.australianarchaeologicalassociation.com.au/about/code-of-ethics/). In addition, those wishing to do research using Aboriginal skeletal remains today must request permission from the appropriate local Aboriginal community. The code of ethics for the ANZFSS is concerned with the provision of evidence by expert witnesses (www.anzfs.org/code-of-professional-practice/). The Heritage Office of NSW also has ethical and legal guidelines on the management of human remains (Bickford, Donlon, & Lavelle 1998, 1999). In Australia all those wishing to do research into human remains must submit their proposals to the ethics committees of their institutions.

The preceding examples illustrate that the use of skeletal collections, both Aboriginal and non-Aboriginal, is highly regulated, and the collections are somewhat difficult to access for the purposes of research in forensic anthropology. The legislation associated with the excavation and exhumation of human remains in Australia is summarised in Donlon and Littleton (2011) and Blau and Sterenberg (2015).

Today: Education, Professional Organisations, Employment, Disaster Victim Identification, and Court Work

The 1990s saw acceleration in the growth of forensic anthropology in Australia. This was probably due to five factors:

- 1 the growth of courses/training in forensic science, more than likely related to the enormous interest generated by the media;
- 2 an increase in the number of forensic anthropologists participating in conferences;
- 3 employment of anthropologists in forensic institutions;
- 4 an increase in terrorist activities, especially in the Asia-Pacific region (for example, the Bali bombings; see Buck & Briggs, Chapter 35 this volume);

- 5 the use of anthropologists and archaeologists as expert witnesses in court (Briggs & Donlon 2014; see Henneberg, Chapter 43 this volume).

1. *Education in Forensic Anthropology and Archaeology*

Forensic science courses proliferated in Australia in the 1990s and 2000s. The first university undergraduate science anatomy program for students majoring in forensic osteology was offered at The University of Queensland from 1990–2001. Today courses in forensic anthropology and/or osteology are offered in many states in Australia.

2. *Professional Organisations and Conferences*

Since the late 1990s the number of forensic anthropologists presenting at conferences of forensic associations has risen, possibly because of the increase in the number of those becoming qualified in the discipline. There are a number of professional organisations that support the discipline:

- *The Australian Academy of Forensic Science (AAFS)*. This association had its foundational meeting in Sydney in 1967. The academy initially included lawyers, medical practitioners, scientists, sociologists, police officers, and government officials. Foundation members included N. W. G. Macintosh (Professor of Anatomy, University of Sydney), who was a member of the AAFS Council and the Executive and Editorial Committees from 1967 until 1973. The academy publishes a journal entitled *Australian Forensic Science*.
- *The Australian and New Zealand Forensic Science Society (ANZFSS)*. The ANZFSS was formed in 1971 with the aim of bringing together scientists, police, criminalists, pathologists, and members of the legal profession actively involved with the forensic sciences. The Society's objectives are to enhance the quality of forensic science, providing formal and informal lectures, discussions, and demonstrations encompassing the various disciplines within the science (www.anzfss.org.au/history.htm). The introduction of the Registered Forensic Practitioner Scheme was approved at the ANZFSS Annual General Meeting in 1998 but was put on hold owing to the lack of applications. Every two years the association holds an international symposium. The first symposium to include a session on forensic anthropology was held in Sydney in 1996 with American anthropologists William Bass and Diane France invited as keynote speakers. All symposia since (except for 2002 in Canberra) have held an anthropology session.
- *The Australasian Society for Human Biology (ASHB)*. The ASHB was formed in 1996 owing to the efforts of Charles Oxnard, then head of the School of Human Biology at The University of Western Australia. The majority of Australian biological anthropologists belong to this society. Nevertheless, it is a very small society of a few hundred members, and it is only in the last nine to ten years that forensic sessions were included in their conferences.
- *The National Institute of Forensic Science (NIFS)*. NIFS is now part of the Australian and New Zealand Policing Advising Agency (ANZPAA). In 1973 a Committee of Enquiry was established by the Attorney General Senator the Honourable Lionel Murphy to investigate the need for a national forensic institution (Davey 2002). This committee laid the foundations for the NIFS, which had its first formal meeting in 1991. The NIFS has provided a small amount of funding for individuals and training in forensic anthropology and archaeology.

Forensic anthropology was a latecomer to participating in conferences of the associations mentioned here. With no specific forensic anthropology (or even physical anthropology) association, forensic anthropologists tend to spread themselves rather thinly among these associations.

3. *Employment of Forensic Anthropologists*

This section examines the recent inclusion of anthropologists and/or archaeologists in forensic institutions. It also updates and extends developments in forensic archaeology since Blau's 1994 article.

Today forensic anthropologists are employed in forensic institutions/mortuaries in most states' capital cities. In New South Wales Dr. Denise Donlon (the author of this chapter) has been employed as consultant in forensic anthropology to the NSW Department of Forensic Medicine in Sydney since 1995. Her work includes casework involving identification, recovery and excavation, court work, and training (Donlon 2003, 2008). In Victoria Dr. Soren Blau is employed as the first full-time forensic anthropologist, where she has worked since 2005 at the Victorian Institute of Forensic Medicine (VIFM) in the Human Identification Services. Her work includes domestic casework, evidence presentation in court, and overseas training programs in Disaster Victim Identification (DVI). Since 2002 Dr. Ellie Simpson has been employed at Forensic Science South Australia, where her position involves casework as well as limited radiography and also case managements for autopsies (Simpson & Henneberg 2002; Simpson 2005). In Western Australia Dr. Alanah Buck works in the forensic pathology department at PathWest. This position was initially part-time (1995), but it was later converted to full-time (2002). Buck's responsibilities include casework, evidence presentation before the Supreme Court, and an expanding role in the training of law enforcement officers. This increase in duties illustrates how the role of the anthropologist has broadened in WA. In Queensland today most of the search, recovery, and analysis of remains is done by Dr. Donna MacGregor, a police officer with a background in archaeology and anthropology (MacGregor, Wood, & Brecknell 1996), and Ms. Debra Whelan at the John Tonge Centre in Brisbane. In Tasmania Dr. Anne-Marie Williams, who works for the Department of Health and Human Services reporting to the Director, Statewide Forensic Medical Services, began part-time work in 2007 (formalised in 2009).

All the employed forensic anthropologists mentioned here are women. What could be the reason for the dominance of women in this field? Possibilities include a female bias toward studies in biological sciences and areas of social justice. It may also be that men are looking elsewhere in forensic science, perhaps to better paid and more full-time jobs. It is possible that forensic anthropology, as with some areas of archaeology, is seen as lab-based rather than field-based work and therefore "women's work" (Phillips 1998). A more positive view is that it reflects a lack of discrimination toward women working in science generally, particularly outside universities.

In 2000 the Australian Defence Forces recruited a forensic anthropologist into the Royal Australian Air Force Specialist Reserves. The role of the anthropologist is to assist with the recovery and examination of remains of servicemen and -women killed in previous wars, especially WWII in Papua New Guinea (Donlon, Duffou, & Griffiths 2000) and the sinking of the HMAS *Sydney* near Christmas Island in 1941 (Donlon 2006a), as well as those from more recent incidents, such as the crash of the Sea King helicopter on Nias Island, Indonesia, in 2005 (Donlon 2006b).

In forensic archaeology it appears that the police and other authorities are increasingly using archaeologists for excavation but not necessarily for searching for graves (Blau & Sterenberg 2015). Police first used archaeologists in the excavation of graves in 1988 (McDonald & Ross 1990). Since then they have occasionally used archaeologists in the search for clandestine graves,

such as that of Samantha Knight (McDonald 1999).⁴ The NSW Coroner has also requested the assistance of archaeologists in the exhumations of Sally-Ann Huckstepp and various Aboriginal deaths in custody.

Many Australian practitioners have contributed their forensic anthropological and archaeological skills in international contexts. In 1990–1991 Richard Wright (Emeritus Professor of Anthropology, The University of Sydney) worked for the Attorney General's Special Investigations Unit, in charge of the discovery and excavation of three graves in Ukraine dating from 1942 and relating to the Holocaust (Wright 1996). From 1997 to 2000 he was contracted by International Criminal Tribunal for the Former Yugoslavia (ICTY) as Chief Archaeologist. His team exhumed some 1,600 bodies from approximately 80 graves at 15 sites and also located another 21 mass graves (Wright, Hanson, & Sterenberg 2005). Australian anthropologist Dr. Carl Stephan worked for over four years at the Central Identification Laboratory in Hawaii. Dr. Stephan and archaeologist Dr. Tim Anson assisted in the excavation and identification of remains for the Mass Graves Team in Iraq (Tim Anson pers. comm. 2006). The Australian Federal Police employ Katie Oakley, a forensic officer with a background in archaeology/anthropology, assisted in the exhumation of graves in the Solomon Islands as part of Regional Assistance Mission to the Solomon Islands (Oakley 2005; see Archer & Dodd, Chapter 33 this volume). Between 2009 and 2013 Dr. Soren Blau directed a project in East Timor involving the search and location of mass graves and exhumation and identification of individuals who disappeared during the 24-year Indonesian occupation (Blau & Fondebrider 2010). Dr. Blau has also worked as a forensic anthropologist for the Solomon Islands Truth and Reconciliation Commission and the International Criminal Court (Democratic Republic of Congo). The preceding cases illustrate that interest in the recovery of remains is increasing (Briggs & Wood 1998).

4. *Disaster Victim Identification*

Recently a number of terrorist acts and disasters occurred in the Australasian region. The associated Australian deaths resulted in the production of the Australasian Disaster Victim Identification (DVI) Procedures (Australasian Disaster Victim Identification Guide 2013) by a combination of Australian Government agencies. The resulting manual includes protocols for anthropologists participating in a specialist team in the field. Australian anthropologists have assisted in a number of DVI (see Buck & Briggs, Chapter 35 this volume; Blau & Briggs 2011).

5. *The Forensic Anthropologist and Archaeologist as Expert Witnesses*

In most cases of simple identification of ancestry, age, sex, and stature, the evidence of forensic anthropologists is accepted and rarely goes to court. Exceptions may occur when the remains are not complete, as in the case of *R. v. Keir* (*R. v. Keir* [2002]) and *R. v. Carter* 2000 (*R. v. Carter* [2000]).

Recent cases involving forensic anthropologists have comprised various methods of facial recognition identification. Such cases involved identification of refugees (*SHJB v. Minister for Immigration and Multicultural and Indigenous Affairs* [2003]) and alleged robbers (*R. v. Tang* [2004] NSWCCA, 24/5/06). These areas of identification are, however, very controversial and focus on the question of whether facial recognition, facial mapping, and body mapping constitute a field of “specialised knowledge” (*R. v. Tang* [2004] NSWCCA, May 24, 2006; *Murdoch v. The Queen* [2007] NTCCA, January 10, 2007; Stephan, Henneberg, & Simpson 2003; Stephan et al. 2005a, b; 2005b; Stephan & Henneberg 2001, 2006; Guyomarc'h & Stephan 2012; Stephan 2013, 2014a, b; Stephan, Simpson, & Byrd 2013; Stephan & Claes, Chapter 27 this volume).

The Future

Forensic anthropology in Australia has been retarded by the small amount of casework and the lack of skeletal collections representing the major population groups in the country. Some of these problems may be overcome by using data from new technologies such as imaging of the living and of cadavers (for example, Blau 2006; Lottering et al. 2011, 2014; Franklin et al. 2013). Other research will involve the collection of data, such as stature, from the living. Standardising the data collected from casework will allow for setting up a database of metric and nonmetric observations on Australian skeletal remains that will further assist with identification.

There will probably be an increase in funding for research into facial and body recognition to assist in the identification of possible terrorists. Notwithstanding these new developments, there will always be a need for experts in the identification of ancient Aboriginal remains in so that they may be eliminated from police enquiries. As for employment, it is likely that a small number of anthropologists and archaeologists will be taken into forensic institutions, the police forces, and possibly also into the Australian Defence Forces.

Australia does not have a professional society equivalent to the American Academy of Forensic Science, which accredits forensic scientists (see Ubelaker, Chapter 8 this volume). The ANZFSS has an accreditation scheme, but it is on hold because of the lack of applications during the early years. No doubt accreditation will eventually happen, but it may be slow in coming. In 2006 the executive of the Senior Managers of Australian and New Zealand Forensic Laboratories (SMANZFL) supported the formation of a Scientific Advisory Group (SAG) made up of forensic anthropologists, forensic odontologists, forensic entomologists, and mortuary managers. The formation of such an advisory group has significantly augmented the professionalism of forensic anthropology in Australia.

What of our future forensic anthropologists? There is a danger that, given the lack of skeletal collections in Australia and the tendency of students to take the “easy” path of a generalised forensic science degree, they will not have the depth of knowledge and experience needed, especially to act as experts. In spite of this problem, the current employment status of forensic anthropologists in institutions in all states bodes well. Forensic pathologists, coroners, and police will no doubt recognise the contributions that the forensic anthropologist can make to the identification of skeletal remains and increasingly to the identification of the living.

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Notes

- 1 The photograph of Macintosh was taken by his wife, and she has given me permission to include it. The photographs of the Pyjama Girl have appeared in the press, and her body was on display to the public. Photographs of her are also currently on display in the Justice and Police Museum in Sydney.
- 2 Rao 1966; Brown 1982; Pardoe 1984; Webb 1984; Collier 1990; Donlon 1990; Bennett 1995.
- 3 These include Wood 1920; Ray 1959; Davivongs 1963a, b; van Dongen 1963; Berry & Berry 1967; Kellock & Parsons 1970; Pietrusewsky 1990.
- 4 In August 1986, 9-year-old Samantha Knight disappeared from a Sydney suburb. It was not until August 2001 that Michael Guider (already in prison for pedophile offenses) was charged with Samantha's murder. In July 2003 Guider finally told police where he had buried Knight's body. Her remains, were, however, never located and are believed to have been disturbed during earlier building works.

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Historical Perspectives on Forensic Anthropology in Indonesia

Etty Indriati

This chapter first presents the current status of forensic anthropology practice and education in Indonesia and then discusses research and case applications that have contributed to the historical development of this field in Indonesia. These studies reveal low levels of sexual dimorphism in many traits and suggest that traditional methods used for estimating sex in biological anthropology may not apply to Indonesian skeletal remains. Training opportunities in forensic anthropology are outlined and various forensic anthropological cases in Indonesia are described in order to contribute to the body of knowledge of casework from different parts of the world. The role of forensic anthropology in disaster victim identification (DVI) is discussed in light of the numerous disasters that have affected Indonesia. The chapter also describes Indonesian laws affecting human identification and the necessary cooperation between forensic anthropology and forensic pathology, police, forensic odontology, and molecular biology. Finally, the future direction of forensic anthropology in Indonesia is considered.

Forensic Anthropology in Indonesia: Current Status

Although knowledge in forensic anthropology covers skeletal and dental anatomy and biological sciences in general, the application of forensic anthropology to casework requires the collaboration of law enforcement agencies, forensic dentists, and the local authorities where remains are discovered or exhumed. In Indonesia this complex relationship is often not supported by sufficient infrastructure, thus limiting the contributions forensic anthropology makes to investigation involving human remains. In 1984 Rathburn and Buikstra (1984: 5) stated that probably very few have heard of forensic physical anthropology. Although this might have been the case 30 years ago in the United States, today forensic anthropology is well recognized there. However, this is not the case in Indonesia. Forensic anthropologists are underutilized owing to a lack of structural organization and limited funding resources to facilitate having a forensic anthropologist work in the event of disaster, exhumation, or identification of unknown human remains. As a result, cases of skeletal remains in Indonesia may not be referred to a forensic anthropologist. When a forensic anthropologist provides assistance, the practitioner's professional work is not financially rewarded, and the travel to the area of disaster is not covered by any organization. Occasionally, forensic pathologists and police personnel consult forensic anthropologists in certain provinces in Indonesia where personal relationships have been built through working on various cases. Thus in Indonesia forensic anthropology is utilized when the contribution that

forensic anthropology can make to cases is understood by forensic pathologists, forensic dentists, and police.

Education

Two Indonesian universities offer introductory courses in forensic anthropology to students enrolled in medicine, biology, anthropology, and archaeology courses. In medical faculties forensic anthropology is taught in conjunction with subjects covering health and disaster. Courses in archaeology may include forensic anthropology within the context of excavation techniques of human skeletal remains. In biology and anthropology forensic anthropology is taught in conjunction with human variation and human evolution. With a small number of forensic anthropologists working in several universities in Indonesia, the development of this field is not optimal. However, forensic anthropology training and human identification workshops are occasionally delivered, especially in conjunction with training provided for mass disaster preparedness. Thus forensic anthropology in Indonesia has generally been viewed as assisting with the identification of human skeletal remains, a specific application that requires the teamwork of forensic pathologists, police, forensic odontologists, and molecular biologists. I occasionally examine trophy skulls from remote islands or naturally mummified remains that have emerged from a sandy beach and that turn out to be archaeological remains.

Although viewed as “bone experts,” consultant forensic anthropologists based at universities in Indonesia are not limited to skeletal identification. The forensic anthropologist may also provide opinions on a range of problems associated with identification. Thus forensic anthropology in Indonesia would probably be better defined broadly as human individuation utilizing biological anthropological traits in a medico-legal context.

Studies on Human Variation in Indonesia

Individuation can be conducted only when population traits are studied. Western literature has offered a large amount of data and methods for individuation (for example, sexing and aging) using reference data from populations far removed from Indonesia. As a result, Indonesian human skeletal remains do not always fit the standard criteria for sexing and aging provided in the Western literature. Based on my research, sexing os coxae, for instance, indicates that male and female Indonesians show a low degree of dimorphism (Indriati 2007). Indonesian female and male pelvises overlap in the width of the greater sciatic notch. This fact is inconsistent with standard Western literature, wherein males have been described as having wide and females as having narrow greater sciatic notch. The same situation is true for the subpubic angle: Indonesian male and female subpubic angles both tend to be wide, inconsistent with the narrow subpubic male and wide subpubic female in standard physical anthropological literature. As to the skull, Indonesians also tend to have less dimorphism in the morphology of the supra orbital ridge in that males do not always have a pronounced supraorbital ridge. Unlike the low degree of sexual dimorphism in the cranium and the pelvis, there is a higher degree of variation in Indonesian statures. Some villages in Central Java in the remote mountainous regions, for example, have populations with an average stature of 140 cm, whereas city dwellers have an average stature of 165 cm.

The diverse array of volcanic and vertical geography, genetics and nutritional intake might have contributed to the vast human variation. For example, a study of stature of Indonesian students in Yogyakarta in the 1990s showed that females were 7% shorter than males. This contrasts to studies of other human groups worldwide in which female stature is 3%–12% shorter than

that of a male (Nguyen 1981; Indriati 2002). The average stature of an Indonesian male student living in Yogyakarta was found to be 165.4 cm and that of a female 153.7 cm ($n = 253$). The sacral index (sacral width/length) in many human groups has been found to be sexually dimorphic (Table 11.1). In comparison, however, the sacral indices in Indonesians are relatively high, reaching 105.6 cm (males) and 108.7 cm (females) (Dewi, Indriati, & Suryadi 2003) and indicate a comparatively low sexual dimorphism of 2.8%. In addition, the superior inlet exhibits inconsistency of shape, which differs from that reported in Western literature, which portrays the male superior pelvic inlet as heart-shaped, whereas the female superior pelvic inlet is more rounded. Regardless of the sex of the individual, the transverse diameter is almost always comparatively larger than the anteroposterior diameter, which is in the category of the gynecoid typical of the female pelvis (Caldwell & Moloy 1933; Caldwell, Moloy, & D’Esopo 1934). Although the values sometimes overlap between male and female, the greater sciatic notch is a common skeletal trait for identifying sex using the pelvis, and its value is higher in the female, as reported by many practitioners. In Indonesian skeletal remains the greater sciatic notch averages 52° in males (however, many male greater sciatic notches are close to 60°) and 78° in females, with a range of 35°–67° in males and 70°–93° in females (Indriati 2007). Thus, based on Indriati’s 2007 study of Indonesian pelvic bones, one can possibly conclude that, in an Indonesian population, a greater sciatic notch greater or equal to 70° indicates a female and that less than 70° a male. This greater sciatic notch value is higher than the values documented by Buikstra and Mielke (1985) of approximately 30° and 60° in male and female, respectively.

A study of Indonesian facial and body shapes and sizes (Indriati 2004) showed no consistent correlation between facial shapes and body types among Javanese (later referred to as simply Indonesian) people. The facial shape is unique and varied: about 50% of faces are pentagonal both in males and females, followed by elliptic, oval, rhomboid, and round in decreased order of frequency (following the facial shape categories of İşcan 1993). However, some relationships occur between facial and body size; for instance, there is a positive correlation between facial height (crinion to menton) and stature, significant at 95% confidence statistically. This strong correlation can be used to construct formulae for facial height in facial reconstruction, using regression analysis (facial height = 0.068 [stature] + 7.687 + /– 3.801 cm).

Indriati’s study (2004b) on Indonesian faces applied regression analysis, which facilitated the development of various formulae to reconstruct facial soft tissue metrically (see also Stephan & Claes, Chapter 27 this volume):

A To reconstruct eyes:

- 1 biocular diameter = 7.23 + 0.83 (nose breadth) + 0.86 cm
- 2 interocular diameter = 1.43 + 0.57 (nose breadth) + 0.68 cm

Table 11.1 Sacral indices for males and females from different populations (after Wilder 1920 in Bass 1987)

Population	Male	Female	Sexual Dimorphism
Black	91.4	103.6	11.7%
Egyptian	94.3	99.1	4.8%
Andamanese	94.8	103.4	8.3%
Australians	100.2	110.0	8.9%
Japanese	100.5	107.1	5.2%
European	102.9	112.4	8.4%

B To reconstruct ears:

- 1 length of ear = $0.018 (\text{stature}) + 3.100 + /- 1.167 \text{ cm}$
- 2 ear breadth = $1.88 + 0.26 (\text{lip length}) + /- 0.43 \text{ cm}$

C To reconstruct lips:

- 1 lip length = $2.26 + 0.23 (\text{biocular diameter}) + 0.92 \text{ cm}$
- 2 lip to lip distance = $-0.12 + 0.33 (\text{menton subnasale length}) + 0.66 \text{ cm}$
- 3 philtrum length = $12.73 - 1.61 (\text{menton to subnasale length}) + 1.72 \text{ cm}$

D To reconstruct nose:

- 1 nose breadth = $1.50 + 0.22 (\text{binocular diameter}) + 0.94 \text{ cm}$
- 2 nasal root breadth = $0.44 + 0.23 (\text{lip length}) + 0.45 \text{ cm}$

Although it is impossible to predict the details of the eye, nose, ear, and lips from the skull, based on George's (1993) assessment it is possible to accurately position these features within and around their bony substrate. This positioning alone may be enough to create the approximation needed for recognition (George 1993). Further results of Indriati's (2004b) study of Indonesian faces noted that, seen laterally, most noses are elevated (in contrast to horizontal or prolapsed), with the tip of the nose higher than the base of alae nasi. This observation suggests that the shape and the direction of the nasal spine are elevated in the skull. The nasolabial groove tends to be concave among Javanese Indonesians. Most Indonesians have free lobule ears, their ear protrusion is strong, and the horizontal profile of the face is weak. When radiographs and photographs are superimposed, the useful anatomical landmarks are nasal aperture, orbital outlines, right and left gonion, as well as gnathion. Approximately 50% of Indonesian facial types are pentagonal, whereas Caucasian facial outlines are mostly oval, or longer superoinferiorly.

The right and left ectocanthion and labrale inferior form a facial triangle useful to start sketching facial reconstruction. The proportion of orbitonasal shows that the distance between endocanthion is about equal to the distance between alare (alae nasi). The vertical imaginary line cutting the medial iris is the same line of chelion (lateral lip), when pupils look directly forward. Most Indonesians are brachycephalic (short-headed). The distance between the eyes is equal to the width of the eye. In other words, the distance from right to left endocanthion equals that of the ectocanthion endocanthion. The important superimposition landmarks for facial photograph and radiograph superimposition are right and left gonion and gnathion to reconstruct the lower face; nasal aperture to reconstruct nasal breadth; gnathion to reconstruct the chin area; orbital bone outline to reconstruct endocanthion and exocanthion of the eyes; zygomatic arch to reconstruct the cheeks; and frontal sinus to reconstruct glabella and thus root of nasal; the second premolars are used to define the length of the lips.

Indriati's study (2004b) of Indonesian faces shows that roentgenographs can be superimposed with photographs in order to evaluate skull and facial structures, when their ratios are 1:1 and both images are taken using Frankfurt Horizontal Plane position. This conclusion suggests that, ideally, frontal cephalograms should be taken for identification purposes for each individual applying for a driver's license, passport, or any government-related identification card. Because the majority of Indonesians lack medical and dental records, such cephalograms should be nationally archived to preserve these data. Shape and volume of frontal sinuses are unique in each individual; thus having a frontal cephalogram would be useful for future needs of identification (Figure 11.1).



Figure 11.1 Frontal cephalograph of a 22-year-old Indonesian male shows deviation of nasal septi and different size and shape of right and left frontal sinuses useful for individuation.

Forensic Anthropological Cases in Indonesia

Indonesian law requires a police request for human skeletal remains to be examined. However, in the wake of a disaster, human identification can be done by health workers without a police request. This process follows the World Health Organization's doctrine of right to health care (1949) and the declaration of health for all (2000), which were adapted into Indonesian law as the Health Law Number 23 (1992, point 53) (Poernomo 2006). There is also a law regarding human identification in cases involving unnatural death, including homicide, suicide, accident, and disaster, when autopsies are conducted by a physician as required by law in the *Kitab Undang-Undang Hukum Pidana dan Kitab Undang-Undang Hukum Acara Pidana* (Book of Criminal Law), No. 2, 2002 (Poernomo 2006).

In Indonesia a request for a forensic anthropologist usually comes from a department of forensic medicine or directly from a police department. Human skeletal remains sporadically come into the hands of forensic anthropologists working in universities, which may be from archaeological contexts (for example, Indriati 2001a) or homicides.

Although traditionally forensic anthropology involves examining human skeletal remains in cases involving questions about identification, the application of forensic anthropology in Indonesia is not limited to this type of work. Seroanthropology using ABO blood groups and dermatoglyphy to determine paternity are also done within the domain of forensic anthropology. Forensic anthropologists may also be involved in the assessment of body parts; for instance, in a suicide bombing such as the Ritz Carlton Hotel bomb blast in Jakarta (Indriati 2014), it was shown that body fragmentation patterns were different for the suicide bomber (who usually carried the bomb on his or her body) and for the victims. The blast of the explosion disintegrates the torso and widely scatters the head and extremities of the bomber. In contrast, the fragmentation in victims is more random. Forensic facial identification using superimposition techniques

is also undertaken to match antemortem photographs and the (sometimes) disfigured head and face resulting from a suicide bombing.

The forensic anthropologist in Indonesia may also be requested to comment on the facial disguises such as fake mustaches, beards, and wigs captured on close circuit television. In such cases frontal and lateral photographs in Frankfurt horizontal plane must be taken, and attention should be drawn to morphological comparisons of eye slanting, nasal root flatness/protrusion, location of epicanthic fold (if any, whether it is medial, lateral), ear shape, and shape of the superior border of the lips. In addition, the distance between the eyes and overall shape of the head may aid identification in the presence of other facial disguises.

Other examples of skeletal remains that may be analyzed by forensic anthropologists in Indonesia, similar to other parts of the world, include decapitations, aborted fetuses, and archaeological or naturally mummified remains. Indriati (2003) describes a case of decapitation in which it was possible to match a body that was discovered in a city and a head that was discovered in another city a month later. Measurements of particular vertebrae (the seventh cervical—C7—and the first thoracic—T1) resulted in congruency of the head and the body, through less than 1 mm difference in measurements of C7–T1 in 5 variables (Indriati 2000). Despite vertebral congruency, supporting evidence that the remains of the head and the body belonged to the same individual included the age at death (approximately 11–13 years) based on unfused vertebral and humeral epiphyses. The dentition also supported this result. In addition, the estimated stature of this forensic case was 143.22 cm $\pm$ 4.25 cm, applying the formula of $(2.68 \text{ humeral length} \times 22.4 \text{ cm}) + 88.19$. This stature is within the range of 12–13.5 years old in human growth (Boyd 1980).

Fetal remains, typically those associated with abortions during late pregnancy, are not uncommon cases. In the analysis of fetal skeletal remains Fazekas and Kosa (1978) summarize several questions that need to be answered (Table 11.2). Indriati (1999) applied four formulae to identify fetal ages in forensic cases and showed that the best-fit formula for Indonesian fetal remains is the method proposed by Ohtsuki (1977) based on Japanese fetal remains. In the case from Kedu (discussed in the next section), the Ohtsuki method (1977) was the closest fit for the age determination (Indriati 1999), and other Indonesian cases involving the analysis of fetal remains have been consistently resolved using Ohtsuki's method.

The Kedu Case

I received decomposed remains in a bottle containing 200 cc of 10% formaldehyde from the Police Department of Kedu, Central Java. Examination yielded 72 pieces of bone from one individual. The apparent proportion of the cranial bones to the extremities and the unfused secondary ossification center were used to determine that the bones were human. Four different

Table 11.2 Questions to be considered when analyzing fetal skeletal remains (after Fazekas & Kosa 1978)

- 1 Are the bones human or animal?
- 2 If the bones proved to be of fetal origin, what is their lunar age? Do the maturity, body length, and age of the fetus correspond to the gestational age of the suspected human?
- 3 Could the fetus have been viable at birth, or was it born prematurely, in a nonviable state?
- 4 Could the fetus have originated from the suspected woman whose pregnancy was terminated in the incriminated way and time?
- 5 Did the investigation furnish data indicating the circumstances or the possible cause of death?
- 6 How much time may have elapsed between the interment of the fetus and its discovery?

methods were used to determine the age of the fetal remains. Mehta and Singh's method (1972) resulted in a fetal age of 6–6.5 months; the Ohtsuki method (1977) yielded an age of 6.5–7 months, and Fazekas and Kosa's method (1978) resulted in an age of 6–8 months. The Olivier and Pineau method (1957) yielded an age of 6.5–9.25 months. The postmortem interval might have been short, because soft tissue (including ligamentous attachments) and hair were present. After the written report was submitted, the police reported that the fetus had been removed from the abdomen of a decomposed pregnant woman in the autopsy room. The suspect's boyfriend confessed that the woman had been seven months pregnant and that they had gone to an unskilled abortionist, which led to the death of the girlfriend.

In addition to determining age using bone measurements in fetal remains, forensic anthropologists may also apply dental eruption schedules for age determination in children and adolescents. The decapitation case mentioned earlier had a dental eruption of almost all permanent teeth, except for the third molars, and his permanent canines were partially erupted. A study of permanent tooth eruption in Javanese children aged 12–13 years ($n = 175$) showed eruption of all permanent teeth except for the third molar; however, 25% of the children had partially erupted upper and lower canines (Indriati 2001b). An age range of 12–13 years was determined for the individual in the decapitated case based on an assessment of the fusion stages of the vertebral corpus and humeral head epiphyses. This result was in accordance with the dental eruption schedule of Javanese children aged 12–13 years.

Disaster Victim Identification in Indonesia and the Roles of Forensic Anthropology

Only a handful of forensic anthropologists practice in Indonesia, and they work mostly in universities. This situation is unfortunate, since natural and human-made disasters requiring human identification frequently occur in Indonesia (Table 11.3). Earthquakes are common in Indonesia because of its geographic location at the juncture of four active tectonic plates and its position in the Eurasian Circumpacific ring of fire, where hundreds of active volcanoes provide a constant threat of possible eruption. The large and dense nature of Indonesia's population increases the probability of large numbers of deaths in the wake of any earthquake, flood, volcanic eruption, or tsunami. Examples of recent disasters that have severely affected Indonesia include the earthquake in Yogyakarta and Klaten, which rated nearly 6.2 on the Richter scale and resulted in about 6,000 deaths on May 27, 2006. Also in 2006, an eruption of hot mud in Sidoarjo, eastern Java, associated with fuel-mining activities by the Lapindo Brantas Company, resulted in more than 5,000 people becoming homeless, because houses and agricultural fields were completely covered by hot mud. Toward the end of 2006 two significant accidents occurred: an Adam's airplane crashed near Kalimantan, killing nearly 100 people, and a boat sank off near Banjarnegara, killing more than 400 people. In February 2007 more than five days of floods in Jakarta caused the evacuation of over 156,000 families from their homes, and communal diseases such as diarrhea and skin irritations spread quickly. Also in the month of February a twister hit Lempuyangan, Yogyakarta, and caused damage to houses and facilities within a heavily populated area. In addition to natural disasters, human-made disasters such as bombings and riots have occurred (Table 11.3).

The role of forensic anthropology in identifying victims of disasters is not always well understood in Indonesia. In some cases forensic anthropologists may not be consulted at all, because most disaster victims are not skeletonized, and many people continue to assume that forensic anthropologists deal only with human skeletal remains. However, a recent disaster involving a plane crash that resulted in burnt soft tissue with exposure of the bones highlighted the important role of forensic anthropology for assistance in individuation. On March 7, 2007, a Boeing

Table 11.3 Disasters in Indonesia 1980–2014 (adapted and modified from Umar 2006)

No.	Disaster	Year
1	Mount Galunggung	1980
2	Food poisoning, west Jakarta	1981
3	Harbor fire, Tanjung Priok, Jakarta	1981
4	Gas leak, Tanjung Priok, Jakarta	1982
5	Earthquake, west Java	1983
6	Hotel fire, Jakarta	1985
7	Plane crash, Krawang, west Java	1985
8	Toll road crash	1985
9	Flood, Atma Jaya hospital, Jakarta	1986
10	Explosion, Fatmawati hospital, Jakarta	1987
11	Train crash, Bintaro, Jakarta	1987
12	Tanjung Priok riots, isolation in Koja hospital, Jakarta	1987
13	Food poisoning, Jakarta's factory	1988
14	Earthquake, Flores	1991
15	Riots, Jakarta	1992
16	Flood, Jakarta	1991–1992
17	Tsunami, Lombok	1993
18	Earthquake, Liwa	1993
19	Mount Merapi eruption, Yogyakarta	1995
20	Earthquake, Kerinci	1995
21	Riots, PDIP political party, Jakarta	1996
22	Earthquake and Tsunami, Biak	1997
23	Earthquake, south Sulawesi	1997
24	Ethnic Riots, Pontianak	1997
25	Earthquake, Bengkulu	1997
26	Ethnic riots, Sampit	2001
27	Displaced persons in Madura, Poso, west and east Nusa Tenggara, Papua, west Java, central Java, Maluku, north Sulawesi	2001
28	Drought, Sampang, Kalimantan/Borneo	2001
29	Mount Papandayan eruption	2002
30	Bomb in Bali I	2002
31	Bomb at the JW Marriott Hotel Jakarta	2003
32	Bomb at the JW Marriott and Ritz Carlton Hotel Jakarta	2009
33	Bomb in front of Australian Embassy, Jakarta	2004
34	Tsunami in Aceh	2004
35	Airplane crash, Lion Air in Surakarta	2004
36	Bomb in Bali II	2005
37	Airplane crash, Mandala Boeing 737-200 A, Medan	2005
38	Bomb Bali II	2005
39	Earthquake in Nias	2005
40	Earthquake in Yogyakarta and surrounding	2006
41	Earthquake in Pangandaran	2006
42	Accident of Senopati Boat in Java Sea Masalembu	2006
43	Airplane crash, Adam Air Makassar Strait	2007
44	Airplane crash, Garuda	2007
45	Bomb at the Ritz Carlton and JW Marriott Hotels, Jakarta	2009
46	Earthquake, Padang Sumatra	2009

(Continued)

Table 11.3 (Continued)

No.	Disaster	Year
47	Airplane crash, Merpati, Jayapura	2009
48	Airplane crash, Hercules C-130 Alpha1324 East Java	2009
49	Train crash ArgoBromo vs. SenjaUtama in Pemalang	2010
50	Merapi volcanic eruption in Yogyakarta	2010
51	Airplane crash Merpati in Jayapura	2011
52	Airplane crash Merpati in Kaimana Papua	2011
53	Airplane crash Sukhoi Superjet 100, Bogor	2012
54	Immigrant boat drowning in Cianjur	2013

737-400 approached Yogyakarta airport too fast for landing and ignited, causing the death of 21 individuals—16 Indonesians and 5 Australians.

I separated 5 Caucasians from the 16 Mongoloid remains through assessment of skull and dental characteristics and further narrowed down the remains into 2 female and 3 male Caucasians and 6 female and 10 male Mongoloids. The assessment of ancestry and sex narrowed down the comparison between post- and antemortem data in the reconciliation. Positive identifications were undertaken using dental and medical records. All Mongoloid (Indonesian) remains were identified and released to the families the day after the disaster. The remains of the 5 Caucasians (2 females and 3 males) were positively identified on the third day post-disaster following the delivery of antemortem data provided by the Australian authorities.

Following the 2004 Boxing Day tsunami some victims (such as tourists in Thailand) could be identified, because their medical and dental records could be retrieved from their home countries. However, in many other countries affected by this tsunami positive identification was not possible (for example, Aceh; see Black, Chapter 34 this volume). In addition to few people having medical or dental records in Aceh, 75% of the region was damaged, and the majority (140,000 or 75%) of the population died as a result of the event. This vast scale of damage highlights the effects of not having medical records preserved locally. Clearly there is more work to be done in enhancing the roles of forensic anthropologists in Indonesia in disaster victim identification and in other areas where identification is required. There is also a need to address concerns regarding appropriate infrastructure and funding. Emergency financial support during the acute phase may be drawn from regional governments at the province level, central government, national police and health department, and later on from various other resources.

Forensic Anthropology in Indonesia: Future Directions

Although there are only a handful of forensic anthropologists available in Indonesia, a wide range of identification cases not limited to skeletal remains have been conducted. Sporadic interest from students to pursue forensic anthropology as a career and the unavailability of positions after graduation makes the development of forensic anthropology in Indonesia a difficult task. Team work and close collaboration among academics, physicians, police, and health personnel are necessary to carry out human identification following death resulting from crimes and/or disasters. Although efforts in that direction have begun to emerge through various DVI workshops and seminars, no formal infrastructure and organizational networking with administrative and funding support from the government have been developed. The formation of the national

DVI team needs to be followed up with adequate recruitment of forensic anthropologists, forensic odontologists, molecular biologists, and forensic pathologists in each region. Adequate funding from an established source should be available for operational costs ideally supported by local and central governments for handling work in human identification.

Although Reichs (1986) defines *forensic anthropology* as the identification of human skeletal remains within a legal context, forensic anthropology should not limit its identification scope merely to skeletal remains, since various identification modes emerge through cases such as paternity, facial matches of old and new photographs, facial disguise, CCTV whole-body outline, and body fragmentation in suicide bombings. For this reason the definition of forensic anthropology should be placed in a broader context, such as human identification and individuation in medico-legal situations utilizing biological traits that are not restricted to human remains or human skeletal remains. Because identification cases in Indonesia are sporadic and there are few practitioners, at present there appears to be no need for the Indonesian forensic anthropology practitioner to be certified. Ideally, forensic anthropologists, forensic pathologists, and forensic odontologists as well as molecular biologists, law enforcement agencies, and local governments should work hand in hand. Such collaboration would allow authorities to see improved results in human identification in both domestic and disaster situations.

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Note

- 1 Bass 1987; Buikstra & Mielke 1985; Buikstra & Ubelaker 1994; Indriati 2004a; Krogman 1962; Krogman & İşcan 1986; Phenice 1969; Ubelaker 1991.

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Forensic Anthropology as Practiced in South Africa

Maryna Steyn, Ericka N. L'Abbé, and Jolandie Myburgh

In South Africa nonnatural causes of death accounted for 10.3% of all deaths in 2013 ($n = 458,933$) (Statistics South Africa 2014). These deaths were due to “external causes of accidental injury” (56.4%), followed by “events of undetermined intent” (16%), transport accidents (12.1%), and assault (10.6%). Norman and associates (2007) reported that in 2000 the leading causes of death by injury were homicide (46%), motor vehicle accidents (27%), suicide (9%), and fire (7%) and that deaths associated with homicide contributed 65 per 100,000 each year, which is one of the highest rates in the world. Therefore the reputation of South Africa as a violent country, with gross socioeconomic inequalities from both past and present political circumstances, is not without reason (Reza, Mercy, & Krug 2001; Norman et al. 2007; L'Abbé & Steyn 2012).

While health and life expectancy has improved in many areas of the country within the last 20 years (that is, since the late 1990s), numerous problems continue to exist, including extreme poverty, lack of access to basic resources such as education and health care, HIV transmission, tuberculosis, malnutrition, unemployment, substance abuse, social inequalities, an influx of migration from other African countries, and political corruption (Mayosi et al. 2012). These problems have led to an outpouring of frustration via interpersonal violence and crime, along with social and physical abuse of the country's most poor and destitute. As one might expect, the country's social problems are also reflected within the large number of unidentified remains in various mortuaries around the country, as has also been discussed in some detail in L'Abbé and Steyn (2012) and Bernitz and associates (2015). The types of cases that forensic practitioners receive from mortuaries around the country has had a significant effect on the focus of research undertaken at different universities across South Africa.

Every year, in Gauteng Province (the largest province located in the north of the country) alone, approximately 5,000 unidentified bodies are cremated, many of whom may be rural migrant labourers from other provinces and/or illegal immigrants. Because many rural migrants are unlikely to access dental care or to return to a hospital for follow-up treatment, the task of identifying an unknown person discovered in large and vastly undeveloped areas known as the veldt in Gauteng is difficult and, at times, impossible. The current situation of unidentified persons in urban areas requires research into human variation of South African groups, with the intention of creating accurate and reliable osteobiographic profiles from skeletal remains. A biological profile is important in supporting a positive identification that may be provided by antemortem dental records, fingerprints, and DNA and is often the point of departure for the investigation (Steyn, Meiring, & Nienaber 1997; L'Abbé & Steyn 2012; Bernitz et al. 2015).

This chapter provides an overview of 18 years of casework undertaken in the Forensic Anthropology Research Centre at the University of Pretoria. This overview offers a mere glimpse into the current situation of unidentified remains in the country and highlights the need for continual research in forensic anthropology in sub-Saharan Africa. A brief overview of research in the country is also provided.

Forensic Anthropologists in South Africa

South Africa has a long history of physical anthropology wherein prominent scientists such as R. A. Dart, R. Broom, P.V. Tobias, and H. De Villiers, among others, made invaluable contributions to the discipline. In South Africa physical anthropology is taught and researched in medical schools, making it different from how it is taught in North America and more similar to the academic environment in Europe. The advantage of the system is that students obtain a strong foundation in anatomy and the biological sciences, but a disadvantage is the limited background that students receive in anthropological theory and, at some institutions, an absence of archaeological methodology.

Within the last few years a number of centres have opened in the country specialising specifically in Forensic Anthropology—namely, the Forensic Anthropology Research Centre (FARC) at the University of Pretoria (established in 2008), as well as units at the Universities of Cape Town (since 2010) and the Witwatersrand (since 2013). Training in the biomedical sciences, with the possibility of completing postgraduate degrees, is offered at these and other universities. However, no clear guidelines are currently available as to who can call themselves a “forensic anthropologist” or what the minimum requirements are for being considered a professional. No mechanisms in quality control for forensic anthropologists exist, and no specific accreditation is required for practice. In the establishment of the Forensic Anthropology Interest Group as part of the Anatomical Society of Southern Africa (ASSA) in 2013 an attempt was made to address this issue, but as of yet no clear guidelines have been forthcoming.

Forensic Anthropology Cases at FARC

Since 1996 the University of Pretoria has developed a strong research team with an established track record in forensic anthropology. The Forensic Anthropology Research Centre (FARC), based at the University of Pretoria, is currently the largest and most active unit involved in forensic anthropological case work in South Africa.

The large numbers of unidentified remains, particularly in Gauteng, provide excellent opportunities for national and international postgraduate students to obtain experience in advanced osteological skills, forensic anthropological casework, and research. However, all work on skeletal material is strictly preempted with the aim of improving education, presumptive identifications, bone trauma analysis, and anthropological skills in the country.

Research aims, styles, and detail of case reports, and ultimate goals for the expansion of forensic anthropology, vary among unit and regions throughout the country. The following summary is an overview of the types of cases received at FARC within the last two decades, with a greater emphasis on the last 10 years.

From 1996 to 2013 a total of 768 individuals were analysed. Within the last decade cases averaged between 30 and 90 per year, with a steady increase in the last few years (Figure 12.1). An increase in cases is associated with concerted efforts by the South African Police Service, in particular the Victim Identification Centre (VIC), to attempt to increase identifications and improve standards of collection and DNA analysis for the masses of unidentified bodies within

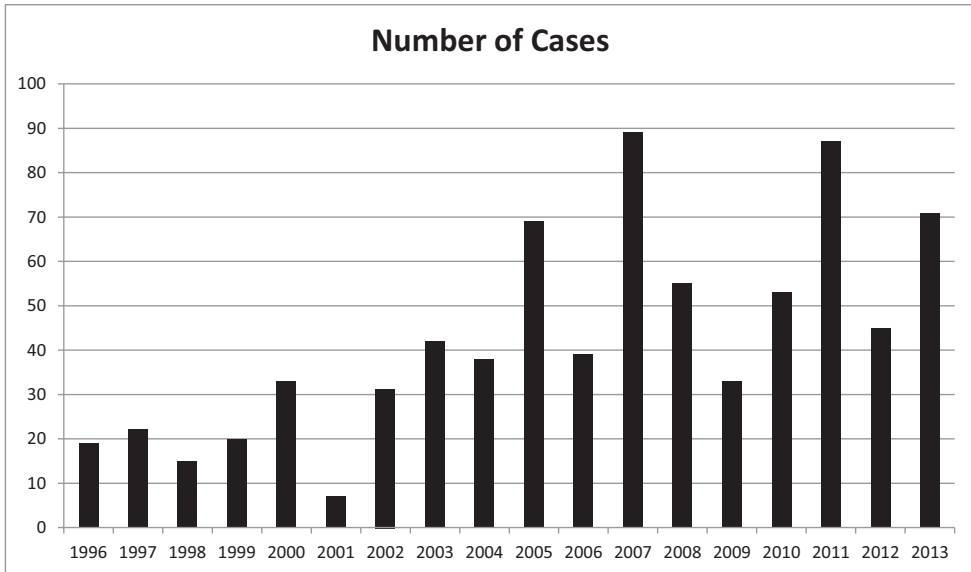


Figure 12.1 Number of cases seen at FARC from 1996–2013

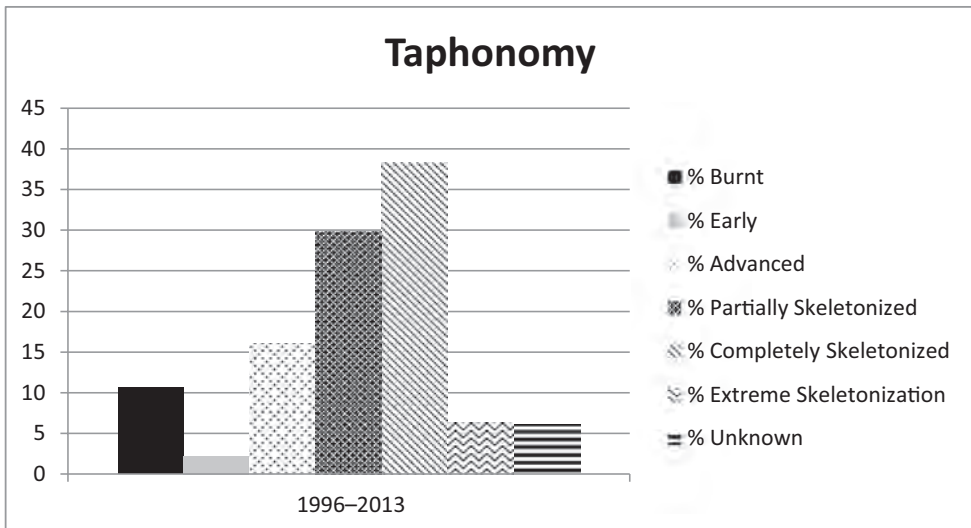


Figure 12.2 State of decomposition of remains received

the province. However, when a person is identified, feedback to the anthropologist is either slow or non-existent. Few cases go to court, and if they do most reports are accepted without cross-examination. It is thus very difficult to assess the success rate of identifications and the accuracy of the methods used.

Most cases are received in an advanced state of decomposition with little or no contextual information (Figure 12.2), because police officers typically recover the remains, and they rarely

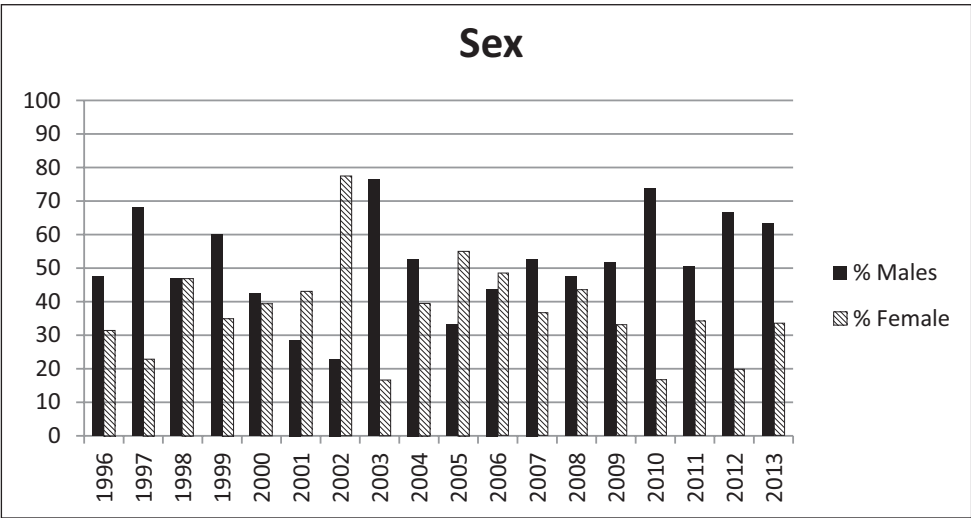


Figure 12.3 Estimation of the sex of cases (1996–2013)

adhere to forensic archaeological principles when they are collecting skeletal remains from either graves or surface scatters. The majority of skeletal remains are estimated to be adults (86%) ($n=660$), of which most were males (406 males; 284 female; 79 unknown) (Figure 12.3). In 2001/2002 and 2005/2006 a greater number of estimated females than males were analysed on account of two serial murder cases involving more than 20 women from areas in Swaziland and Kwa-Zulu-Natal, respectively. Males (13.1%) are overall more often affected by nonnatural deaths than are females (4.3%) (Statistics South Africa 2010).

The South African veldt offers shelter to the destitute and cover for the disposal of a body. In later winter and early spring within the interior of the country, fires are common in the veldt, and burning of the grassy areas leads to the discovery of many skeletal remains. The situation is clearly reflected in the last 10 years (since 2006) of casework at FARC, with most cases being found in the veldt in an advanced state of decomposition or skeletonised with evidence of burning on dry skeletal elements (see Figures 12.2 and 12.4).

Transport accidents (including both motor vehicle and pedestrian) and assault are the leading causes of nonnatural deaths in South Africa. Therefore, evidence of bone trauma is frequently encountered on skeletal cases (Figure 12.5); yet limited investigation into many of the cases and a lack of contextual information about the discovery of the bodies hinders the interpretation of most bone trauma analyses. Many of the South African cases show evidence of excessive use of violence in the form of multiple impacts (Figure 12.6). All bone trauma analysis, particularly cases of multiple blows, are time consuming and may take a month or more to complete. However, the analyses can provide invaluable information should further investigation into the case be forthcoming.

Almost 50% of the cases ($n=358$) demonstrated bone trauma (see Figure 12.5), with the vast majority representing healed antemortem trauma. With regard to perimortem injuries, blunt force trauma is the most abundant (21%), followed by ballistic and sharp force injuries. Dismemberments are extremely rare, with only three cases received since 2013.

In many instances the cause of the trauma was unknown (7%)—possibly due to poor preservation, the inexperience of the observer, and/or the difficulty in distinguishing between

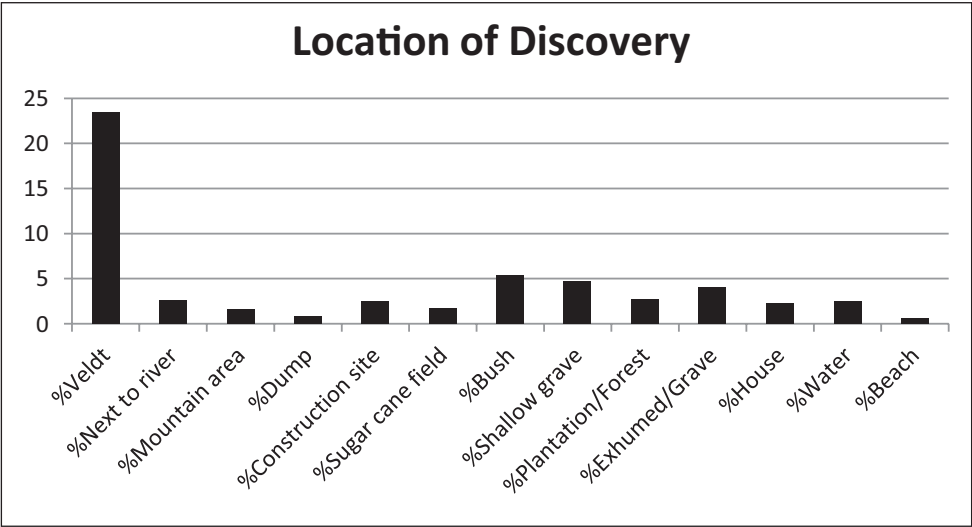


Figure 12.4 Location of discovery of remains

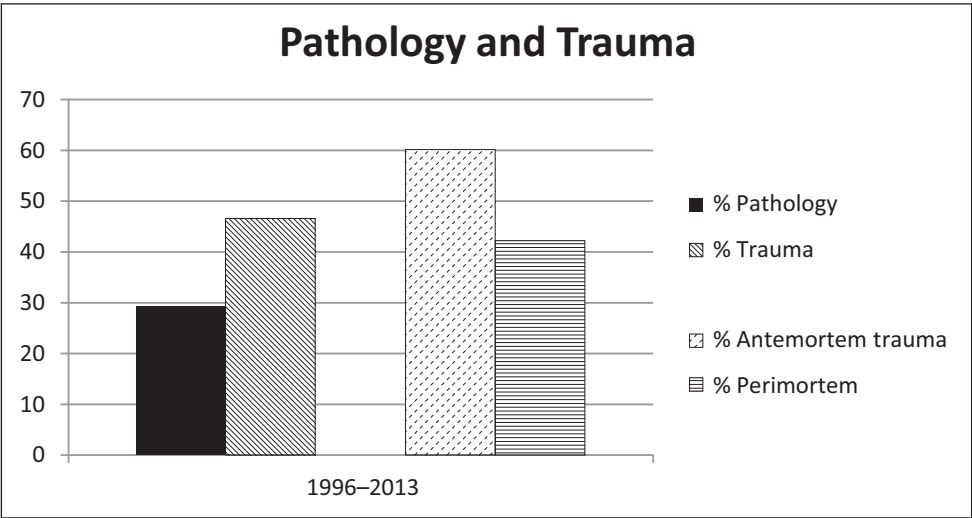


Figure 12.5 Trauma and pathology in received cases

peri- and postmortem fractures without contextual information about the body. Many cases ($\pm 30\%$) also present with signs of bone pathology (see Figure 12.5), suggesting a possibly high degree of untreated diseases or inadequate medical treatment within the community. Such signs indicate the importance of the investigator having skills in assessing skeletal pathology.

Since 2003, and within the guidelines of the National Health Act (Act 61, 2003), unidentified skeletal remains of approximately 440 individuals from cold cases have been accessioned into an evidentiary archival collection at the Department of Anatomy, University of Pretoria, for the purpose of medical and postgraduate education and research. Skeletons include various

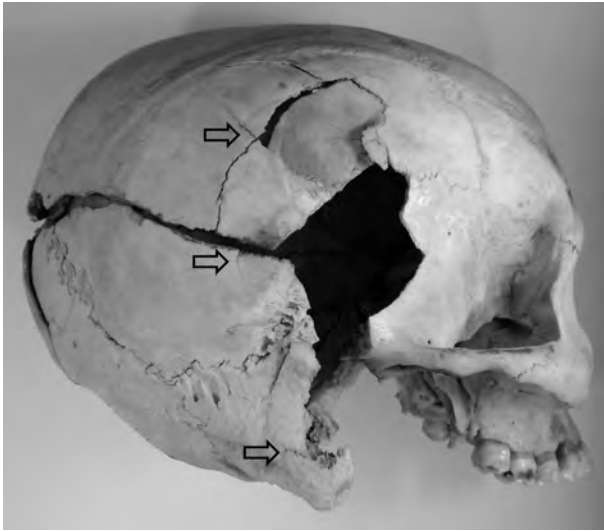


Figure 12.6 Case with multiple blunt force trauma-related impacts. Arrows indicate points of impact.

examples of ballistic trauma, postmortem burning, carnivore activity, blunt force trauma, and small-scaled commingling of remains.

Examples of Unique South African Cases

Many of the cases received for analysis have no signs of trauma or disease; however, in a number of cases interesting features were noted, some of which may be unique to the South African situation or may require specific skills from the anthropologist. For example, cases of *muti* (a word deriving from Zulu meaning “traditional medicine”) murders, in which a specifically selected individual is murdered and parts of the body are removed for medicinal/magical purposes, are sometimes seen. One such case has been reported on by Steyn (2005): a white, young adult male was abducted and killed, and his body parts harvested. Although worldwide the use of body parts for ritual purposes is not uncommon (for example, Wetti & Martinez 1981), this case was unusual in that skulls (of the aforementioned male and then also a skull possibly collected from a grave or skeletonised body) were used to construct ritual, highly decorated pots containing medicine, body parts, coins, and other objects.

As mentioned, many cases are received with evidence of disease, and one such case was reported as an individual possibly showing signs of Fetal Alcohol Syndrome (FAS), which is a major problem in many communities in South Africa. As the name suggests, FAS occurs when the fetus is exposed to excessive amounts of alcohol in utero (for example, Thackray & Tiff 2001). The expression of this condition may vary considerably among individuals, but is usually characterised by facial dysmorphology, pre- and postnatal growth deficiencies, and central nervous system dysfunction (Jones & Smith 1973). In this particular case the skeletonised remains of a 12–15-year-old individual showed a combination of delayed growth, craniofacial asymmetry with midfacial hypoplasia, abnormal head shape with small cranial capacity (Figure 12.7), spina bifida occulta, cribra orbitalia, and enamel hypoplasia. The individual was identified, and severe long-term parental alcohol abuse confirmed. A variety of developmental or congenital disorders should be considered in the differential diagnosis, among them FAS, although it is very difficult to diagnose this condition specifically. Details of this case are discussed in İşcan and Steyn (2013).



Figure 12.7 Anterior view of the skull of a young girl with craniofacial asymmetry and a hypoplastic midface possibly associated with a congenital disorder

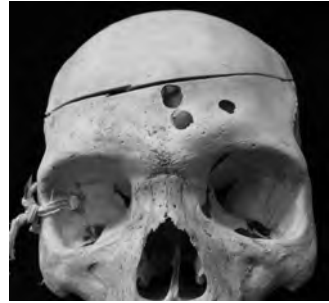


Figure 12.8 Taphonomic changes to the skull where lions were involved. The circular defects were probably caused by lion canines.

In two cases remains were received in which lions consumed the body and parts of the skeleton. In one case the individual worked on a game farm and was reportedly overwhelmed while feeding the lions in their enclosure. The skull of this individual had circular defects, presumably formed by the canines from the animal(s) (Figure 12.8). In the other case the body of the victim was thrown into an enclosure on a game farm where there were lions, and the remains were extensively damaged. In court there was a debate as to whether the victim was dead or alive when he was eaten by the lions, but this fact could of course not be established from the skeletal analysis. In this case, although the skull was completely defleshed by the animals, no carnivore bite marks were present on the cranial vault. Large bite marks were, however, evident on other bones (Figure 12.9).

Other frequently encountered features in cases include excessive blunt force trauma with multiple impacts as explained previously, fleshed and defleshed burning, child abuse, and carnivore damage. The high number of serial killings with multiple victims (mostly female) is also of particular concern.

Overview of Research Undertaken in South Africa

The presumptive identification of a person is based on the presence of biological features (human variation) and the relationship of these features to sociocultural identity; therefore, sex and ancestry estimations are important components of the osteobiographic profile and are a focus of research within FARC and also elsewhere in the country. With recent international developments and collaborations, a strong focus has also emerged on the evaluation of bone trauma (for example, Symes et al. 2012, 2014). Facial reconstruction, craniofacial superimposition, and photo-to-photo identification received less research attention, since the duties are handled within specialised units of the South African Police Service (SAPS).

Papers on sexual dimorphism from various researchers in the country include, for example, sexual dimorphism of the skull (De Villiers 1968; Steyn & İşcan 1998; Dayal, Spocter, & Bidmos

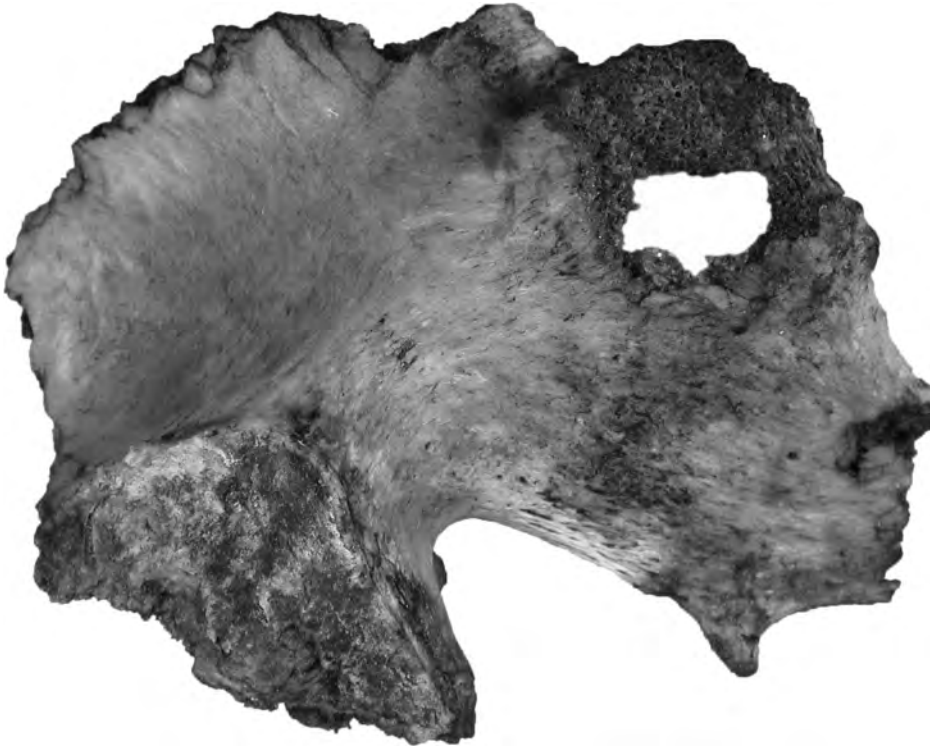


Figure 12.9 Large carnivore (lion) damage to the skeleton of a male individual

2008; Krüger et al. 2014), mandible (for instance, Loth & Henneberg 1996; Oettlé, Pretorius, & Steyn 2005; Franklin et al. 2006, 2007b; Oettlé et al. 2009), pelvis (such as Patriquin, Loth, & Steyn 2003; Patriquin, Steyn, & Loth 2005; Steyn & Patriquin 2009; Small, Brits, & Hemingway 2012), and long bones (Steyn & İscan 1997, 1999; Asala 2001, 2002; Asala, Bidmos, & Dayal 2004; Barrier & L'Abbé 2008; Krüger 2015). Data are also available for smaller and less dimorphic bones, such as the sternum (Macaluso 2010), patellae (Bidmos, Steinberg, & Kuykendall 2005; Dayal & Bidmos 2005), and calcaneus (Bidmos & Asala 2003, 2004). Whereas many of these papers focus on straightforward size and shape-based characteristics of the skeleton, aspects of sexual dimorphism have also been elucidated through the use of geometric morphometrics (for example, Pretorius, Steyn, & Scholtz 2006; Franklin et al. 2007b; Scholtz, Steyn, & Pretorius 2010; Vance & Steyn 2013). The effect of ageing on sexual dimorphism has also been addressed (Vance et al. 2010), and Stull, L'Abbé, and Ousley (2014) studied sexual dimorphism in the postcranial bones of juveniles.

Because white and black South Africans display lower sexual dimorphism than do their North American counterparts (L'Abbé et al. 2013), the creation of custom databases of cranial data from a South African group was warranted. With the use of the statistical software program *FORDISC3.0* (FD3) multivariate analyses were conducted on cranial data collected from the three largest population groups in South Africa—namely, black, white, and coloured—as a means to assess variation (McDowell, L'Abbé, & Kenyhercz 2012; L'Abbé et al. 2013; Krüger et al. 2014; Stull, Kenyhercz, & L'Abbé 2014; Krüger 2015).

The heterogeneous population composition of South Africa makes the development of population specific standards an interesting and challenging task, particularly with the estimation of ancestry. Research in the estimation of ancestry strongly focuses on exploring intra- and interpopulation human variation, with an emphasis on countries that contributed to the genetic composition of modern South Africans. Evaluation of human variation is directly associated with forensic applicability. Craniometric and geometric morphometric techniques demonstrated a correspondence between peer-reported race and morphological differences in the crania of black, white, and coloured South Africans (McDowell, L'Abbé, & Kenyhercz 2012; Stull, Kenyhercz, & L'Abbé 2014). Research into the estimation of ancestry has provided a more scientific approach to discussing social identity and ancestry in South Africa. In a country of social, biological, and cultural heterogeneity, the cranial data can be used to show that forensic anthropologists need to focus more on differences between populations rather than distinct race groups. As shown with the use of multivariate statistics, we are no longer able to state that a person is white, black, or coloured; rather, we are able to demonstrate the statistical probability of an unknown person belonging to one (or none) of these socially defined groups based on their biological (ancestral) features.

Yet limitations do exist; the biggest problem is that only three socially defined groups are available for comparison in the South African custom database. To address this issue research on various population groups—namely, Indian South Africans, Chinese, and Zimbabweans—is to be examined and added to the South African database and will improve our interpretation of the probable ancestry of an unidentified person.

Postcraniometric variables were shown to distinguish among peer-reported social race groups, using various statistical models, including flexible discriminant analysis (Liebenberg 2015). This type of analysis is a fairly novel statistic in the field of forensic anthropology and in the future may demonstrate better classification accuracies than do our current methods. Discrete cranial and postcranial trait variation in modern peer-reported social race groups in South Africa and their parental populations has been investigated. Biological distance statistics were used as a means of addressing population structure as well as past and present relationships among groups in the country. Preliminary results from discrete cranial variation among peer-reported social race groups are mimicking observations with craniometric and postcraniometrics, suggesting that a holistic approach to the estimation of ancestry is warranted.

Papers on assessment of ancestry include those dealing with morphology (De Villiers 1968; L'Abbé et al. 2011; McDowell, L'Abbé, & Kenyhercz 2012) and metric characteristics of the skull (İşcan & Steyn 1999; Franklin et al. 2007a; Franklin, Cardini, & Oxnard 2010), including the addition of South African data to FORDISC (L'Abbé et al. 2013). A paper was also published with regard to ancestry in juvenile remains (Steyn & Henneberg 1997).

Less research has been published on the estimation of age at death, although a number of such projects are currently underway. Most of these studies include the use of modern statistical techniques such as transition analysis (Boldsen et al. 2002; Jooste 2015). Data for specific populations are available for sternal ends of ribs (Oettlé & Steyn 2000) and dental maturation sequences (Phillips 2008). Some research has also been completed on cranial suture closure (Dayal 2009) and histomorphometrics from the anterior midshaft of the femur (Keough, L'Abbé, & Steyn 2009). A new and exciting addition is the work of Stull, L'Abbé, and Ousley (2014) on long bone data from children to estimate age, for which data were obtained from Lodox (low radiation full-body digital X-ray imaging) scans. A group of researchers from University of Cape Town is also busy working on age estimation in the living, in particular using wrist radiographs.

Although population-specific formulae are available for stature estimation of both black (Lundy & Feldesman 1987) and white (Dayal, Steyn, & Kuykendall 2008) South Africans, more information is needed on secular trends and limb proportions in South Africans, for which a large project is currently underway. Also, Bidmos (2006, 2008a, b, c, 2009) and others (for example, Pininski & Brits 2014) have done considerable work on estimation of stature, still being followed up by researchers from the University of the Witwatersrand. General information on South African stature can be found in Steyn and Smith (2007).

Publications dealing with personal identification and identification of living individuals are much less common but include aspects of skull-photo superimposition (Thomas, Nortje, & Van Ieperen 1986; Steyn et al. 2000; Gordon & Steyn 2012), photo identification (Roelofse, Steyn, & Becker 2008), and facial reconstruction (Aulsebrook et al. 1995; Phillips & Smuts 1996; Cavanagh & Steyn 2011). A Ph.D. study dealing with facial growth and tissue thickness in children has just been completed (Briers 2015).

Taphonomy and trauma (ante-, peri-, and postmortem) interpretations now occupy much of forensic anthropologists' energies in international areas (Symes et al. 2012, 2014), but the disciplines are still in its infancy within anthropology and certainly within South Africa. A number of taphonomic studies have been undertaken at FARC, all using pigs as substitutes for humans. Myburgh and colleagues (2013) assessed the use of Accumulated Degree Days to study the decomposition rates of bodies in a temperate region of South Africa. A follow-up study by Sutherland and associates (2013) made use of juvenile pig carcasses to study the effect of body size on the rate of decomposition. Keough and colleagues (2015) studied heat-induced alterations to bone in different stages of decomposition. Currently research is being undertaken to look at the effect of burial on the rate of decomposition. Other studies at the University of Witwatersrand and University of Cape Town include taphonomic changes due to burning and decomposition in a marine environment, respectively.

Conclusions

Until recently forensic anthropology research in South Africa lagged behind that of the international community, possibly on account of social isolation from most academic communities. Yet forensic anthropology in South Africa does not suffer from lack of casework, and indeed the cases that are referred for specialist analysis most probably represent only a fraction of the many unidentified bodies that should, in an ideal world, all be followed up. With high rates of violence and crime as well as the many problems outlined in this chapter, this situation is unlikely to change in the near future. The major challenges that exist include limited forensic capacity and funding as well as relatively poor communication between law enforcement agencies and forensic practitioners. The lack of recognition by the wider forensic community of the potential contributions that can be made by a forensic anthropologist is also problematical, because forensic anthropology does not fall within the mainstream of forensic analyses, and referrals from pathologists depend on personal preference.

Nevertheless, considerable advances have been made since the early 2000s, in particular as far as population-specific standards for skeletal identification are concerned. Research on other aspects, such as identification of the living and age estimation in paedo-pornographic material, for example, will probably expand in the future. In addition, the existence of large collections of contemporary skeletons such as those at the Universities of the Witwatersrand, Pretoria, Cape Town, and Stellenbosch will, we hope, continue to attract scholars and students from across the world, thereby providing additional impetus to our research efforts. And contributions from countries elsewhere in sub-Saharan Africa may increase, to also encompass the human variation seen in other regions.

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Part II

Forensic Archaeology

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The Search for and Detection of Human Remains

Thomas D. Holland and Samuel V. Connell

Forensic human skeletal analysis frequently begins in the dirt. The systematic recovery, to include the complete documentation of “archaeological” contexts, is every bit as critical to the successful identification of the remains as are the remains themselves. This fact tends to be overlooked by physical anthropologists operating in academic environments concerned with humans at the population level, as well as by researchers trained on museum collections and other curated resources for which the source and recovery context of the material being analyzed is either unimportant or may not be fully (or accurately) documented. It is obvious, therefore, that any training regimen in forensic anthropology and forensic archaeology should begin with a thorough understanding of methods for locating buried human remains.

When Alfred Kroeber (1916: 20) said that “the proof is in the spade,” he was simply articulating the fundamental weakness of archaeology as a science—namely, the difficulty in reconciling academic models with a prehistoric past to any degree of certainty. Only through careful and systematic excavations, Kroeber argued, was there hope of establishing a verifiable nexus between the past and the present.

Humans have in fact been recovering the remnants of the past for centuries. What sets archaeology apart from the casual collection of cultural detritus, however, is the systematic manner in which it is pursued, at least when it is done well. Indeed, British archaeologist Sir Mortimer Wheeler said: “The excavator without an intelligent policy may be described as an archaeological food-gatherer, master of skill, perhaps, but not creative in the wider terms of constructive science” (1956: 152).

The value of archaeologists in the realm of forensics can be categorized colloquially into two broad contributions: (1) archaeologists are good at systematically finding things that are buried, and (2) they are good at systematically recovering what they find. The latter contribution is discussed in detail in Chapter 12 (Cheetham & Hanson, Chapter 14 this volume) and is discussed here only to the extent that it overlaps with the topic of human remains location.

Traditional Methods

Buried human remains (such as those commonly of interest to forensic anthropologists and forensic archaeologists) typically are found either through accident (for example, construction activities, erosion, and so on) or through the recognition of surface indicators during an intentional search. The basic techniques of intentional searches have remained the same for the last several hundred years, and, more recently, new techniques involving remote sensing have been

developed. In the United States archaeological work often is characterized by three phases: survey, testing, and recovery. The phase system is well suited to traditional archaeological projects where multiple sources of funding and multiyear recovery schedules are often in place. However, the phase system often applies poorly to forensic recoveries where time, budget constraints, and legal urgency may not allow for the individual phases to be kept discrete and may require that the process be compressed into a single recovery effort. Nevertheless, it is conceptually useful to consider the search for buried human remains within the traditional phase concept.

Traditional Survey Methods

Traditional survey involves the systematic inspection of a large surface area, often hundreds of square meters or even square kilometers, for the presence of surface indicators of subsurface features. Historically, surveys have relied on one or more of the five senses, principally sight, touch, and smell, employed unaided. For buried remains the survey is most commonly made on foot, although wheeled vehicles or even aircraft might be employed under certain circumstances. For example, during our search for missing service members in Southeast Asia, helicopters have been utilized to interpret altered topography. As an extension, aerial photography might also be used, especially in situations involving vast areas or hostile or relatively inaccessible terrain, but, in any case, the underlying principle remains the same: the detection and recognition of surface indicators that past experience has demonstrated are correlated to some degree with the subsurface presence of human remains.

A typical pedestrian survey involves the searchers walking a circumscribed area in a systematic fashion, such as a “skirmish” line or linear transects spaced at regular intervals (Figure 13.1). Various search patterns can be employed—for example, S-shapes, zigzags, and/or spirals. The “pattern” of the search is not as important as is the completeness. The distance between two transects is site- and context-specific and may be dictated by physical constraints such as topography and



Figure 13.1 Typical pedestrian surface surveys involve searchers systematically walking the suspected burial area while noting indicators of possible buried remains. Parallel transects, spaced at 2–3-meter intervals, work well under most conditions. Common surface indicators of a burial include mounded earth; depressions; areas of increased or unusual plant, animal, or insect activity; differential moisture retention; and inexplicable changes in the floral community.

vegetation. A 2–3 meter interval works well in most cases; however, in flat terrain and/or low vegetation, wider intervals might be employed, provided that they allow the searchers to readily identify common surface indicators of buried remains. When indicators are encountered, such as disturbances in the soil, clothing, or remains appearing to be human in nature, the searchers should mark the area with survey flags, survey tape, or some other means and continue the search. At the completion of the survey marked areas of interest can be revisited, and the indicators that were marked can be reevaluated within the context of all the marked areas within the search area.

Surface indicators of buried remains typically reflect physical and chemical changes to the surface as the result of a burial pit being dug. For example, human burials often can be detected by the presence of either a mound, usually associated with more recent inhumations, or a depression, resulting from settling and compaction of the burial pit over time (Morse, Duncan, & Stoutamire 1983; also Killam 1990). With interments involving humans, a secondary slump near the center of the pit depression may result from the collapse of the thoracic cavity over time. In addition, physical alteration of the surface may lead to drying cracks around the perimeter of the burial pit as the result of differential moisture retention between the fill and the surrounding soil matrix. The vegetation may also show differences as weed pioneers colonize the newly disturbed soil. These pioneers often are replaced with a succession of plant species that may differ markedly from the established floral regime in the general area. Chemically, the soil in the burial pit is enriched by the decomposition of the body and the aeration of the soil during the inhumation process and typically manifests in a darkened or stained soil that may be visible on, or near, the ground surface. This chemical change, combined with the physical change, has the effect of creating a small, self-sustaining system, whereby the richer, looser pit fill traps and holds more moisture that encourages animal, insect, and plant activity, which further aerates and enriches the soil. The results of this self-sustaining system often remain visible as soil stains hundreds or thousands of years later (Figure 13.2). In situations involving incidental inhumations, such as burials in mudslides or resulting from floods and other natural events, some physical changes may not be readily recognizable. Similarly, in cases where remains are deposited on the surface and become covered by sediment built up over time, there will be no evidence of a burial pit or unnatural disturbance to the soil.

Another survey approach for forensic cases is the use of a cadaver dog. Cadaver dogs are trained to detect the odor of decomposing human remains, ignoring other animal remains, and alert their handlers to their location (Rebmann, Koenig, & David 2000). They can locate remains scattered on the surface or buried shallowly below it and are particularly useful when a search area is loosely defined but too large for a pedestrian search.



Figure 13.2 Physical and chemical changes to the burial fill, brought about by the decomposition of human remains and the aeration of the soil during inhumation, often are manifested as burial “stains.” Burial stains, such as the one demarcating a mass grave in North Korea dating to circa 1950, may persist for hundreds or thousands of years.

The purpose of traditional survey methods is to narrow down a large search area to a manageable number of smaller areas of interest that can then be subjected to a more thorough examination. Consequently, a good survey should be reductive without excluding any reasonable feature of forensic interest.

Testing

Testing seeks to take the reduced set of interest points and reduce them further, with the goal of identifying a specific location for full-scale excavation and recovery. Like the survey, testing typically involves the use of one or more of the human senses, but, unlike the survey, the purpose of testing is to extend the range of those senses below the ground surface. Subsurface indicators of a burial mirror many of those found on the surface. They also include features such as buried organic material, which is surface vegetation that is incorporated into a subsurface context as the result of digging and back-filling a pit, and inverse stratigraphy, which is the disruption and disarrangement of normal soil layers as the result of back-filling activities.

Testing actually constitutes the initial examination, commonly called “ground-truthing,” of the areas of interest identified through the survey. Unlike the relatively large areas encompassed by the survey, testing is limited to smaller, well-circumscribed areas. A wide variety of procedures fall under the definition of testing. Many of these—for example, pH analysis of the soil, organic-content analysis of the soil, and gas detection—are not discussed here, because they are less frequently used, harder to interpret, and tend to be more time consuming. Instead, the focus is on the more traditional methods of subsurface testing: probing, coring, and limited excavation.

Probing

Probing is the least technical of the traditional subsurface testing procedures, but it is fast and inexpensive to accomplish. It involves the use of a metal probe, commonly 1–2 m in length, which is inserted into the ground for the purpose of assessing soil compaction (Figure 13.3). As with all the survey and testing procedures, probing is best accomplished in a systematic fashion, with probe insertions being made at regular intervals (for example, 20 cm) along a transect that initiates and terminates on either side of the suspected burial location. By beginning and ending outside the suspected pit location, one can readily detect the relative compaction of the natural soil matrix as opposed to (generally looser) burial fill. Since the insertion of a probe can be damaging to any human remains or other fragile evidence encountered, it is the detection of the burial fill—not the detection of buried remains themselves—that is the goal. The depth of insertion should be sufficient to detect differences in soil compaction but should not be so deep as to run the risk of damaging any buried evidence. Often several parallel or perpendicular transects may be required to adequately assess the area under consideration.

Coring

Coring is similar to probing in that it involves the insertion of a metal coring tube into the soil, but unlike a solid probe, the soil corer has a metal tube attached to the end. (Augur coring devices, which effectively “drill” a hole into the ground, are not recommended in forensic cases owing to the high potential for significant damage to any buried remains encountered.) When the coring tube is inserted into the soil and then removed, it brings with it a cylindrical plug, or core, of soil (Figure 13.4). By removing and examining cores of subsurface soil along a transect



Figure 13.3 Probing with a metal rod is a fast and efficient method of assessing subsurface soil compaction. By probing in a systematic fashion, differences between loose burial fill and the more-compact surrounding soil matrix can often be readily detected.



Figure 13.4 Coring is similar to probing except that it allows the actual examination of small plugs of subsurface soil. The archaeologist shown surveying a Vietnam War era aircraft crash in northern Vietnam was able to determine the subsurface distribution of the 30-year-old wreckage field by noting the presence or absence of residual jet fuel trapped in the clay soil.

that initiates and terminates on either side of the suspected burial location, one can infer the actual stratigraphy. In addition, the soil cores may be examined for other burial related features and materials such as buried organics or even possible fragments of human remains or clothing.

Soils tend to be arranged in distinct, orderly layers called *horizons*. Intrusive pits such as burials effectively mix or invert the stratigraphic components when they refill. In addition, surface organic material (for example, leaves, grass, twigs) may incidentally become buried in the process. The detection of these mixed or inverted stratigraphic elements and buried organics in a soil plug removed during coring is an indication only that a subsurface disturbance is present and that additional work is required to determine the nature of the disturbance.

Limited Excavation

Limited excavation is the most intuitive means of subsurface testing in that it involves actually digging holes. Indeed, the dividing line between testing and recovery often is difficult to discern, and in many forensic cases the former evolves seamlessly into the latter with no clear procedural demarcation. Testing, however, is really a continuation of the systematic procedure that began with the identification of possible surface indicators. The function of testing is to further narrow down the area of interest so that recovery resources can be applied more efficiently. Limited excavation can be categorized into three broad techniques: shovel testing, trenching, and limited block excavation.

- *Shovel testing*: Shovel testing is the quickest, least expensive, and least rigorous of the limited excavation techniques. It involves the excavation of small holes, often the width and depth of a shovel blade, for the purpose of examining a larger area of subsurface soil than can be achieved with a soil corer. As with probing or coring, shovel testing is best accomplished in a systematic fashion, with the tests applied along transects that begin and end outside the suspected burial area in order to establish a basis of comparison between the native soil context and the possible burial fill.
- *Trenching*: Trenching, both manually and with heavy equipment (such as a backhoe), is also a quick and efficient means to examine the subsurface for possible indicators of a burial; however, considerably more care must be exercised to avoid destroying the context and material evidence associated with any burial encountered. As with the other methods, the key to successful trenching is to accomplish it in a systematic fashion. Instead of probe holes or shovel tests placed at discrete points along one or more transects, trenching is effectively the removal of the uppermost soil layers along the entire transect. To achieve maximum coverage of the suspected burial area, parallel trenches should be spaced no farther apart than the minimum suspected width of the burial pit. Depending on the nature of the underlying soil strata, cross-trenches running perpendicular to the initial set of parallel trenches may be required (Figure 13.5).
- *Limited Block Excavation*: Limited block excavation is effective when the suspected burial area is relatively small and circumscribed and can be undertaken either by hand or with the aid of a mechanical excavator. As with the typical block excavation of traditional archaeological excavation, limited block excavation can be an effective means of systematically exposing subsurface indicators of intrusive activities. Just as with the spacing of cross-trenches, the size and the placement of excavation blocks should be suited to the size and the configuration of the suspected burial area. Often block excavation follows directly from trenching when the latter reveals subsurface anomalies that require further investigation (Figure 13.6).

Regardless of the testing method employed, the goal remains the same: to expose the underlying soil strata for the purpose of detecting disturbances related to intrusive activities such as the digging of a burial pit. Once such areas are detected, they can be evaluated, and recovery resources can be applied effectively.

Remote Sensing

In addition to the more traditional testing measures, numerous geophysical studies (Clark 1996; Bevan 1998; Conyers 2004; Cheetham 2005; Wiseman & El-Baz 2007) have documented the ability of geophysical instrumentation to detect and map near-surface features without the removal of the uppermost soil strata and thus expand the archaeologist's ability to detect burial contexts beyond that limited by the traditional use of the five human senses. A clear benefit to remote sensing is that, as its name implies, it is remote and therefore non-, or at least minimally,



Figure 13.5 Systematically excavated trenches, and parallel cross-trenches, are an effective means to examine large areas of subsurface soil. The burial location of a U.S. Air Force RB-29 crewman, shot down over Yuri Island, Russia, in 1959, was readily identified using well-placed trenches that exposed the outline of the burial pit intruding into the undisturbed subsurface soil matrix.



Figure 13.6 Limited block excavation as a testing procedure has the advantage of easily leading directly into full-scale recovery. The key is to systematically remove only the uppermost soil layers in order to expose evidence of intrusive pits.

intrusive. This can be important when searches must be conducted in areas of cultural, ethnic, or political sensitivities.

Remote sensing technologies should not be misinterpreted as “bone-finders.” All remote sensing techniques function by detecting differences between two or more media, usually different soil strata. In practical terms this fact means that if there is uniform underground soil composition, or if the soil composition exhibits a patterned distribution (for example, discernable strata), then remote sensing techniques can document any intrusive features as *anomalies*. In these cases the analyst is relying on the remote sensing equipment to isolate stratigraphic differences that do not exhibit the same pattern as the subsurface surroundings do. Historically these disturbances were detected only through the traditional survey and testing techniques outlined previously (or through accidental exposure), but, under the right geomorphological conditions, geophysical instruments may be able to detect and resolve differences in subsurface composition and pattern without recourse to soil removal (Clark 1996; Conyers 2006). How these differences are made manifest, however, varies depending on the material in question, the surrounding environment, and the equipment being used.

Many detailed treatments of geophysical instrumentation can be found (Clark 1996; Bevan 1998; Conyers 2004; Cheetham 2005), including those dealing specifically with forensic archaeological work (Buck 2003; Dupras et al. 2006). The main points to understand are that the geophysical principles used by each piece of equipment are different in their application and that context-specific background knowledge about the recovery locations is a critical presurvey step. Because of the complexity of this equipment, geophysical experts are increasingly, although perhaps not yet commonly, being called on to consult in finding the location of interments in historical cemeteries (Conyers 2006). Three different but widely used remote sensing technologies are outlined in the following sections: the soil resistivity meter, the cesium magnetometer, and the ground-penetrating radar (GPR).

Soil Resistivity

The remote sensing technique of soil resistivity is based on the demonstrated tendency of soil to differentially resist (or conduct) electrical currents. The resistivity of a given soil matrix depends on a number of factors, including the structure and the morphology of the soil and its water and ion content. The presence of impermeable constituents in the soil, such as volcanic rock, or more permeable soil structures, such as features excavated into the sterile horizon, will also alter the flow of electricity through the ground (Clark 1996: 27–63). By passing a known current through a circumscribed section of a suspected burial site, variations in current, which are read using a resistivity meter, can be used to infer the presence of natural and cultural subsurface anomalies. Disturbances in the soil that result from soil compaction (for example, floors, paths) or loosening (for instance, burials) can be detected during resistivity surveys, although burial pits often constitute relatively “small” anomalies within the range of potential subsurface disturbances. Complications can also arise when the soil in the survey area has been disbursed by modern building and agriculture (Bevan 1996: 72–73), or where other sources of electrical current, such as underground cables, are present.

The resistivity meter is commonly employed using steel or copper-clad electrodes (Figure 13.7). As a general rule, the distance between the electrode poles is roughly the depth below the ground surface that the equipment will measure. As with the traditional survey techniques of probing, coring, and trenching, resistivity readings should be taken along transects that begin and end outside the suspected burial area for the purpose of establishing baseline values. Readings may be imported into a database and plotted using commercially available graphing software, or by hand onto a contour density map.



Figure 13.7 Soil-resistivity testing can be accomplished with minimal equipment. A resistivity survey of a site in Vietnam illustrates readings being taken along transects with the electrodes (arrows) spaced at 2-meter intervals.

Magnetometry

Burials often can be detected by analyzing changes in the magnetic field in a given area. Magnetometers are devices which measure field variations in the earth's magnetosphere. The metal detector is the most common means of conducting magnetic surveys and detects local spikes in an induced electric field. Owing to their ubiquity and intuitive nature of their use, metal detectors are not discussed here. There are several types of magnetometers, fluxgate and cesium gradiometers being among the most common in archaeology. In recent years, cesium-vapor magnetometers (a type of alkali-vapor magnetometer) have come to be the dominant type used by forensic anthropologists owing to their sensitivity and speed of use. Cesium-vapor magnetometers use a photon emitter and a cesium-vapor chamber to detect energy quanta, specifically energy quanta related to anomalies in the earth's magnetic field at any given point on the ground surface. Subsurface magnetic anomalies can result from subsurface inclusions (especially metal objects) or from changes in the magnetic polarity of individual soil particles that result when soil is disturbed or mixed. One-person, hand-carried cesium-vapor magnetometers are available (Figure 13.8), and the actual survey consists of systematically walking over the suspected burial site and surrounding area to detect local variations in the magnetic field. As with all of the survey procedures magnetic data should be collected in a systematic fashion, such as along transects or a discrete grid nodes. Data can be collected in continuous mode and downloaded to commercially available postprocessing software for analysis. Most magnetic-field gradient surveys can also be performed in the same grid established for the soil-resistivity assays and researchers may find it cost effective to simultaneously conduct two or more types of remote sensing surveys on a site, although level grassy environments are ideal for magnetic data collection (Clark 1996: 114). As with soil-resistivity data, magnetometer data may be rendered as contour density maps.

Unlike soil-resistivity meters, magnetometers are largely unaffected by differentials in the retention of moisture in soil (Bevan 1983: 50; Clark 1996: 64–98). However, there are a



Figure 13.8 Cesium magnetometers are portable and readily usable by single investigators. Note that the readings are being taken at 1-meter intervals marked by wooden stakes.

number of potential obstacles to conducting a magnetic survey in an alleged burial area. For example, in more populated areas, purported burial sites may be contaminated with sources of modern magnetic surface interference such as electrical wires, underground pipes, and non-incident-related metal surface objects. One way to mitigate this problem is to conduct a metal-detector survey before the magnetometer survey to detect and, when possible, to remove all metal objects found at or near the ground surface. In addition, the underlying magnetization of bedrock material, called *thermoremanent magnetization*, may make magnetic surveying of an area impossible (Scollar 1965), particularly when the underlying magnetization of bedrock material in the study area overwhelms subtle gradients triggered by cultural anomalies (Dorbin & Savit 1988: 651). In these difficult cases carefully measuring the magnetic susceptibility of the near-surface soil deposits may be more productive (Clark 1996: 116). There is also the factor of solar diurnal variation in the earth's magnetic field, which alters readings over the course of a day, a problem that is mitigated by continually standardizing the readings using a control point outside the area being surveyed or, in smaller areas, by simply completing the survey quickly.

Ground-Penetrating Radar (GPR)

Ground-penetrating radar (sometimes known as subsurface interface radar, or SIR) operates by directing a short, controlled, electromagnetic pulse into the ground and then measuring the time required for the pulse to be reflected back to a radio receiver. Since the signal's propagation time is a constant, any variation in the time required for the signal to leave

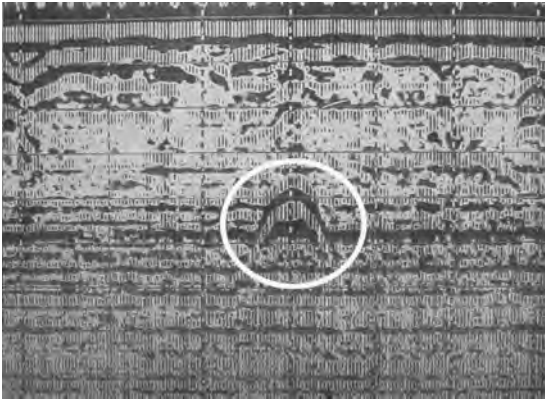


Figure 13.9 Ground-penetrating radar data showing the relatively uniform horizontal bands representing undisturbed soil strata and the characteristic hyperbolic “echo” (white circle) of a burial

the radio transducer and be reflected back to the receiver is a function of the depth and the density of objects that the pulse encounters as it passes through the ground (Vaughan 1986; Conyers & Goodman 1997; Conyers 2004). It follows that GPR surveys work best when the underlying soil strata are relatively uniform and the subsurface anomalies occur abruptly, meaning that intrusive features such as burials are readily apparent (Conyers 2006) (Figure 13.9).

Earlier GPR systems involved numerous pieces of heavy equipment and employed ground-contact transducer sleds that often required extensive site preparation to ensure a relatively smooth ground surface on which to drag the sled. The amount and the nature of the equipment limited the usability of GPR in many search locations and conditions. Also, failure to properly prepare the ground surface prior to conducting the survey often resulted in numerous data-acquisition errors. Modern systems can now be mounted on a wheeled cart capable of transiting uneven terrain without introducing significant data-acquisition errors. In addition, the cart can be equipped with a survey wheel that measures distance traveled over the survey area (Figure 13.10), thus facilitating accurate and systematic coverage of the survey area. Most of the modern GPR systems allow collected data to be viewed in real time as each line scan is produced as well as allowing the data to be uploaded to postprocessing software. Different radar transducers, or antennae, capable of generating different frequency signals (for example, 400 MHz and 900 MHz) are available. The choice of antenna is dictated by the geomorphology at the site and the nature and depth of the target to be detected. Lower frequency antennae, for example, send relatively longer waves into the ground that generally provide deeper penetration but with lower resolution. Conversely, higher frequency antennae typically sacrifice sensing depth for greater resolution. The 400-MHz antenna generally provides good resolution to a depth of 3.0 to 4.0 m, whereas the 900-MHz antenna is useful to approximately 1.0 m. It should be emphasized, however, that local conditions, such as moisture content, often dictate actual penetration depths.

Postprocessing

Any survey, but especially those involving remote sensing techniques, is only as good as the analyst's ability to postprocess the data. Although analysis can be a long-term endeavor, a number of simple techniques exist for viewing the data that allow it to be interpreted efficiently and quickly after the survey takes place or even directly in the field, facilitating on-the-spot adjustments to survey



Figure 13.10 Ground-penetrating radar equipment is increasingly becoming more portable. Many of the devices now are cart-mounted and can be used with minimal ground-surface preparation.

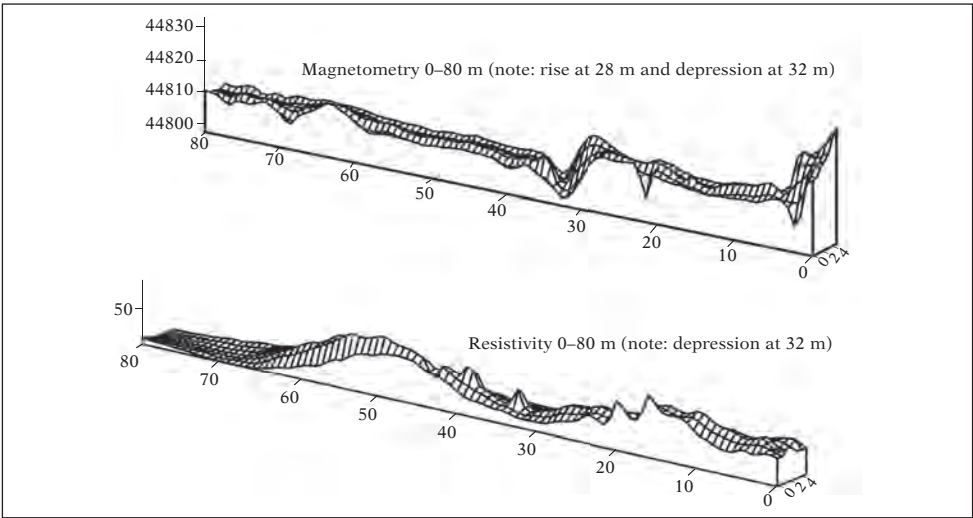


Figure 13.11 The combination of two or more remote sensing techniques, such as magnetometry and soil resistivity, allows for subsurface anomalies to be recognized that might go unnoticed or be misinterpreted based on a single line of evidence.

or excavation strategies. These techniques are obviously essential in the forensic world, where no one can afford to wait for the consulting expert to analyze and interpret data.

Both soil resistivity and magnetometry data can be converted to three-dimensional x, y, z coordinates and imported into an off-the-shelf computer mapping program for easy viewing (Figures 13.11 and 13.12). If a grid survey was employed during the survey, then one can simply overlay the data maps generated by the two techniques for quick analysis. There are a number

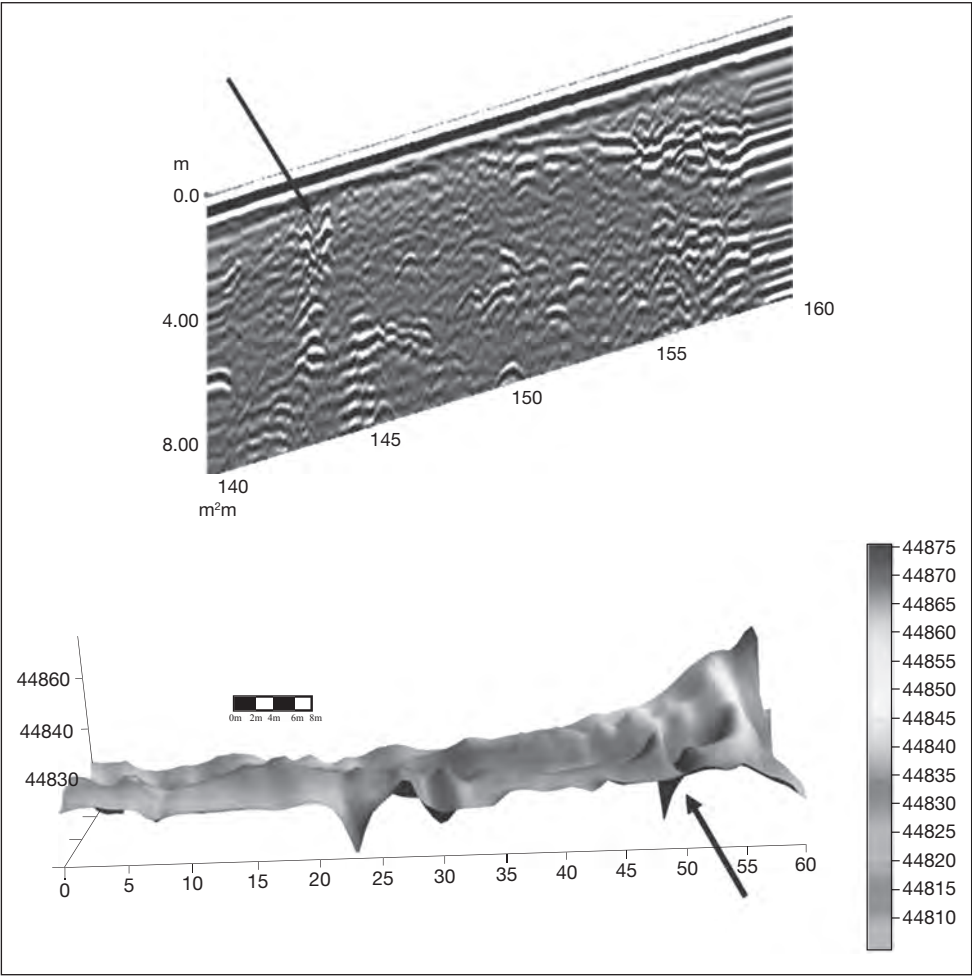


Figure 13.12 Anomalies identified by ground-penetrating radar and magnetometer located within a 2-meter radius. Note the radar hyperbola and the dipolar gradient readings where the intrusive feature is located.

of other techniques, such as filtering out the extreme high and low readings, that can be used to isolate the gradients that are important for the analysis.

As with the traditional survey techniques, remote sensing surveys should seek to reduce the area that will require ground-truthing, in the form of test trenches or limited block excavations, but they should not be so exclusive as to erroneously eliminate actual buried remains. Data filters should thus be set at a level to achieve this end, but since remote sensing analysis operates by detecting differences in the subsurface matrix (which may represent the presence of an intrusive cultural anomaly or feature), most surveys result in the detection of numerous anomalies. Consequently, the placement of test excavations may best be determined by assumptive hypothesis; that is, whenever two or more of the three pieces of instrumentation register an anomaly at one location, there is a stronger likelihood that a subsurface feature exists and is not a figment of data acquisition.

Conclusion

The application of archaeological methods and procedures to the detection of buried human remains has been slow to mature. Although forensic anthropology has emerged over the last 40 years as a viable subdiscipline of anthropology, the recognition of forensic archaeology as a distinct specialty has lagged behind. This is changing.

Buried human remains are best located by the application of methodical, systematic procedures. Many of these procedures (probing, coring, searching for surface indicators) have changed very little over the last hundred years or so. Other procedures, such as magnetometry, ground-penetrating radar, and soil resistivity, represent more recent developments and offer great promise. These remote procedures carry the added benefit of being less intrusive and therefore more appropriate in areas where political, cultural, or ethical concerns may otherwise be constraints.

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Excavation and Recovery in Forensic Archaeological Investigations

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The chess board is the world, the pieces are the phenomena of the universe, the rules of the game are what we call the laws of Nature.

(Thomas Huxley 1909)

Why involve archaeologists in forensic investigations? This chapter discusses practical reasons. Archaeologists have begun to be used when excavation and recovery of buried evidence at crime scenes is required, because they demonstrate expertise in untangling the seemingly chaotic structure of scattered and buried features, artefacts and deposits. With Huxley's chess board view of the world in mind, archaeologists have specifically developed strategies for managing and organising the spatial and temporal control and analysis of complex sites—playing the chess game of investigating buried landscapes with rules utilising the laws of nature. This chapter provides considerations for archaeologists (and others, including anthropologists, crime scene managers, investigators, and humanitarian organisations) engaged in archaeological work, not so much on specific excavation or recording methods but on what challenges exist in undertaking archaeological interventions within forensic investigations.

Historically, few agencies in charge of crime scene and forensic cases have realised both the complexities of buried environments and the need for archaeologists' specialist skills in winning the game of uncovering "hidden" evidence; the pathologist Sir Sydney Smith in 1924 saw "something of the worries of an archaeologist" when excavating a mass grave during a murder investigation in Cairo (Smith 1959: 71). The pathologist Keith Mant (1987) realised the spatial control required in exhumations and the effects of taphonomy on remains and evidence while recovering missing servicemen in postwar Germany. Stuart Kind (1987) of the United Kingdom Forensic Science Service (the government-owned company supporting police investigations up to 2012) noted the similarities between crime investigation and archaeology: reasoning hypotheses from fragmentary physical evidence, determining events along time lines, and understanding principles of evidential identification, deterioration, and change. Such realisation is still limited globally but has spread as professional archaeologists and anthropologists have applied themselves to forensic questions (for example, Morse, Crusoe, & Smith 1976; Bass 1978; Skinner 1987; İşcan 1988; Davis 1992; Spennemann & Franke 1995; Hunter, Roberts, & Martin 1996; Brickley & Ferlini 2007), entering mainstream forensic and media consciousness in North,

Central, and South America; the United Kingdom, Europe, and Australia (for example, Groen, Márquez-Grant, & Janaway 2015); and in some international war crimes investigations. What is clear is that archaeologists or anthropologists engaging in forensic work must adapt to a medico-legal framework, which may involve time constraints and evidential and information controls that are outside their usual realm of experience.

Concepts

There are several perspectives to consider in forensic investigations requiring archaeological excavation and recovery. Archaeology and archaeologists are defined very differently depending on where and how they exist (Carver 2009; Groen, Márquez-Grant, & Janaway 2015). Differences exist in academic and field archaeologist approaches to excavation. Archaeologists, who excavate salvage/rescue sites for commercial companies employing rapid sampling strategies; who excavate “classical sites” focussing on structures; who undertake excavation in Europe, Central America, or Southeast Asia, all have different approaches and understanding of how techniques and archaeological methods should apply to fieldwork. Archaeologists may be from anthropological, historical, landscape, geographical, or broader analytical science backgrounds. When utilising forensic archaeological work, investigators should appreciate the context, experience, and professional background from which archaeologists come and indeed apply a “histiographical” approach (the study of particular sources, techniques, and theoretical approaches used) to understand how the requirements of an investigation will be affected by a particular method approach. There is no standard approach to archaeological fieldwork globally (see, for example, Carver, Gaydarska, & Monton-Subias 2015), and therefore there is no common agreed-on forensic approach—and consequently no common standards. This situation has fundamental implications for fieldwork taking place within a legal framework—a framework with serious ramifications for archaeologists (which many do not commonly encounter in their everyday work) in terms of how they interpret, define, and present archaeological evidence.

Archaeologists must conduct their work with full understanding of the investigative questions, crime scene management and science principles, and pertinent laws and jurisdictional guidelines relevant to the context of the investigation. Conversely, forensic archaeologists need to be aware of the cultural, social, political, legal, and historical agendas in their work, something many archaeologists are well aware of from their understanding of a subjective past and how archaeological interpretations affect and change society or can be used inappropriately in political contexts.

Archaeologists operating in the forensic context are field archaeology specialists with an experienced and competent fieldwork background, in the same way as a forensic pathologist is a specialist pathologist. What constitutes experience and competence? Even the definition of what constitutes the differences between a forensic archaeologist and anthropologist is not clear (for instance, Skinner, Alempijevic, & Djuric-Srejjic 2003). Little attempt has been made to define these things at a practical level, but defining competence and experience are important for the expert witness process. Some definition began for forensic archaeology in the United Kingdom, with the now defunct Council for the Registration of Forensic Practitioners (CRFP 2006), followed by the Forensic Archaeology Expert Panel (FAEP) in 2009 and the Forensic Archaeology Special Interest Group (FASIG) within the Chartered Institute for Archaeologists in 2011 (see, for example, Chartered Institute for Field Archaeologists 2014a, b, c). In the United States the Scientific Working Group for Forensic Anthropology incorporates scene processing (SWGANTH 2010, 2013), and in the Netherlands the Netherlands Forensic Institute has produced a quality manual for forensic archaeology (De Leuwe & Groen 2015). More generally the

management of archaeological work is being standardised in the United Kingdom and Europe under the ISO 9001 and ISO 14001 systems (for example, BS EN ISO 14001 2004; BS EN ISO 9001 2008), and forensic crime scene work under ISO 17020 (such as BS EN ISO/IEC 17020 2012). However, what is understood to constitute existing norms for competence, experience, and practical techniques to be employed varies greatly. The breadth of how forensic archaeology is perceived, understood, and used globally is amply illustrated in Groen and associates (2015).

In legal terms archaeologists may be undertaking recovery in the context of burials in domestic homicide and other police or legal support work, such as recovering buried stolen goods, weapons, or ransom money (Hunter 1996: 99), resolving land boundary/ownership disputes, international humanitarian identification, international criminal investigation for war crimes tribunals, and recovery after disasters (for example, Hunter, Simpson, & Sturdy Colls 2013). The requirements in each circumstance are different depending on the strictures of the legal system under which the archaeologists find themselves working. In domestic murder cases archaeologists may find themselves defined as scientists fulfilling one task in a formal legal system assisting a pathologist or forensic pathologist on the scene and providing a statement and expert witness testimony in court. In a humanitarian exhumation recovering the missing from a mass grave the archaeologist may be the only scientist undertaking most aspects of a field exercise, including search, location, recovery, and analysis, recovering bodies to return to families with no legal obligation to provide testimony or reports (Skinner & Sterenberg 2005). However, a common experience is the archaeologist not directing the process, as is the case on normal excavation, but being managed as just one scientific element in a larger judicial, medico-legal, and detective hierarchy and strategy (Wright, Hanson, & Sterenberg 2005; see also Wright & Hanson, Chapter 41 this volume).

Crime scene protocol governing the responsibilities and therefore the actual activities of the forensic archaeologist can vary from scene to scene even within national boundaries and common legal systems; for example, the 43 police forces in England and Wales may use scientific support differently. An archaeologist may be brought to advise and implement a recovery strategy at the start of a case or be used to assist a forensic pathologist in a recovery after the fact with frustratingly very little influence over some aspects of the recovery process. Internationally the archaeologist may be controlling the scientific element of a mass grave excavation (Wright, Hanson, & Sterenberg 2005), coordinating a range of experts that are drawn into the archaeologist's domain of the buried environment. What is important in any investigation involving excavation and recovery is that the roles and responsibilities as well as the reporting structure (whom they report to and how they report) are defined at the outset of the work.

The Search Never Ends

In terms of planning, explaining, and organising the process of fieldwork, it makes sense to break this process into manageable modules along a timeline; this practice of using standard operating procedures is common in many professions, such as those of fire brigades and armed forces. It has now also been described for the forensic archaeological process (Cox et al. 2008). Such procedures are necessary for basic training, implementation, and understanding for the inexperienced; for the experienced professional they become merely prompts. Therefore on one level for the competent forensic archaeologist there should be no processual distinction between search, location, and recovery. After pinpointing a site and dealing with the search, identification, and recovery of surface material, the process of excavation commences. This process is one of a continual search to locate and define bodies and artefacts (evidence), and features or deposits (which also have strong evidential value). The excavation by spatial units is defined by the surviving anthropogenic and environmental stratigraphy itself but reduces in space and

time as excavation progresses. The focusing and defining of spatial and temporal evidential perimeters from a wide regional to a (potentially) microscopic resolution are a key element of archaeological assistance in a forensic investigation, as is the appropriate recording of such a process (see the subsequent section Similarities and Differences between the Archaeologist and the Crime Scene Investigators). One important element of this concept of continuity is the importance placed on it by the criminal justice system in terms of evidence control and chain of custody and continuity but also data exchange and management of the investigative process. What logically follows is that the forensic archaeologist is on site at all stages of the search and recovery to ensure that vital contextual evidence is not lost.

The Requirements of Forensic Archaeology in Excavation and Recovery

The investigational aims and benefits of archaeological involvement in forensic work at the scene have been discussed (Hunter et al. 1994; Haglund 2001; Haglund, Connor, & Scott 2001; Juhl 2004; Hanson 2007) and include recovering and evaluating evidence for:

- Identification of the dead;
- Identification of ethnic, religious, and cultural groups;
- Assistance in determining manner and cause of death;
- Determining if the dead have been moved after death;
- Reconstruction of the crime scene;
- Linking crime scenes;
- Evaluating the perpetrators actions;
- Determining perpetrator identity; and
- Establishing the sequence and dating of relevant events.

Achieving these aims benefits from the (often) short time from deposition to excavation, meaning that there is often good archaeological evidential survival and the possibility to reconstruct events in time very accurately. Examples of what have been described as the “Pompeii premise” (where artefacts and evidence are left on occupation surfaces and rapidly sealed by overlying deposits) are common when mass burial occurs and are often verifiable by witnesses, aerial imagery, and video (Hanson 2004; Cox et al. 2008). Such burial preservation and how to deal with it are the reasons for involving archaeologists in forensic excavation; they, along with the requirements of investigations, guide the demands on archaeology. In fact it has been the involvement of archaeologists and forensic scientists in cases such as the investigation of the Srebrenica massacre in Bosnia in 1998 that has informed criminal investigators of what can be recovered from buried crime scenes—for example, recording of vehicle tracks and marks, detection and analysis of foreign soils in secondary burials, and recognising multiple stratigraphic deposits in graves demonstrating grave reuse (Hanson 2004; Brown 2006; Cox et al. 2008). These skills have provided support to investigators (in areas outside their expertise) in:

- Physically locating and defining graves;
- Recognition of disturbed soils;
- Soil removal and safety issues of soil stability;
- Familiarity with the usefulness and pitfalls of heavy earth-moving machinery;
- Recording the location of objects in 2D and 3D and representing them in plans and computerised images;

- Understanding and competence in excavating human remains;
- Recognising when to use other experts, such as soil scientists and dating expertise;
- Managing large teams of scientists (after Wright, Hanson, & Sterenberg 2005);
- Defining the excavation and recovery process within a crime scene context; and
- Reporting on forensic archaeological matters.

These procedures are based on founding archaeological processes and principles, discussed in the literature (mainly in the form of case studies) (for example, Connor & Scott 2001; Hanson 2004; Hunter & Cox 2005; Wright, Hanson, & Sterenberg 2005; Cox et al. 2008; Hunter, Simpson, & Sturdy Colls 2013). The field archaeologist must be able to excavate and interpret quickly and simultaneously, establishing the stratigraphic record and its relevance and distribution for each site. Little has been published on the practical techniques for achieving this goal; some practical techniques are discussed in the section on Variations of Methods.

Archaeologists are required to be flexible, because every site is unique. In the forensic context this flexibility becomes adaptability, because the procedures of different agencies managing the crime scene must be respected. Understanding these differences requires developing experience that allows archaeologists to advise, demonstrate, and provide the relevant scientific support in forensic investigation to optimise data capture during excavation and recovery. Since forensic archaeology is a discipline that is still developing in many countries, the onus is often on the forensic archaeologist to prove to investigators that he or she has constructive input and has revealed something of interest—something the investigator would not have recognised or appreciated evidentially. The main considerations that archaeologists need to make investigators aware of within the investigative excavation and recovery framework include:

- The spatial extent of the scene (often best achieved through open area excavation);
- Site formation processes affecting the timeframe of interest;
- The stratigraphy reflecting the sequence of events at scene relevant to the specific investigation (including any bodies that can be viewed as a deposit);
- Identifying and contextualising physical evidence within deposits such as hairs, fibres, and shell cases and demonstrating their relevance to the case;
- Identifying physical evidence on surfaces such as hairs, fibres, tool marks, and prints and demonstrating their relevance to the case;
- Identifying taphonomic influences to evidence and bodies;
- Strategies for optimum recording, recovery, and preservation of such evidence—for example, block lifting;
- Strategies for sampling deposits to collect such evidence;
- Appreciating the accumulation of evidence in a reverse examination of a sequence of archaeological features and deposits that reflects moving back along a “line” through time;
- Identifying the needs for conservation of evidence recovered; and
- Ensuring planning and recording formats and measures suitable to produce competent verifiable documentation and archaeological reports for courts.

Archaeologists therefore need to employ appropriate methods to demonstrate that the evidence they reveal is relevant and sound not only to a prosecutor and a court but also to investigators while still at scene. Will the archaeologist in the forensic chess game be able to make all these moves without being checked? At present much depends on the awareness of a particular medico-legal and investigative structure of the scientific potential available to them; often that comes down to the enlightenment (or not) of a single senior investigator in charge of scenes

or cases and the ability of the archaeologist to demonstrate the suitability of the methods to be applied for that scene, the resources needed, the time required, and the veracity of their findings.

Similarities and Differences between the Archaeologist and Crime Scene Investigators (CSI)

Key concepts with which archaeological approaches can inform investigative process (and vice versa) can be both practical and strategic. For example, the cordons and grids used to delineate the crime scene impose artificial boundaries on the landscape to control access and allow systematic search and recording. However, such visual two-dimensional boundaries can override the ability of both investigators and archaeologists to “see” the landscape. The crime scene becomes defined by the cordon, the grid becomes the limit of site, and the “pit” excavated to access a burial becomes the grave itself. In this way the aesthetic symmetry of a grid or an inner and outer crime scene boundary replaces the actual reality of defining the area of criminal events or the relevant archaeological record; a mechanical and thoughtless standard operating procedure replaces the flexibility required on a site-by-site basis. For example, gridding a site is an excellent way to delineate a landscape for controlling and undertaking systematic searches, but, for domestic murder scenes of small scale, setting out a grid is of limited assistance given time and space restrictions and when a pair of datum points will suffice. On a disaster recovery scene such as a plane crash the outer cordon set to control scene access and define evidential distribution can become obsolete overnight when by daylight strong winds have blown documents, clothing, and personal effects 300 metres past the cordon, and dogs have carried remains away.

There are differences between archaeologists and investigators in their approaches to photography. Archaeologists have a formalised approach to archaeological photography and documenting sites, so that additional interpretation can be undertaken by others: features are recorded from formal views, and a professional panoramic style is presented (where photography captures images with elongated fields of view, recording the excavation in the landscape). Crime scene photographers, in contrast, record what is there from as many angles as possible, with a limited concept of the vertical, so that many single images do not provide the “diorama” that an archaeological image present. The scales used in crime scene photographs are not adequate to scale many archaeological site photographs. For many investigators the main evidential record for a scene is the photograph with the crime scene sketch as a supplement; for the archaeologists it is the scale-drawn plan, profiles, and sectional elevations that are the primary record, while photographs supplement the interpretive build-up of single and multiple context and phase plans.

The detail of planning undertaken on archaeological sites is now extending into police work, often through accident investigation teams, but is not systematic, and so archaeologists may have to do all or part of the surveying and plan and section drawings themselves. Perhaps the difference lies in the degree of interpretation that archaeologists make after leaving the site and the degree to which they need to analyse plans and sections and photographs made by others. There are lessons in the detail of archaeological recording that can be learnt by investigators; it is perhaps overlooked, because many criminal cases are solved quickly and do not fall into the long-term interpretive category, unlike many archaeological records that accumulate and require frequent reviewing. The increasing use of digital recording methods, including 3D laser scanners and photogrammetry, adds to this mix of approaches, visually and dimensionally capturing the crime scene and enhancing the potential for postrecovery analysis and possibly reinterpretation.

How archaeologists and investigators justify their actions is important to contrast. Both seek to undertake objective processes and analyses in what is also a subjective undertaking. Police forces, for example, have standard procedures, forms, and logs. Within this arrangement they

have an incident and policy change logbook in which to record when and why there were changes to the standard procedures, so that they have a written record to justify their actions in court. This logbook is controlled by the crime scene manager to minimise reporting conflict among officers. Archaeologists often operate in a more egalitarian way, with all team members completing recording forms. Archaeologists would benefit greatly from formalising the recording of methods and policy in an incident and policy change logbook. Control of recording by one archaeologist on a large forensic excavation team is often appropriate to limit interpretive conflicts and errors (Cox et al. 2008).

A checklist of evidential considerations for forensic archaeologists would be a great benefit (as is issued to CSIs for crime scene evidence), but such a checklist does not yet exist. The complexity of many forensic excavations (especially mass grave work) makes continual record-taking essential. Photographic working shots are a necessary way to record archaeological excavation method; they allow review of the excavation process and allow errors to be checked. Although for many police officers photography outside evidential shots is not encouraged (because it may record errors that will be noticed in cross-examination), for complex archaeological scenes it is vital. You may record 10,000 survey points and collect 2,000 pieces of evidence on a mass grave excavation. There will be error rates in records, labelling, and documentation on such scenes, and such process recording photography can allow inconsistencies to be resolved.

What is important is that there is an error-checking, quality-assurance process and that it is seen to be implemented. Repetition on forms for archaeologists and investigators may seem onerous, but it allows errors to be spotted and rectified or noted. Archaeologists have something to learn in many cases from the discipline of the exhibits officer who controls the error-reduction process to the satisfaction of a crime scene manager. At the same time, for U.K. domestic cases, the defence tactics of searching for errors to attack evidence has led to a lack of flexibility in recording crime scenes. Investigators stating the error rate discovered when checking records and describing this rate as normal (given the scale of personnel at the scene and the volume of documentation generation) may be the best way to counteract such inflexibility.

Variation of Methods

As mentioned in the section on *The Search Never Ends*, the requirements of the work depend on the nature of the investigation: policies and regimes change, and work originally undertaken for humanitarian reason and with limited expectations may be reviewed and later required for courts. In this example, data from an excavation undertaken to return victims to families may be required latterly as evidence in tribunals but will be critically analysed under a different set of criteria. To this end defining standards of fieldwork in terms of appropriate or inappropriate techniques is valid in a sense, where it has not normally be deemed necessary in other nonforensic archaeological excavations. The basic premise for archaeologists excavating in a forensic setting must be that it is presumed that any work done may be scrutinised and used by a court of law and should be of a standard acceptable to those courts,¹ whatever the original motivation for commissioning the work. If the archaeological record is viewed as forensic evidence, work undertaken must ensure that methods are in general practise and that they have been peer reviewed, and that they minimise evidential loss and destruction and are defensible in court; the results must also be presented in a way that allows them to be independently checked and verified. In the end—once they are informed—it may be the courts rather than the archaeologists that decide what archaeological standards and techniques are suitable for forensic work.

Huxley's "laws of nature" lie as a firm basis for appropriate archaeological methods in that gravity and the principles of geological and archaeological stratigraphy provide universal rules

for scientific interpretation of the archaeological record in forensic cases. Thus stratigraphic identification and excavation of individual archaeological contexts and systematic recording of these using plans and matrices extensively fulfil requirements of scientific evidence for courts.

All excavation methods are ultimately destructive of the source of the evidence they are attempting to recover and record. Excavation has been described as an “unrepeatable experiment” (Barker 1987); however, re-excavation of sites is possible and can provide productive results (see Hodder 2000; Hanson, Rizviç, & Parsons 2015). But once completely removed, deposits cannot be re-excavated using a different method. Methods that arbitrarily remove stratigraphic boundaries and do not record systematically lose evidence and are liable to be exposed as doing so. These methods are in common usage: Pedestalling—the digging of a grave by removing the surrounding material so as to leave the body on a sort of artificially created mortuary table—allows access but destroys the grave structure. And excavating in spits (removing arbitrary thicknesses of material across an area in horizontal slices) mixes soils (and so the evidence therein) from different stratigraphic units and limits stratigraphic understanding, the recording in plan and section, and the recovery of features as created. These arbitrary excavation methods are appropriate to use in some circumstances if they observe, obey, and do not destroy (without recording) the stratigraphic sequence of a site, but too often they are used because they are the conventional approach; they are convenient, straightforward, and require relatively little skill to undertake. And in many cases stratigraphic units are not recognised or deemed not to require individual identification, and so excavation evidence is lost and can be demonstrated to have been lost.

Why are these methods conventional? In part because there is a tradition of use in the background archaeological or crime scene culture or because they appear in published manuals or publications (see method examples in Bass 1978; Joukowsky 1980; United Nations 1991), now superseded for many purposes. For many archaeologists, there is also a good deal of variation in archaeological language; what is understood by specific terminology and recording conventions and techniques varies regionally and between institutions. Default methods become established, and dogmatic use can replace investigative suitability, appropriateness, and application (see Hanson 2004; Carver 2009, 2011). It is necessary to ensure that the most effective excavation interventions are used; such assurance requires planning and assessment of what methods to employ. However, many archaeologists may lack experience dealing with varied methods, diverse landscapes, and complex stratigraphy; they are simply not used to identifying or excavating complex stratigraphy, because it may not be identified or exist in their normal work environment (such as in plains of horizontal loess build up). This is a slight “chicken and egg” situation in that a method that limits stratigraphic exposure during excavation does not promote stratigraphic understanding; without that understanding the appropriate method to maximise stratigraphic exposure will not be realised. In forensic contexts there is always stratigraphy: cut features, surfaces, and deposits intruding into previously established deposits and strata caused by anthropogenic (together with sometimes natural) activity.

Another convention for excavation in the forensic arena comes from physical anthropology: the focus of the excavation is the body or bodies, rather than their context in the crime scene, as well as the crime scene history itself. In practice these foci are not mutually exclusive. Stratigraphic excavation is a cornerstone of the recovery of buried remains and evidence in archaeological or forensic archaeological excavation. It can demonstrate and establish the stratigraphic sequence of a site, provide secure contexts for dating evidence, and reveal occupation surfaces relevant to events under investigation—advantages over other often employed methods. And herein lies the crux of the matter and so the crux of the whole recovery process—archaeological excavation is destructive; a missed stratigraphic unit not only is usually destroyed when excavated, but its

stratigraphic relevance cannot be established and potentially its existence not even realised by the excavator and thus by anybody else, if it is not recognised. The stratified nature of buried geological, environmental, and archaeological layers, features, and deposits—and their direct relation to dating events and sequencing activity—is still not grasped by many involved in criminal and human rights investigation. Often the ground is seen as the surface of a sea of mud that has no more definable structure and subtlety than the perceived nature of the oceans. So what is not recognised cannot be found, and there is no knowledge that anything has been lost.

Ultimately there is potential for evidence or criminal activity not being fully recognised, investigations not progressing, the missing not being found, and perpetrators not being convicted. In such circumstances lack of stratigraphic recording and understanding becomes a gift for defence lawyers, allowing them to raise questions of reasonable doubt; evidence destroyed could have provided proof of innocence for the accused.

Debate at institutional level about such methods has been limited thus far, because the methods of excavation and recovery used by archaeologists in forensic cases have not been thoroughly examined and challenged in any national or international courts. Why? Many criminal investigators, lawyers, and judiciaries are not yet as aware of the status, issues, and science behind archaeology in its application to the criminal and forensic field in the same way as they are of other areas of the forensic process, such as the rules of chain of custody and fingerprinting methods. No doubt in the future certain moves in this archaeological chess game will be seen as too liable to checkmate in court to be valid for forensic purposes.

The idea that excavation itself is a mechanical, technical, and systematic exercise is also widely accepted by archaeologists and investigators. Many archaeologists define their ability to excavate by the relative accuracy of their spatial control (for example, removing soil in fixed, horizontal, arbitrary spits) instead of defining the nature of the archaeological record. This definition is an important concept—removing spits by levels is a method of boundary control in three dimensions, and one can easily gain competency in it, but this competency does not equal competence in stratigraphic understanding, which is needed to demonstrate scientific rigour in forensic archaeological excavation. What then is appropriate? A flexible strategy is needed.

Archaeologists, when asked how they know what methods should be used for excavating a site, often respond: “you do it from experience.” This response is scant help to graduates and archaeologists seeking to develop their skills in this new area of the profession, or for crime scene, investigative, and medical-legal professionals seeking clarity and guidance, and it is a difficult argument to sustain under cross-examination without further explanation. Paradoxically there are hundreds of guidelines, manuals, and procedures used for excavation by archaeologists and forensic practitioners according to their needs and experience (Evis 2014). These guidelines, manuals, and procedures include a wealth of forms and logs for capturing information that, while having common data fields, vary greatly in the type and detail of data that they are prompting to record. The aim for the archaeologist, as for a chess player, is to have a mental store of moves for the right game strategy—a “tool box” of techniques and methods that can be applied for the right circumstance. Competent forensic archaeologists, however, do not spend a great deal of time calculating moves, their experience leads them (by pressing need) to rapidly understand a site and its requirements and to make decisions. There are standard methods—for example, stratigraphic excavation, levelling, spitting, single context planning, and half sectioning have been described in the archaeological literature (Harris 1979; Barker 1987; Museum of London 1994; Roskams 2001) and are frequently used. Although such methods may be a starting point, in truth, the excavation process is reflexive and involves employing all the physical senses wielding a skill borne out of extensive experience. The archaeologist’s experience comes into play when the standard methods are perceived to be limiting for maximising data recovery and crime scene reconstruction

because the site presents archaeological or environmental extremes out of the ordinary realm of practice or of the practical application of a specific method. Examples in forensic cases may be logistical in nature (for instance, when deep mass graves penetrate the water table and require remedial engineering works) or technical (such as when the grave cut extends into the vegetative layers and O horizon—the top, organic layer of soil, made up mostly of leaf litter and humus—of the relevant stratigraphy). The archaeologist has the expertise to adjust methods to take account of active bio-turbation in the O and A horizons (“often described as ‘topsoil’”) that may have displaced evidential material downward to an artificial horizon of deposition. What is important is that any method used must be justifiable to the management of the investigative process and also to any court or critical review. The consequences of potential data loss from use of certain methods in certain circumstances must also be assessed and justified.

Demonstrating and knowing, however, which excavation and recording methods are appropriate to forensic investigations (which often means burials) are difficult for practitioners, because relatively little has been published in detail on the practical processes of archaeological excavation and the pros and cons of such techniques (for example, Hanson 2004; Hunter & Cox 2005; Connor 2007; Cox et al. 2008; Dupras et al. 2011; Hunter, Simpson, & Sturdy Colls 2013; Hanson 2015). Many writers and organisations state that methods used should be “appropriate” or “demonstrably fit for purpose” (see, for example, The Chartered Institute for Field Archaeologists 2014b) without describing what these requirements mean, and often methods end up being used out of convention rather than suitability. This situation may prove problematical under critical review in court, because it can leave archaeologists in some circumstances without defined and justified methods or standards that have been agreed on. Also, definition of how methods and techniques have progressed and developed in terms of applicability has been limited, but this situation is improving in response to discussion of approaches, methods, and standards for forensic evidence (Hanson, Evis, & Pelling 2011; Evis et al. 2014; Groen, Márquez-Grant, & Janaway 2015) and excavation (Harris 2006; Carver 2009; Lucas 2012). It could be claimed that the development of standardised approaches has been avoided in archaeology more generally in an attempt to limit confrontation over views on excavation methods historically undertaken and consequently the level of data recovery they may reflect. However, critical discussion has occasionally taken place in field archaeology (Droop 1915; Wheeler 1954; Harris, Brown, & Brown 1993). Although the strictures of defining archaeological definitions may be considered an anathema in an archaeological academic context, avoidance of defining methods and their effects is not possible for forensic work in an inquisitive judicial domain. Differing excavation methods do produce different results, but equally significant is that different excavators using the same methods can also produce different results and interpretations (Evis 2014). Thus how one tests for excavating competence is something the discipline of archaeology, and now forensic archaeology, needs to address.

Archaeologists as Facilitators for Multidisciplinary Investigation

The field of forensic archaeology is now widely seen as a useful tool for certain investigations and is one of an increasing number of scientific specialties utilised by investigators. Archaeologists, who within their own professions may view their extensive knowledge of the natural sciences as giving themselves a “jack of all trades” status, need to consider this position carefully in the forensic arena. Archaeologists are usually very good at identifying anomalies and archaeological features in landscapes as well as a wide range of artefact types of potential relevance to investigations. They are often well placed to draw in the necessary specialists to appropriately sample and analyse material of interest. In the forensic setting the pressures from investigators to rationalise

costs and personnel at the crime scene often lead to demands of one specialist (for example, the archaeologist, geologist, or palynologist) to undertake sampling and recovery of all evidence, some of which falls outside their level of expertise. This situation must be resisted. Few archaeologists have the qualifications or experience to undertake the role of anthropologist or other specialists and then defend themselves in court as experts in these areas (and vice versa). Although the archaeologist, as does the crime scene manager, habitually uses many experts in site/scene analysis, his or her role in forensic terms should, in the first instance, be limited to advising investigators on what other experts may be required to maximise evidential identification and recovery.

Internationally, archaeologists have at times led the scientific management and recovery at mass graves, because they have been the most experienced and suitable to make sense of these large-scale scenes. The skills required can often be acquired through experience gained on the excavation of stratified urban sites where the stratigraphy is typically complex and archaeologists must deal with financial and time constraints, health and safety and staff welfare issues, and logistics, machinery, and engineering problems. The senior investigating officer, crime scene manager, and scientific support fulfil many of these roles in domestic investigations, and this arrangement is a useful model to be considered for international work. Clearly any murder, mass murder, or disaster scene is such a complex investigative environment that a multidisciplinary approach, especially in terms of locating and recovering evidence by scientific specialists, should be the standard.

The standard process undertaken by archaeologists at the beginning of a project involves desktop research and analysis to assist in designing archaeological investigations (see, for example, The Chartered Institute for Field Archaeologists 2014c). This process should be more widely adopted within the discipline globally and as part of international investigation approaches. Integrating planning input from specialists, including archaeologists, into domestic and international crime scene investigations can be only beneficial. How the landscape is analysed to define how to approach, resource, and organise field work provides the basis for effective site assessment and excavation. However, having limited investigative timeframes to complete work and organise forensic archaeological assistance is often quoted as a barrier to formal desktop research and planning. The same argument of limited time is also used to justify the speed of excavation. Time pressure always has a significant impact on excavation, when the design and undertaking of archaeological interventions are curtailed. The forensic archaeologist has a responsibility to inform investigative authorities of the likelihood and nature of the effects of a shortage of time and what a reasonable planning and practical investigation timeframe would be. Investigative authorities should be expecting such advice.

Conclusion

The use of archaeology and archaeologists in criminal, humanitarian, and disaster excavation and recovery is slowly becoming incorporated into standard operating procedures, management strategies, and tactics of practical scene investigations. Defined archaeological practice and methods need to be synthesised into the processes of crime scene management and should consider auditing, quality review, error reduction, evidential control, and custody management. At the same time, the benefits for crime scene investigation of archaeologists bringing a wide spectrum of processual and analytical approaches utilising the interpretation of the natural history, archaeological, and environmental record to landscapes and burial scenes are clear. This situation provides very useful tools for investigators to maximise evidential recognition and recovery as well as crime scene and event reconstruction. Archaeologists are important facilitators, researchers, and planners within multidisciplinary forensic investigations. Archaeologists

need to describe the methods and approaches they apply to forensic cases to demonstrate that the work they undertake is appropriate and can be explained and justified according to the needs of the legal and evidential process; it should be presumed that all cases of excavation and recovery in the forensic arena may end up in court. Archaeologists have a role in opening up lines of enquiry to be explored and have a responsibility to inform the forensic community of the strategies that will maximise evidential recovery and archaeological potential.

Note

- 1 Debating which standard and which court consequently arises; standards of evidential control enforced on U.K. domestic murder scenes are different, for example, from those of an international tribunal. Perhaps a key argument is that precedence in both national and international law is developing so that citizens of any country might be indicted and seized for trial in an international or national court for crimes committed abroad; for example, see the Zardad case (BBC 2005). Applying a standard of optimum evidential recovery in all circumstances seems a logical approach as these global cases begin to determine common approaches to crime scene recovery.

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Part III

Forensic Anthropology

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Differentiating Human from Nonhuman Skeletal Remains

Dawn M. Mulhern

One of the first questions faced by a forensic anthropologist is whether skeletal remains are human or nonhuman. When complete or partial bones are present, gross analysis of morphological features can often be used to confirm or rule out whether the remains are human. Extreme fragmentation makes morphological analysis more difficult if not impossible and may require microscopic, biochemical, or DNA analysis. This chapter explores the morphological differences between human and nonhuman bone and discusses the most common examples of misidentification. Next it investigates microscopic techniques for distinguishing human from nonhuman bone. Finally it reviews chemical and biomolecular analyses.

Gross Analysis

Human bone is most similar to the bone of other mammals and therefore most likely to be confused with mammalian species. When encountering skeletal remains, one must consider what species are most likely to be present in that area. The unique combination of a very large brain case, a nonprojecting jaw, and adaptations to bipedal locomotion in humans provides many morphological differences between humans and nonhuman mammals that are useful for distinguishing individual skeletal elements. Subadult human bone can also be distinguished from adult mammalian bones that are similar in size by the presence of unfused or partially fused epiphyses. A number of sources for archaeologists provide illustrated atlases comparing and describing the differences between human and nonhuman bone (Cornwall 1956; Schmid 1972; Gilbert 1973; Olsen 1973). Photo atlases by France (2009), Adams and Crabtree (2012), and Beisaw (2013) are intended for archaeological and forensic contexts. Some of the most important differences between human and nonhuman bone are summarized in the following sections.

Skull

Compared to that of other mammals the human cranial vault is very large relative to body size; also, the human cranium has a more domed shape and thinner cortex compared to that of other mammals. The frontal, temporal, and occipital bones fuse in early childhood in humans but remain as separate elements in many mammals (Cornwall 1956). The human vault exhibits gracile muscle attachment sites and lacks sagittal and nuchal crests. A notable exception is the large mastoid process, the attachment site for the sternocleidomastoid muscle, which functions in swiveling and tilting the head in humans to accommodate a vertical posture. The foramen

magnum is also centrally located in the cranial base; in quadrupeds the foramen magnum is more posteriorly situated.

The mandible is short antero–posteriorly in humans, resulting in a lack of prognathism. The coronoid process is only slightly higher than the mandibular condyle. In some mammals the coronoid process is much more superiorly located compared to that of the condyle (horse, cow, deer, sheep, rabbit, bear, beaver) and is also located much more anteriorly in humans compared to other mammals (Schmid 1972). Humans have a projecting chin, or mental eminence.

Dentition

Human teeth are easily differentiated from the teeth of most other mammals owing to size and morphology. Humans exhibit small canines with apical wear, lack a diastema, and have nonsectorial premolars. Human premolars and molars have low, rounded cusps adapted to an omnivorous diet; they are easily distinguished from the teeth of herbivores, which have distinct crests, and carnivores, which are sharp and pointed with cutting edges. Other mammals with similar molar form to humans include bears and pigs; however, bears have much larger teeth than humans. In pigs the first three premolars are sectorial (and therefore have a sharp cutting edge), and the three molars are larger than human teeth. The only possible point of confusion is between the fourth premolar in a pig and a human molar (Byers 2005).

Vertebral Column

The human spine is characterized by an S-shaped curve that accommodates a vertical posture. The vertebral bodies gradually increase in size from the superior to the inferior aspect of the vertebral column, owing to the need to support increasingly more weight. This pattern is not as dramatic in quadrupeds, since compression forces from gravity are similar throughout the spine. The number of vertebrae differs among mammals—for example, members of Order Carnivora have 1–3 more thoracic vertebrae and 1–2 more lumbar vertebrae than humans do (Cornwall 1956).

Compared to that of other mammals, the human atlas exhibits shallower occipital condyles and a much smaller distance between facets for the occipital and axis. The human axis has a short, stout odontoid process. The spinous processes of the cervical vertebrae are often bifid in humans. In addition, spinous processes are short in humans compared with those of other mammals, because they do not support the massive musculature needed by quadrupeds in the neck and back. In humans, all the spinous processes are oriented inferiorly. Quadrupeds have an anticlinal thoracic vertebra with a vertical spinous process; all other spinous processes are inclined toward it, caudally for the cervical and upper thoracic spine and cranially for the spinous processes of the lower thoracic and lumbar spine (Cornwall 1956). Human vertebral bodies are shorter and broader compared to those of other mammals of comparable size. As shown in Figure 15.1, many nonhuman vertebrae exhibit a ridge on the anterior vertebral body along midline (France 2009). In addition, elongated accessory processes on the thoracic and lumbar vertebrae that are located lateral to the caudal apophyseal facets and project caudally are found in a variety of mammals (for example, dog, bear) but are not found in humans (Figure 15.2). These processes are sites of attachment for the epaxial muscles.

Sternum and Ribs

The human rib cage is broad and shallow, like that seen in apes. Most mammals have a horizontal posture that is characterized by a narrow, deep thorax. The human sternum is a flat bone; the



Figure 15.1 Bear vertebra with vertical ridge on anterior body



Figure 15.2 Posterior view of bear vertebra with inferior accessory processes lateral to the caudal apophyseal facets

manubrium (topmost segment) is somewhat triangular in shape, and the sternal body is made up of several fused elements that are roughly rectangular. Comparisons between the human sternum and sternal elements from horse, bear, and pig show distinct differences in both size and morphology (Adams & Crabtree 2012). The curvature of the ribs is different in humans and most mammals, with human ribs exhibiting a more pronounced curve. Furthermore, ungulates have bony rib elements that connect the anterior end of the vertebral ribs with the sternum (Stewart 1979).

Pelvis

The morphology of the human pelvis is unique, owing to bipedal locomotion. The ilium is broad and ventrally wrapped in humans, in contrast to the elongated, dorsally positioned ilium in quadrupedal mammals. The broad shape of the human ilium is apparent at all phases of development, including fetal bone. The pubic symphysis is rarely fused in humans, whereas it is often fused in other mammals. The sacrum is broad and wedge-shaped in humans; it is generally narrower in other mammals, either with an overall triangular shape or a combination of a wider first segment with pronounced tapering caudally. The coccyx in humans takes the place of tail vertebrae found in other mammals.

Shoulder Girdle

The human clavicle is long and robust, because the upper limbs are located on the sides of the body. The retention of a clavicle is a primitive trait in mammals. In addition to primates other

mammalian orders that exhibit functional clavicles include insectivores, rodents, and bats. Although ape clavicles are similar in size and morphology to human clavicles, other mammals that would potentially be confused with humans based on size either have reduced clavicles or lack clavicles completely. Adams and Crabtree (2012) note a similarity in morphology between the human clavicle and the femora of crocodiles and alligators.

The human scapula is triangular in shape, with a large infraspinous fossa. Nonhuman scapulae exhibit a much smaller postspinous fossa relative to the size of the bone. The neck of the scapula is particularly long in artiodactyls (even-toed ungulates). The shape of nonhuman scapulae ranges from triangular to oval to rectangular; the bear scapula exhibits a second spine (France 2009). Also the human scapula is longest perpendicular to the spine, whereas other mammals exhibit scapulae that are longest along the axis of the spine (Figure 15.3).

Long Bones

Long bones in humans are more slender and exhibit less pronounced muscle markings compared to long bones in other mammals. The articular surfaces of human long bones are also flatter with less of a sculpted appearance than other mammalian bones (Figures 15.4 and 15.5). In the humerus the deltoid tuberosity and supracondylar crest may be particularly well-developed in nonhuman mammals. The head of the humerus in humans is hemispherical, allowing a wide range of motion in the shoulder. This feature is found in suspensory primates, but other mammals

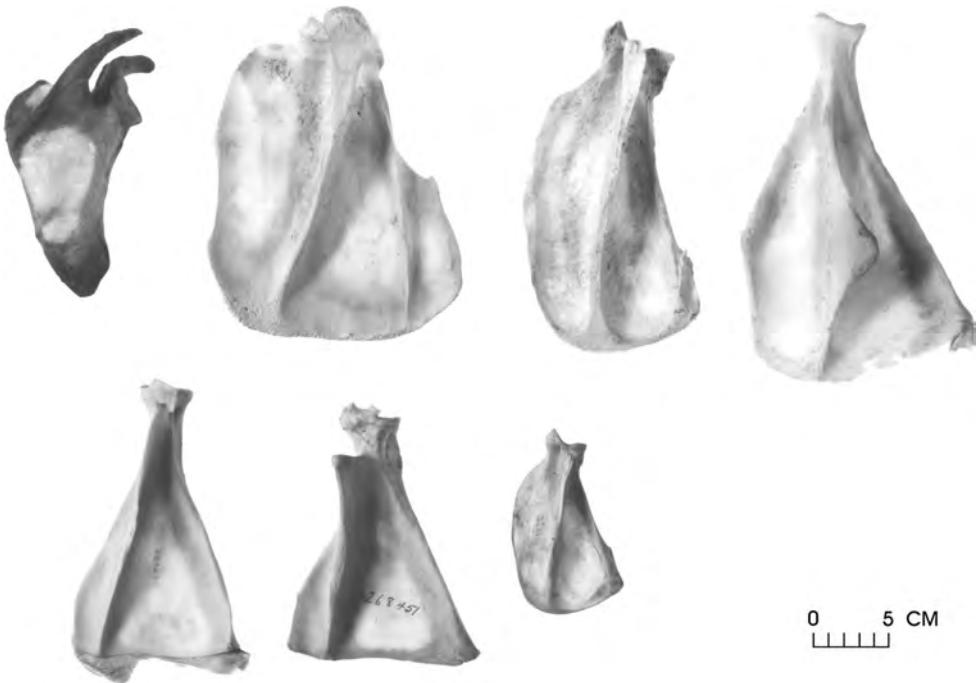


Figure 15.3 Scapula of an adult human compared with that of a black bear, large dog, hog, deer, domestic small dog (left to right) (photos previously published in Ubelaker 1989 as Figure 63; courtesy of D. H. Ubelaker and Taraxacum Press)



Figure 15.4 Humerus of an adult human compared with a black bear, large dog, hog, deer, domestic small dog (left to right) (photos previously published in Ubelaker 1989 as Figure 63; courtesy of D. H. Ubelaker and Taraxacum Press)



Figure 15.5 Radius and ulna of an adult human compared with a black bear, large dog, hog, deer, domestic small dog (left to right) (photos previously published in Ubelaker 1989 as Figure 63; courtesy of D. H. Ubelaker and Taraxacum Press)

have flatter humeral heads. The greater tubercle of the humerus in humans does not extend above the humeral head, unlike in other mammals, such as cows, deer, sheep, and pigs. The capitulum is prominent in the human humerus, to accommodate the enhanced mobility of the radial head. In most quadrupeds the radius also articulates with the trochlea. The coronoid process is more prominent and the olecranon fossa is less prominent in humans than in quadrupeds. A supratrochlear foramen is found in pigs, wolves, foxes, bears, and rabbits. An entepicondylar foramen is present in some mammals, such as raccoons, weasels, otters, pumas, and bobcats (Cornwall 1956; Olsen 1973). Human populations variably exhibit a supratrochlear foramen with incidence ranging from 4.2%–58% (Nayak et al. 2009). The human ulna has a very short olecranon process, allowing a wider range of motion in the elbow than typical of most mammals. In quadrupeds the olecranon process is extended, providing more leverage for the triceps. The radial head is more rounded in humans than most other mammals, allowing a wide range of supination and pronation of the forearm. The radius and ulna are fused together in some mammals, such as the sheep, goat, cow, horse, and pig (Olsen 1973; France 2009; Adams & Crabtree 2012).

The femur is long and the shaft is medially angled in humans. Compared to that of other mammals, the human femoral shaft has a smaller circumference for its length. The human femur exhibits a robust head and a long neck. The angle between the neck and the shaft is greater in humans compared to most quadrupedal mammals (Figures 15.6 and 15.7). The attachment site for



Figure 15.6 Femur of an adult human compared with a black bear, large dog, hog, deer, domestic small dog (left to right) (photos previously published in Ubelaker 1989 as Figure 63; courtesy of D. H. Ubelaker and Taraxacum Press)



Figure 15.7 Tibia of an adult human compared with a black bear, large dog, hog, deer, domestic small dog (left to right) (photos previously published in Ubelaker 1989 as Figure 63; courtesy of D. H. Ubelaker and Taraxacum Press)

the leg extensors, *linea aspera*, is well developed in humans (Cornwall 1956). A lateral lip is present on the anterior aspect of the distal femur; this feature of the distal articular surface helps to hold the patella in position during the force of a striding gait. The distal anterior articular surface of the femur in other mammals tends to be more sculpted (France 2009). The proximal and distal articular surfaces of the tibia are flat and platform-like, to accommodate the weight of a biped. The fibula is absent or rudimentary in many artiodactyls, and the tibia and fibula are fused together in many smaller mammals, such as rabbits and rodents (France 2009; Adams & Crabtree 2012).

Hands and Feet

Unlike most mammals humans retain the primitive trait of five digits. The heads of the metacarpals and metatarsals are rounded, allowing extensive mobility of the digits; they lack a median ridge. The metapodials of artiodactyls exhibit deep grooves and prominent foramina (France 2009). The articular surfaces of the hand and foot phalanges in humans are flatter than in other mammals, which typically exhibit median grooves on the proximal and distal articular surfaces. The first digit of the human hand is opposable with a saddle-shaped trapezium. The first metatarsal is more robust than the other metatarsals in humans. The tarsal bones in humans are robust owing to bipedal locomotion. In particular, the talus has a very flat, platform-like superior articular surface.

In North American contexts bear paws and human hands and feet have been shown to exhibit similarities that may lead to confusion, particularly in cases where a bear paw is partially fleshed and lacks the claws (Stewart 1959). Bears exhibit larger carpals than humans, with a fused navicular and lunate. In the hand, the second or third metacarpal is longest in the human, whereas the fourth metacarpal is longest in the bear (Stewart 1979). The differences between the metacarpals and the phalanges of a human and bear are shown in Figure 15.8.

In the foot, the first human metatarsal is more robust than the others, whereas in the bear all five metatarsals are comparable in robusticity. The second metatarsal is longest in humans, and the fourth metatarsal is longest in the bear (Gilbert 1973). The distal ends of the phalanges exhibit deeper grooves in the bear. Bears also exhibit sesamoid bones on the heads of all of the metacarpals and metatarsals, whereas humans typically have sesamoid bones only on the head of the first metatarsal (Hoffman 1984).

The third pedal proximal phalanx of the turkey is similar in size and morphology to a second or third human toe phalanx (Figure 15.9) and might be confused, particularly if found in isolation at an archaeological site. A slight groove is present at the distal end of the turkey phalanx, and the human phalanx shows more constriction of the shaft. The proximal articular surface of the human toe phalanx is oriented more dorsally.

X-Ray Analysis

Chilvarquer and colleagues (1987) conducted a comparative radiographic analysis of long-bone patterns in human and nonhuman bones. They found that the trabeculae of the spongy bone in human long-bone midshafts sometimes show homogeneous but sparse distribution, whereas the trabecular pattern in nonhuman bone is more homogeneous and dense. Unlike nonhuman



Figure 15.8 Comparison of an adult human hand (left) with the front paw of a young bear (right), including metacarpals, proximal and middle phalanges



Figure 15.9 Comparison of proximal third phalanx from a turkey (left) and a human (right)

bone human bone often lacks a clear border between the cortical and trabecular bone. Finally, nonhuman bones are characterized by small, spicule-like invaginations from the cortex into the trabecular bone and the penetration of nutrient canals into the midshaft. A test of this method on 20 samples resulted in the correct classification in 86.8% of cases by archaeologists and 81.9% by dentists (*ibid.*).

Beckett and colleagues (2011) conducted a study of human and nonhuman bone mineral density using powder X-ray diffraction (XRD) and found significant differences in bone mineral lattice parameter values, recrystallization behavior, and thermal decomposition products between human bone and nonhuman bone (including 11 nonhuman species) in both unheated and heated bone. However, a larger XRD study by Piga and colleagues (2013) on 42 nonhuman bones and 53 human bones showed too much overlap between human and nonhumans samples using lattice parameter values to distinguish the two.

Microscopic Analysis

Microscopic analysis may provide useful information in differentiating human from nonhuman bone when remains are fragmentary and gross differences are not observable. Differences in bone microstructure among species have been recognized by numerous studies dating back to the mid-19th to the early 20th century (Quekett 1849; Foote 1916; Enlow & Brown 1956, 1957, 1958). A number of more recent studies investigating the histomorphological as well as histomorphometric characteristics of mammalian bone¹ and human bone² have also contributed to the comparative literature.

The overall pattern of bone microstructure may be useful, particularly in ruling out that the bone is human. Mammalian bone includes both lamellar and fibrolamellar bone. Lamellar bone may be identified as concentric layers of circumferential bone at the periosteal or endosteal

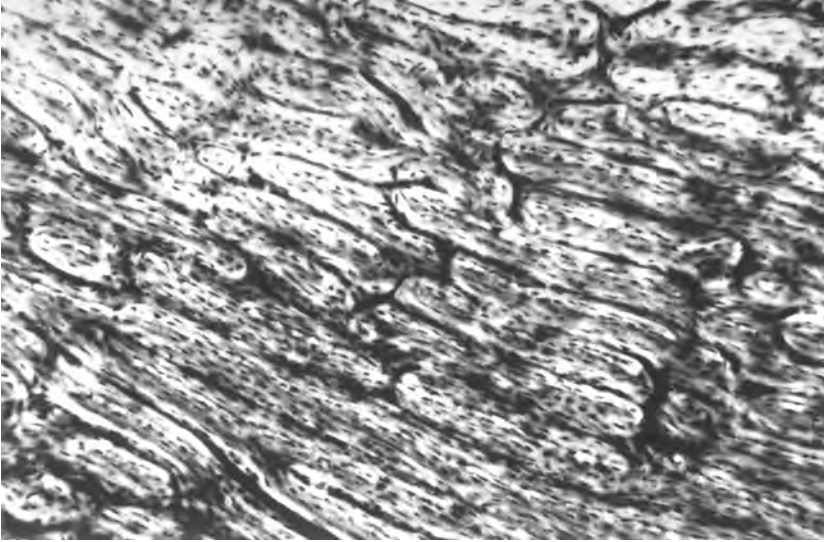


Figure 15.10 Sheep femur showing plexiform, or fibrolamellar, bone

cortex, as discrete units of concentric layers surrounding a Haversian canal (also known as a Haversian system, or secondary osteon), or as interstitial lamellae that represent remnants of old osteons. Fibrolamellar bone is characterized by a network of woven bone that is laid down quickly and filled in more slowly by lamellar bone, often resulting in a regular, rectangular pattern known as plexiform bone (Figure 15.10) seen in many mammals.

Large mammals, including many artiodactyls (for example, cows, sheep, pigs, and deer), have bone diameters that grow quickly and exhibit mostly plexiform bone, with Haversian bone primarily near muscle attachments. Sometimes the blood vessels in fibrolamellar bone anastomose and are surrounded by layers of lamellar bone, resulting in the creation of primary osteons (Currey 2002). Primary osteons are distinguished from secondary osteons by the lack of a reversal line. As illustrated in Figure 15.11 the arrangement of these primary osteons is often linear, with multiple rows, or bands, of these structures. The primary osteons may also eventually be replaced by secondary osteons. This pattern is common in mammalian bone but uncommon in human bone (Mulhern & Ubelaker 2001; Brits, Steyn, & L'Abbé 2014).

Fibrolamellar bone is common in nonhuman mammals, but can also be found in fetal human bone (Pfeiffer 1996). In general, large mammalian bones that could be confused with human bones based on size can be ruled out as human if the overall pattern is plexiform or laminar with multiple osteon rows, or bands. Haversian systems are common in both human and nonhuman bone. In primates and carnivores Haversian bone replaces primary bone (Currey 2002). Haversian systems can be isolated, scattered, or densely packed, depending on various factors, including chronological age and mechanical demands. If such a pattern is encountered and plexiform bone and osteon banding are absent, human bone cannot be ruled out. Haversian bone is shown in Figure 15.12.

Ubelaker (1989) used osteon banding to identify a large bone fragment as nonhuman. Authorities initially identified the fragment as human, because it had a pseudoarthrosis held together with a surgical plate. Microscopic analysis of the fragment revealed a pattern of

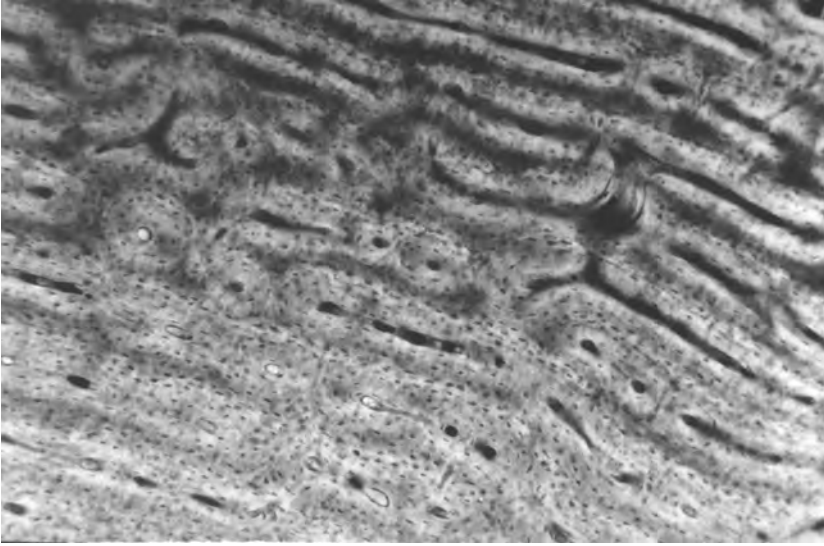


Figure 15.11 Fibrolamellar bone, including osteon banding in the femur of a miniature swine

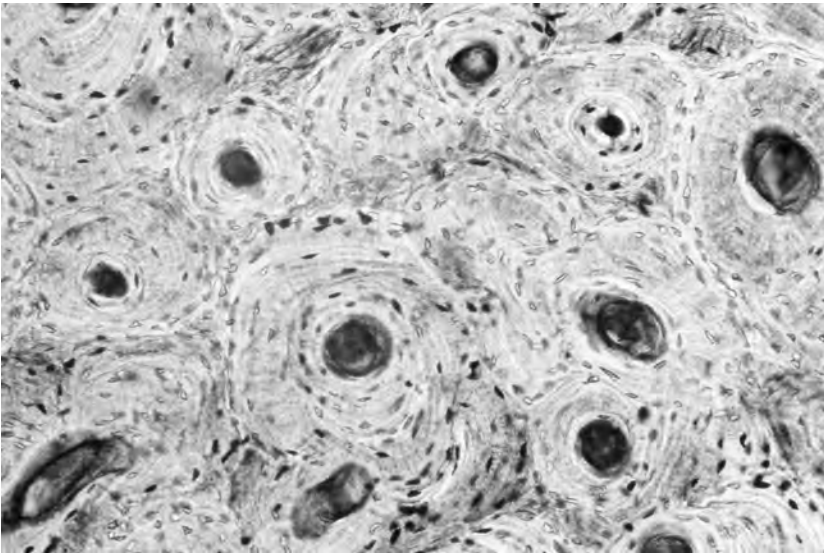


Figure 15.12 Haversian bone in an adult human femur

alternating osteon bands, including both primary and secondary osteons, and lamellar bone. The fragment was most likely from a large dog, with the surgical work performed by a veterinarian.

Microstructural variables, such as osteon number or size, have varying potential to distinguish species. Osteon density is partially age dependent and therefore a poor indicator for discriminating among species. Differences in microstructural measurements including osteon

size, and Haversian canal size show some promise. The current literature includes a number of quantitative studies on nonhuman bone (Jowsey 1966; Georgia et al. 1982; Albu, Georgia, & Georoceneau 1990; Martiniaková, Vondráková, & Fabiš 2003; Mori et al. 2005; Martiniaková et al. 2007b). Haversian canal sizes are typically smaller in nonhuman species. Problems with studies comparing histomorphometric variables in human and nonhuman bone include small sample sizes and measurements of different dimensions requiring conversion to a common variable for comparison resulting in a wide range of variability of results. Additional studies are needed for nonhuman taxa, particularly those like the dog, with such extensive variability in body size.

Cattaneo and colleagues (1999, 2009) and Martiniaková and colleagues (2006, 2007a) used quantitative data to generate discriminant functions for distinguishing human and nonhuman bone. These techniques show some promise, particularly for adult long bones, with correct classification ranging from about 70%–76%, but accuracy is not high enough to be used reliably in forensic contexts. Martiniaková and colleagues (2006) suggest combining qualitative and quantitative analysis when attempting to distinguish human and nonhuman bone.

Owsley, Mires, and Keith (1985) used bone microstructure to help determine the origin of several unknown bone fragments that belonged to a homicide victim. The suspect in the case claimed that the bone fragments found in his truck belonged to a deer that he had shot. The bone fragments from the truck were compared with bone from the victim's humerus as well as a deer humerus. Osteon density and Haversian canal diameter were consistent with the human bone and inconsistent with deer bone. In this case the comparison with the victim was important, because the values for osteon density and Haversian canal diameter observed in the deer did not fall outside the human range, but they were not comparable to the victim.

In a case involving numerous, small unknown bone fragments Stout and Ross (1991) used cortical thickness and a lack of plexiform bone to rule out bone from larger mammals and used osteon size to rule out dog bone. Further, the cortical thickness and the orientation of the osteons suggested that the fragments were from the skull. This information, in conjunction with evidence from DNA and chemical analyses, was used to convict the murder suspect, even though the body of the victim was never recovered.

Recently osteon circularity has been examined as a possible distinguishing characteristic of human and nonhuman bone. Crescimanno and Stout (2012) found differences between human and nonhuman (deer, pig, and dog) long bones and ribs, with more circular osteons in nonhuman bones. No differences were observed between the sexes or among the three nonhuman species in osteon circularity. Dominguez and Crowder (2012) looked at both osteon circularity and osteon area in deer and dog ribs and long bones and human ribs. They found that osteon circularity was a poor discriminating characteristic alone (76.3% correct classification for ribs and 66.1% for all elements), but osteon area was a good discriminating factor (92.1% for ribs and 93.5% for all elements). Combined variables had an accuracy rate of 100% correct classification for ribs and 98.4% for all elements.

Chemical Analysis

McLaughlin and Lednev (2012) tested the potential of Raman spectroscopy in distinguishing the bone chemical composition of four nonhuman species (turkey, chicken, pig, and cow). In this method a laser is used on bone samples, generating information about the composition of bone, particularly the relative amounts of bioapatite and collagen. All four species were successfully discriminated using this method, supporting the need for future studies that include human bone as well as controls for age, sex, and other variables.

Biomolecular Methods

Biomolecular methods are also potentially important for distinguishing human and nonhuman bone and are useful for identifying species. Ubelaker, Lowenstein, and Hood (2004) applied a technique developed by Lowenstein (1980) for identifying human albumin to a sample of three human and three nonhuman bones. The technique involves extracting protein from the bone and then conducting a solid-phase double-antibody radioimmunoassay. Rabbit antisera were exposed to albumins or sera from different known species. The resulting species-specific antibodies were then allowed to bind to antigens in the bone protein samples. Radioactive antibodies were used to identify the strongest reactions, which indicated species-specific relationships. All six samples were correctly identified as human or nonhuman, although some protein depletion was noted in the one human sample of archaeological bone. A deer sample was tested for species-level identification and was successfully distinguished from other nonhuman species, including cow, deer, dog, goat, and pig. One benefit of this method is that only a small bone sample (200 mg or less) is required.

Techniques involving repetitive mitochondrial DNA markers have been used successfully in wildlife forensics for identifying the species of an unknown sample, including a variety of game and commercial species such as pig, cow, sheep, deer, moose, elk, bear, and turkey (Guglich, Wilson, & White 1994; Murray, Clymont, & Strobeck 1995). Melton and Holland (2007) reported the use of polymerase chain reaction (PCR) and sequencing of a short fragment (~150 base pairs) of mtDNA that codes for mitochondrial 12S ribosomal RNA in successful species identification for hair and tissue in 19 samples, but they suggest that this method is also applicable to bones and teeth and is particularly useful in cases involving degraded samples. Techniques that apply the use of restriction enzymes are potentially preferable to DNA sequencing methods, because they are faster and more cost-efficient.

Conclusion

In terms of cost and efficiency, gross analysis of bones is the preferred and most common method of distinguishing human and nonhuman bone. Anthropologists may even be asked to provide such a distinction from photographs when discoveries are made in more remote locations or as an initial assessment in determining context. Photographs must be of high quality, include a scale, and preferably include several different views. In cases of highly fragmented remains that lack diagnostic features, more specialized approaches involving nondestructive (X-ray) or destructive techniques (microscopic or biomolecular analyses) may be necessary.

Notes

- 1 Albu, Georgia, & Georoceneau 1990; Brits, Steyn, & L'Abbé 2014; Burr 1992; Castrogiovanni et al. 2011; Cattaneo et al. 2009; Cuijpers 2006; Georgia & Albu 1988; Georgia et al. 1982; Jowsey 1966, 1968; Martiniaková, Vondráková, & Fabiš 2003; Martiniaková et al. 2006; Martiniaková et al. 2007a; Martiniaková et al. 2007b; Mori et al. 2005; Mulhern & Ubelaker 2001, 2003, 2006; Schaffler & Burr 1984; Singh, Tonna, & Gandel 1974.
- 2 Cho et al. 2002; Currey 1964; Eriksen 1991; Evans 1976; Kerley 1965; Pirok et al. 1966; Singh & Gunberg 1970; Stout & Paine 1992; Thompson 1980.

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Dating of Anthropological Skeletal Remains of Forensic Interest

Shari Forbes and Kimberly Nugent

Traditional areas of research in forensic anthropology have dealt with variation in sex and population affinity and with estimation of age and stature for purposes of identification (Roberts 1996; İşcan & Loth 1997; İşcan 1998, 2001). Although the importance of these subjects has in no way diminished, additional foci have become increasingly visible over the last decade. Emerging areas of research and practice in forensic anthropology focus on factors relating to the context of the crime scene. Of the newly developing areas, the determination of time since death (or postmortem interval) has proven to be among the most challenging.

The initial determination of postmortem interval (PMI) can assist in distinguishing between modern and ancient bones (Nafte 2000; Ubelaker 2001). Establishing whether skeletal remains are of forensic significance is of prime importance in determining whether a criminal investigation will be launched (Knight & Lauder 1969; Jarvis 1997). In a forensic context, establishing PMI of skeletal remains is important in providing investigators with a timeframe in which the person may have disappeared, thus increasing the likelihood of a positive identification (Forbes 2004; Blau In press). It also plays a key role in determining the final movements of a victim and identifying potential suspects within the investigation (Pollard 1996; Haglund & Sorg 1997).

Owing to its importance in forensic investigations PMI estimation of skeletal remains has been extensively researched by anthropologists and other disciplines in the forensic community, such as entomology (Smith 1986; Catts & Haskell 1990; Anderson 2001; Anderson & Cervenka 2002; Amendt et al. 2011). Early studies focused on morphological characteristics, such as bone consistency, weight, and specific gravity, as a means of differentiating modern and ancient skeletal remains (Berg & Specht 1958; Berg 1963). However, such techniques achieved limited success, and the focus soon shifted to studying chemical and immunological characteristics of bone, which proved slightly more successful in distinguishing the two groups.

Of the numerous chemical and immunological studies conducted over the last 60 years, most have focused on the organic components of bone, bone extracts, and bone diagenesis (Cook & Heizer 1952; Knight 1968, 1969; Hare 1976). Many of these studies, although initially unsuccessful, provided the basis for future research and further development of the techniques (Knight & Lauder 1969; Facchini & Pettener 1977; Yoshino et al. 1991; Jarvis 1997; Collins et al. 2002). The major limitation encountered in these pioneering studies was an inability to account for the effect of environmental variables on bone degradation.

Radioisotope studies provided a means for overcoming such barriers and have become the most extensively researched methods for dating skeletal remains during the past two decades

(Taylor et al. 1989; Wild et al. 2000; Tuniz, Zoppi, & Hotchkis 2004; Zoppi et al. 2004; Ubelaker, Buchholz, & Stewart 2006; Cook & MacKenzie 2014). Radioisotope measurements have the advantage of being more readily quantifiable than other techniques and are less influenced by environmental variations. Although radiocarbon dating has been around for more than half a century, the technique has found new success in forensic investigations (Ubelaker 2001; Cardoso et al. 2012; Cook & MacKenzie 2014; Ubelaker 2014) and appears to be the most reliable method to date.

This chapter provides an overview of the morphological, chemical, immunological, and radioisotope dating techniques investigated within the last 60 years and their potential application to the field of forensic science.

Morphological Studies

Forensic pathologists typically estimate PMI based on the morphological and physical characteristics of soft-tissue remains (Berg 1963; Knight 1968; Knight & Lauder 1967, 1969). Characteristics such as the cooling of the body temperature (*algor mortis*), fixation of hypostasis (*livor mortis*), and stiffening of the muscles (*rigor mortis*) are commonly employed to assist with estimating the time since death. Once the early postmortem period has passed, autolytic and putrefactive changes are used as markers but have the potential to provide wide margins of error in the estimation of PMI. Typically, within the first five years postmortem, fragments of ligaments, tendons, skin, hair, and cartilage are still present on the decomposed remains. Yet soft tissues are prone to environmental modifications and do not generally survive the decomposition process, rendering the use of these morphological characteristics in dating human remains problematic (Haglund & Sorg 1997).

Skeletal material is considered more resistant to postmortem decomposition but nonetheless vulnerable to taphonomic processes. General changes in bone appearance and morphology may provide indicators of time since death; however, the physical changes of bone over time are largely influenced by size of the skeletal element, climate, and surrounding environment (Bell, Skinner, & Jones 1996; Blau In press). After several decades, for example, the bone may exhibit dark discoloration and an overall soapy texture in addition to small pieces of collagenous tissue. Over a century after death bone may appear light and crumbling. The six weathering stages of bone proposed by Behrensmeyer (1978) continue to be a useful guideline in assigning robust postmortem timelines based on the physical change of skeletal elements in certain environments. However, the environmental variables must be considered when one is applying these weathering stages to date skeletal remains, particularly in environments where freezing and thawing may vary the degree of weathering observed (Janjua & Rogers 2008; Blau In press).

Chemical Studies

Chemical studies were initially employed in an attempt to apply more scientific principles and objectivity to PMI estimations of skeletal remains (Knight 1968, 1969; Knight & Lauder 1969). Many chemical studies have focused on the structural and compositional modifications that occur in bone following death and weathering (Prieto-Castello et al. 2007). Initial studies in this field investigated both organic and inorganic constituents of bone (Cook & Heizer 1952). An early study by Berg and Specht conducted in 1958 was considered the first comprehensive attempt at using chemical methods to date skeletal remains (Berg & Specht 1958). A range of tests were investigated with varying results. The test for carbonate by reaction with hydrochloric acid produced a lively reaction when testing petrified bone but gave only a weak

reaction for younger samples (Berg 1963). Additionally, analysis of younger samples under a mercury vapor lamp produced an intense blue-violet fluorescence that weakened as the age of the sample increased. A decline in fluorescence was also correlated with a gradual loss in affinity for the chemicals indophenol and a higher susceptibility to Nile blue. All these techniques were, however, subjective and not sufficiently reliable. Tests involving determination of specific gravity and superconductivity produced similar results and were not considered useful as a stand-alone method for dating recent bone material (Berg & Specht 1958; Berg 1963; Facchini & Pettener 1977).

Subsequent methods were targeted toward practical use at crime scenes and were intended to be rapid and inexpensive. A range of chemical techniques was investigated by Knight (1968, 1969) and Knight and Lauder (1967, 1969) in order to differentiate between “modern” (<0–100 years) and “ancient” (>70–100 years) bone. Several methods that were found to have the most promise were further developed and used by other researchers decades later (Facchini & Pettener 1977; Jarvis 1997).

A modified version of the Kjeldahl technique (developed by Johan Kjeldahl to determine the amount of nitrogen in chemical substances) was used to analyze nitrogen content in bone and demonstrated a progressive decrease in nitrogen levels with postmortem age. Samples less than 50 years old (and therefore considered to be of forensic interest) were reported to contain a nitrogen content of more than 3.5 gm%, and these values were consistent with an earlier study by Berg (1963) that showed nitrogen levels of more than 3.6 gm% for bone samples up to 40 years postmortem (Knight & Lauder 1967, 1969). However, a lack of samples in the time interval of interest (0–50 years) and the interval immediately preceding it (50–100 years) rendered these early results insignificant.

A later study that aimed to enhance this technique investigated nitrogen levels in long bones interred for a period of 26–90 years (Jarvis 1997). The results further confirmed both the Berg (1963) and Knight and Lauder (1967, 1969) studies, which demonstrated a general decrease in total nitrogen content with time since deposition. Prieto-Castello and associates (2007) used a similar Kjeldahl method but failed to identify any significant correlation between postmortem age of bone and nitrogen content. However, they reported an increase in nitrogen content in the cortical and medullar zone of human femurs when the samples were divided into two groups: those dating from 10 years or less and those over 10 years (Prieto-Castello et al. 2007).

The study by Prieto-Castello and associates (2007) also investigated the potential of sulfur, phosphorus, potassium, urea, and protein concentrations to act as markers for estimating PMI in the cortical and medullar zones of human femurs. A significant relationship with PMI was identified for sulfur, phosphorus, and urea for the samples collected from both zones. Phosphorus concentrations were directly correlated with sulfur concentrations in the cortical zone and potassium concentrations in the medullar zone suggesting that phosphorus tends to disappear with increasing PMI. The researchers demonstrated a high degree of correlation confirming the parallel behavior of nitrogen, sulfur, and phosphorus in their relationship with proteins. The correlation with urea was not as strong owing to its production by both proteins and amino acids. Overall, they recommended urea, potassium, and sulfur as the most promising markers for dating osseous remains.

The fluorescence of bone has limited value as a confirmatory test but may provide useful information in combination with other indicators (Knight & Lauder 1969). Fluorescence under ultraviolet light is a measure of the organic constituents remaining in the bone material, and as these constituents are lost fluorescence weakens considerably. Samples of forensic interest will still contain enough organic material to produce an intense bluish-white fluorescence across the entire cross-section of the surface, even when recovered from a range of deposition environments

(Facchini & Pettener 1977). The use of spectrofluorimetry improves the subjectivity associated with this method, because it reduces spectral interference in the region where emission occurs, by employing a reflection grating rather than a filter. In addition, it allows both qualitative and quantitative determinations of fluorescence.

Studies involving the quantification of amino acids demonstrated a decline with postmortem age (Knight 1968, 1969). As proteins in buried bones hydrolyze over time, they are released as amino acids that are ultimately lost to the environment as the postmortem age increases. According to studies conducted by Knight (1968, 1969), the presence of numerous amino acids (generally seven or more) demonstrated a high probability that the bone was less than 100 years old, and, if proline and hydroxyproline were present, it was reported that the bone may be closer to 50 years old. A bone in excess of 100 years old was not likely to contain more than three or four amino acids (Knight 1968, 1969).

The value of declining citrate levels found in bone was demonstrated in principle by Schwarcz, Agur, and Jantz (2010), who proposed a strong correlation between citrate content and PMI with a limit of detection of roughly 100 years. Declining citrate concentration is independent of temperature and precipitation; however, rates are affected by storage temperature of the skeletal remains.

Benzidine (an organic compound) testing of bone surface showed a strong positive reaction for recent bone samples analyzed (Knight & Lauder 1969; Facchini & Pettener 1977). The intensity of the reaction decreased with time, and a negative result indicated a bone sample in excess of 150 years old. Since the test relies on the presence of blood, the results are susceptible to alterations in different environmental conditions and the rapid loss of blood remnants. However, once these limitations are factored into the analysis, the benzidine reaction may provide a useful indicator for dating skeletal remains of forensic interest.

An alternative analysis dependent on the presence of blood is luminol testing. Luminol is a solution that produces a bluish-white light following a reaction with hydrogen peroxide in the presence of blood. In bone samples that have a recent time of death, the chemiluminescence produced will be intensive. As with the benzidine test, the intensity will decrease as the age of the bone increases, owing to the loss of hemoglobin proteins (Introna, Di Vella, & Campobasso). A negative result is believed to be indicative of older bone samples. Luminol testing is one of the more recent developments in chemical techniques used to date skeletal remains particularly because of its application to crime scenes. The method provides some correlation between the levels of intensity of the chemiluminescence with the difference in PMI of the bones. Objectivity of the method can be achieved by the use of image analysis procedures that provide quantitative determination of the intensity and the distribution of the chemiluminescence reaction (Introna, Di Vella, & Campobasso 1999). However, Ramsthaler and associates (2009) caution that chemiluminescence of bone should not be used as the sole method for determining PMI as they demonstrated false positive results in 7.5% of historical samples analyzed and false negative results in 15% of recent samples analyzed. Their later studies suggested that a lack of luminescence and weak UV-fluorescence was more applicable for excluding forensic relevance than a positive luminol reaction (Ramsthaler et al. 2011).

In addition to these chemical studies, a range of analytical techniques have been investigated over the past 20 years; including X-ray diffraction, which can determine the crystalline structure of bone (Bartsiokas & Middleton 1992), and Raman spectroscopy, which can identify the organic and inorganic components of bone (Bertoluzza et al. 1997; McLaughlin & Lednev 2011; Patonai et al. 2013). The use of Fourier transform infrared (FTIR) spectroscopy has also been investigated for discriminating between archaeological and forensic relevance by grading the mineral phase of bone samples using the crystallinity index and carbon-phosphate index

(Nagy et al. 2008; Patonai et al. 2013). Unfortunately, most studies have suffered from a lack of bone samples in the time interval of interest. Although further research with appropriate samples may yield more promising results, the accuracy achieved by these methods is generally not sufficient for practical use in forensic investigations.

Immunological Studies

Gel Diffusion Test

Immunological techniques have focused on the detection of residual serological activity of bone protein as an indicator of postmortem bone age (Camps & Purchase 1956; Berg 1963; Knight & Lauder 1967, 1969; Knight 1969; Castellano, Villanueva, & von Frenckel 1984). Immunological reactions between bone powder and antihuman rabbit serum were evaluated using precipitation times with a gel diffusion test (modified from Ouchterlony's method 1948 and 1958). Based on positive reactions, Camps and Purchase (1956) reported PMI estimates within the first 10 years postmortem, whereas Knight and Lauder (1969) and Knight (1969) reported an age of origin of less than 5 years using this technique. Berg (1963) quoted a PMI of up to 50 years if the protein precipitation was delayed and weak, but a rapid reaction most likely indicated a postmortem age less than 20 years. Inconsistent results between studies were attributed to the quality of the antiserum and strength of the bone extracts (Knight 1969; Knight & Lauder 1969). Expanding on this earlier research, Castellano and colleagues (1984) demonstrated an important correlation between loss of proteins and lipids with postmortem aging of skeletal remains. Protein content, in particular zinc, which was hypothesized by the authors to be linked to protein in some way, displayed strong regression values and standard errors between 3–9 years, depending on the confidence intervals used.

Note that even though these methods offer potential for further investigations, the quality of the intact protein is questionable, since protein decomposition commences immediately after death (Knight & Lauder 1969; Hare 1976; Wiechmann, Brandt, & Grupe 1999; Collins et al. 2002). The reliability of immunological techniques to postmortem bone dating has been discussed (Lendaro et al. 1991; Brandt, Wiechmann, & Grupe 2002), and inconsistent findings are thought to have resulted from nonspecific reactions of serum against bone, soil contamination, and the presence of false-positives arising from unknown contaminating antigens.

Fat Estimations & Histological Examinations

Expanding on the work of Gangl (1936), various studies have attempted to correlate the fat content of bone with postmortem age (Cook & Heizer 1952; Berg 1963; Knight & Lauder 1969; Castellano, Villanueva, & von Frenckel 1984). Work by Buerger and Maestre in 1962 (Castellano, Villanueva, & von Frenckel 1984) showed a decrease in bone lipid within 8–10 years postmortem. Berg (1963) also provided evidence that fat content decreases with bone age; however, Knight and Lauder failed to confirm this correlation in their 1969 study. Castellano, Villanueva, and von Frenckel (1984) validated the findings of Buerger and Maestre (Castellano, Villanueva, & von Frenckel 1984) and Berg (1963), documenting a sharp decrease in bone triglycerides over time. Moreover, they successfully detected lipids in bones that were more than a century old.

Studies have well described the histological features of skeletal decomposition (Ascenzi 1955; Kerley 1965; Piepenbrink 1986; Yoshino et al. 1991); however, there has been less success in attributing postmortem age using histological bone sections. Knight and Lauder failed to obtain significant results in their 1969 study, ascertaining that it was technically impossible to analyze bone extracts unless undecalcified samples were available. The most promising results stemmed

from Berg's research (1963), wherein he was able to assign robust age estimates based on fat remnants found within compact bone. Through the course of the postmortem decay process, marrow may be converted into adipocere, which then diffuses into the Haversian canals of femoral bones. For several decades thereafter, cross-sections provide a visible indicator of bone age. A bone cavity filled with adipocere indicated a bone age of less than 30 years postburial, whereas scanty adipocere material suggested a maximum bone age of 50 years. The use of this technique is limited, however, since both age and contents of the burial environment influence the formation of adipocere.

Colorimetry and Ion-Exchange Chromatography

In 1969 Knight and Lauder modified a colorimetry technique first described by Moores, Spackman, and Stein (1958) and Ho (1965) in which bone powder was resuspended in dilute acid. The optical density of the resulting supernatant was analyzed by ion-exchange chromatography. Results demonstrated a promising correlation between bone color and age, but the technique did not prove reliable for routine use. Furthermore, no relationship between free amino acids and postmortem bone age was apparent, since results failed to identify more than a few free amino acids among the ten samples analyzed.

Environmental Conditions

Determining PMI of skeletal remains is a complex task owing to the considerable number of intrinsic and extrinsic factors that may influence the postmortem process. The previously discussed investigations have attempted to establish methods for dating bone that are less dependent on environment than on time. However, taphonomic agents vary significantly based on the climate, ecology, and geology of an environment each of which will influence the postmortem decomposition processes differently. These variations in turn affect the reliability of dating techniques. Ambient temperature, humidity, moisture, soil pH, and geological events (erosion, flooding) are some of the primary abiotic environmental pressures encountered (Berg 1963; Knight & Lauder 1969; Hare 1976; Piepenbrink 1986; Haglund & Sorg 1997). The effect of these factors on decomposition and skeletonization has been discussed extensively in the literature (Rodriguez & Bass 1985; Micozzi 1991; Haglund & Sorg 1997) and is not considered here. However, biotic agents, such as microorganisms and plants, should be considered when dating skeletal remains and will be discussed here.

Biotic Factors

Arguably the most common mechanism of postmortem bone deterioration is the product of microorganisms, in particular fungi and bacteria (Marchiafava, Bonucci, & Ascenzi 1974; Piepenbrink 1986; Yoshino et al. 1991; Child 1995; Bell, Skinner, & Jones 1996; Collins et al. 2002). Microbial activity affects morphological structure and chemical composition of bone and has been shown to occur very soon after death and in many burial conditions (Bell, Skinner, & Jones 1996; Collins et al. 2002). Characteristic features of bone deterioration by microorganisms include bone staining, tunneling, demineralization, and fluorochroming and vary with the type of invading microorganism (Marchiafava, Bonucci, & Ascenzi et al. 1974; Piepenbrink 1986; Yoshino et al. 1991; Bell, Skinner, & Jones 1996). These combined effects may lead to misinterpretations of postmortem history and thus compromise the accuracy of skeletal dating techniques available at this time.

Plants may grow in and among skeletal remains, particularly in clandestine burial environments (Cardoso et al. 2010). The use of plant roots as PMI indicators of bone has found some success (Willey & Heilman 1987; Quatrehomme et al. 1997; Cardoso et al. 2010). Root cross sections, branch growth, and root damage have been outlined as possible indicators of PMI. Roots that are contacting or penetrating bones may be cross-sectioned and their annual rings counted in order to establish a minimum postmortem timeframe. If the surrounding burial environment has been disturbed, the damaged roots may produce a permanent scar or point of reference, from which the annual growth rings may be counted. A relationship between annual growth (longitudinal and radial) and branch length (originating from the point of contact with remains) can be estimated and a timeframe for growth established.

Cardoso and associates (2010) demonstrated the application of this technique in a forensic investigation involving an adult male in an advanced state of skeletonization. Several taphonomic changes were evident at the scene including the presence of green algae, bryophytes, and shrub roots growing in, around, and through the remains. The age of the shrub roots and bryophytes were determined to be approximately three years old, indicating a minimum time elapsed since death. The individual was subsequently identified and had been reported missing six years earlier (Cardoso et al. 2010).

Radioisotope Studies

The use of radioactive isotopes to date archaeological bone material is not a new technique. Since its introduction in 1949 radiocarbon dating has been used extensively to estimate the approximate age of ancient remains (Ubelaker 2001; Cardoso et al. 2012; Fournier & Ross 2013; Cook & MacKenzie 2014; Ubelaker 2014). Although the technique predominantly uses the collagen fraction of bone, other fractions, including osteocalcin, have been investigated (Ajie & Kaplan 1990). Uranium-series dating (Pike, Hedges, & van Calsteren 2002; Grun et al. 2005) and thorium series dating (Kandlbinder et al. 2009) have found limited success; however, most radioisotope methods are hampered by the relatively large errors associated with determining an accurate PMI (van Calsteren & Thomas 2006).

Between 1950 and 1963 extensive nuclear weapons tests caused a high level of radiocarbon (^{14}C) to be released into the atmosphere, particularly in the Northern Hemisphere (Hua 2004; Tuniz, Zoppi, & Hotchkis 2004; Fournier & Ross 2013). During this time the atmospheric radiocarbon level almost doubled compared to the reference level recorded in 1890 (Libby et al. 1964; Reimer, Brown, & Reimer 2004). Following the implementation of the Nuclear Test Ban Treaty in 1963 the atmospheric ^{14}C level decreased exponentially to a concentration approximately 10% higher than the level recorded before nuclear testing (Hua 2004; Tuniz, Zoppi, & Hotchkis 2004). This higher concentration, known as the “bomb pulse,” was initially used to assess the potential hazard of ^{14}C in medical use (Libby et al. 1964) and is now recognized as being a potential parameter in distinguishing pre-bomb from post-bomb organic remains (Ubelaker 2001; Ubelaker & Houck 2002; Fournier & Ross 2013). As part of the biological cycle, both plants and animals (including humans) incorporate the bomb ^{14}C via the food chain (Geyh 2001; Ubelaker & Buchholz 2006). Therefore, this temporal change may be used to date skeletal remains that are less than 50 years postmortem and therefore of forensic significance (Tuniz, Zoppi, & Hotchkis 2004; Zoppi et al. 2004; Ubelaker, Buchholz, & Stewart 2006; Cardoso et al. 2012; Fournier & Ross 2013).

The earliest study to utilize bomb pulse dating in a forensic context was that conducted by Taylor and colleagues (1989). The study identified three different periods based on ^{14}C data that could be used for estimating the PMI of skeletal remains. Specifically, these intervals were classed as (1) a nonmodern period (before about 1650 C.E.) of no forensic science

interest, (2) a premodern period (1650 to 1950 C.E.) of potential forensic science interest, and (3) a modern period (1950 to present) of definite forensic science interest. Owing to the broad categories devised the study was successful in differentiating modern from nonmodern bones. However, limitations of the technique included the length of time and costs associated with analyzing the samples, the amount of bone required, and the inability to provide a PMI estimation referring to a specific year.

Further attempts to date the collagen fraction of recent bone samples by means of bomb radiocarbon demonstrated more precise ranges (from approximately three years to several decades) compared to the earlier study (Geyh 2001). Additional corrections were included to account for the cessation of ^{14}C uptake in adult humans at the age of 19. However, even with these corrections, the ranges were not considered sufficiently precise to be used in forensic cases. This problem may be attributed to the relatively long carbon turnover rates of bone collagen compared to other bone fractions (Wild et al. 1998; Ubelaker, Buchholz, & Stewart 2006). For example, total bone turnover takes approximately four years for trabecular bone but approximately 30 years for cortical bone (Fournier & Ross 2013). Hence, the radiocarbon present in the collagen of trabecular bone more closely represents the age at death compared to cortical bone (Ubelaker, Buchholz, & Stewart 2006). Lipids from bone and bone marrow have been shown to provide a more reliable estimate of the time since death for recent bone samples using ^{14}C measurement (Wild et al. 1998, 2000). In instances where the bone lipid has completely degraded or is not recoverable, hair or dental tissue can also provide a reliable estimate (Wild et al. 1998; Geyh 2001; Ubelaker, Buchholz, & Stewart 2006; Fournier & Ross 2013). With the selection of appropriate material (that is, material with a rapid carbon turnover rate), the radiocarbon bomb-pulse method appears to be the most accurate method currently available for dating skeletal remains that are considered to be of forensic significance. The technique has successfully been employed in forensic casework to distinguish between ancient remains and more recent remains that warrant a forensic investigation (Ubelaker & Houck 2002; Ubelaker, Buchholz, & Stewart 2006; Cardoso et al. 2012; Fournier & Ross 2013).

The fallout from nuclear weapons testing led to the contamination of the environment with additional radioisotopes such as strontium-90 (^{90}Sr) (Papworth & Vennart 1984). Investigations of ^{90}Sr activity in bones have demonstrated significant differences in concentration between pre-bomb and post-bomb skeletal remains (MacLaughlin-Black et al. 1992). The method is simple to use compared to radiocarbon techniques and is reliable in determining whether an individual died pre- or post-1950 (Neis et al. 1999). With a half-life of 29.5 years, ^{90}Sr is a good candidate for use within a radiometric method for estimating PMI (Schrage et al. 2012). However, most samples analyzed tend to suffer from groundwater contamination following burial in soil. The technique still requires further investigation in order to correlate the ^{90}Sr burden with the PMI of skeletal tissue.

An alternative method for dating human skeletal material involves the measurement of lead-210 (^{210}Pb) and polonium-210 (^{210}Po) concentrations in bone (Swift 1998). The relatively short half-life of ^{210}Pb (22.5 years) makes it an ideal radioisotope for forensic analyses. Further, it is an abundant isotope in the environment, and its ratio with ^{210}Po can be quantitatively measured. Preliminary studies suggest that there is a correlation between certain radionuclide content and time since death and an intercorrelation between trace elements and time since death of recent skeletal material (Swift 1998; Swift et al. 2001; Schrage et al. 2012). Specifically, trace lead levels from a historical period have been shown to be higher than the concentrations observed for both recent bone samples and ancient bone samples (Swift 1998; Swift et al. 2001). Higher levels of incidental lead ingestion from sources such as lead plumbing and paints common until the 1930s provide the most likely explanation.

Schrag and associates (2012, 2014) have recently highlighted the value of determining both ^{90}Sr and ^{210}Pb (^{210}Po) activity levels in human skeletal remains to estimate PMI. Individually each method is prone to large error margins but in combination the results yield a satisfactory estimation of PMI. Because ^{90}Sr and ^{210}Po are both subject to diagenesis in burial environments, a decontamination method is necessary before one uses these radionuclides for dating skeletal remains. Individual habits such as dietary intake and smoking can, however, represent sources of uncertainty in the PMI estimation (Schrag et al. 2012, 2014). In cases of forensic interest that present these limitations, radiocarbon bomb pulse dating is recommended instead.

Ongoing studies have shown that the combination of activity concentration values for ^{210}Po , ^{238}U (uranium-238), and ^{226}Ra (radium-226) can potentially separate bones derived from individuals who have died in archaeological (>150 years ago), historical (75–149 years ago), and recent (<75 years ago) periods. Investigation of the thorium decay series, which includes ^{228}Ra (radium-228), ^{228}Th (thorium-228), ^{232}Th (thorium-232), and ^{230}Th (thorium-230), has shown that several of these radionuclides are principally well suited to PMI estimation owing to their independence from external influences such as nutrition and the process of decomposition (Kandlbinder et al. 2009). However, the uncertainties associated with their measurements are currently too high for accurate PMI estimation, and further research is required to improve this technique. The results of these studies have shown great potential for the use of radioisotopes, including radiocarbon, and will likely shape the future for skeletal dating techniques.

Conclusion

In many investigations the PMI estimation provided by the anthropologist is more likely to be based on experience, in particular, regional/environmental contexts, than any of the previously mentioned techniques. However, such estimations may vary considerably among anthropologists owing to the subjectivity involved in analyzing the remains. The need for objective and accurate methods for dating skeletal remains continues to be acute, and considerable research has been focused in this area. Determining whether human skeletal remains are of possible or of definite forensic interest should be established before any death investigation; such determination will ultimately shape the course of that investigation.

Original attempts at dating skeletal remains using morphological and physical characteristics were not successful and led to the investigation of chemical characteristics instead. Although many chemical techniques have been investigated and some success achieved, the majority of studies yielded contradictory results. Immunological studies proved equally inaccurate, and all techniques suffered from the unknown effects of environmental parameters. Recent radioisotope studies have shown the most promise, and further studies in this area may provide an accurate method for dating skeletal remains of forensic significance.

In all criminal investigations, regardless of their nature, the estimation of time since death is one of the most important variables. Although methods exist for estimating this timeframe in the early postmortem period, accurate techniques applied to the subsequent (skeletal) post-mortem period are lacking. For this reason research in the field of forensic anthropology should continue to focus on the important task of dating forensically significant skeletal remains.

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Analysis of Commingled Human Remains

John E. Byrd and Bradley J. Adams

Commingling is a problematic aspect of many anthropological analyses. Regardless of whether the context is archaeological, such as a Native American ossuary, or forensic, such as an aircraft crash, commingling of human remains complicates every facet of the process from recovery to final disposition. Most analyses that can be conducted by anthropologists pertain to individual remains, and the desired end-state is typically a set of skeletal elements attributable to one person. One of the earliest articles to address the topic of commingling was by Charles Snow (1948), in which he outlines protocols used in the anthropological analysis of American war dead from World War II. Despite the significance of the subject, relatively little attention has been given to the analysis of commingled remains until somewhat recently (Ubelaker 2002; Byrd & Adams 2003; Adams & Konigsberg 2004; Adams & Byrd 2006; Adams & Byrd 2008, 2014; Nikita & Lahr 2011; Osterholtz, Baustian, & Martin 2014), all of which provide comprehensive lists of references on the topic.

When dealing with commingled assemblages, individuals must be properly trained to participate in all phases of the project. In the field the recovery should be directed by archaeologists or archaeologically trained forensic anthropologists familiar with the excavation and documentation of human remains and associated evidence. In the laboratory two primary objectives are to sort the bones into specific individuals and quantify the number of dead. When feasible (such as with modern mass casualties), a major component of the effort is also to seek positive identification of victims. Only experienced osteologists should be used for these undertakings, or the results may be incomplete or incorrect.

Scale of the Incident

The complexity of a commingled assemblage is clearly dependent on the overall number of dead involved in the incident and the preservation of the remains. It is useful to broadly categorize commingling into two types: small- and large-scale.

Small-scale commingling is much easier to deal with and exists when (1) there are few disassociated portions and/or (2) the number of individuals is small. Even in cases where the overall number of individuals is large (such as a mass grave), the degree of commingling may still be considered small-scale, as when the skeletal elements are predominately articulated on their recovery. In this context one must exercise careful excavation in order to preclude inter-mixing between individuals during the recovery effort. In other small-scale situations there may be extensive mixing of skeletal elements or body parts, but there are only a few individuals

represented. In this situation it may be feasible to reassociate the parts to specific individuals with great confidence. Adams and Byrd (2006), for example, present a case example of small-scale commingling resulting from the crash of a helicopter with two individuals aboard. In this case it was possible to use gross techniques to confidently reassociate almost all the extensively commingled and fragmentary skeletal elements.

Large-scale commingling involves large numbers of individuals whose bodies are mixed together in what can be taken as a random manner (though formal analysis may reveal patterning). It may also be the case that the number of individuals alone is not daunting, but extreme fragmentation greatly complicates the process and magnifies the scale of the analytical undertaking. With extensive fragmentation it is possible that a large proportion of the body parts cannot be associated by traditional anthropological means and therefore cannot be attributed to any individual without extensive DNA testing. The remains recovered from the World Trade Center attacks in New York City in 2001 represent an example of large numbers of individuals and extreme body fragmentation. In this case 2,749 individuals were confirmed killed on September 11, 2001, and more than 20,000 human remains of varying sizes and preservation states have been recovered (Mundorff 2008; Sledzik et al. 2009; Mundorff 2014; Mundorff et al. 2014). In addition to a greater reliance on DNA analysis large-scale commingling often presents numerous other logistical challenges (for example, facilities, number of qualified personnel, records management, and the like) as outlined elsewhere (International Committee of the Red Cross 2009; Adams & Byrd 2014).

Field Recovery

In any scenario resulting in the discovery of commingled human remains, there must be a thoroughly documented and controlled retrieval process in order to preserve contextual evidence from the field (Skinner 1987; Dirkmaat & Adovasio 1997; Haglund 2002; Hochrein 2002; Schmitt 2002; Skinner, York, & Connor 2002; Skinner, Alempijevic, & Djuric-Srejec 2003; Tuller & Duric 2006; Tuller & Hofmeister 2014). Without accounting for spatial data, one may lose many important associations. Successful accomplishment of this step will greatly assist in the laboratory analysis and ensure that secondary commingling is not caused as a result of careless recovery techniques. The same care is necessary in the laboratory to make sure that the important recovery scene information is preserved. For example, the maintenance of field provenience through specimen labeling is recommended in order to preserve field context data. It is most frequently in the laboratory that the number of individuals represented is estimated, portions are reassociated to specific individuals, and, within the forensic context, remains are identified and returned to the next of kin. Without proper field recovery protocols and subsequent laboratory care of provenience data, all facets of the laboratory process will be greatly complicated.

Laboratory Sorting

Depending on the circumstances of death and deposition, the condition of the commingled remains may range from fleshed to skeletonized, and from intact to fragmentary. Thermal alteration, such as cremation or burn trauma, may add yet another facet to the complexity of the analysis (Kennedy 1996; Warren & Maples 1997; Warren & Schultz 2002; Bass & Jantz 2004; Naji et al. 2014; Warren & Van Deest 2014). When working with mutilated, fleshed human remains, one may find it difficult to grossly recognize the full extent of commingling. In some traumatic events (such as an explosion following a bombing or high impact event such as a plane

crash) it is possible for body parts from one individual to become attached to and/or embedded into the body of another individual. Although radiography has traditionally been used for identification purposes, it can also be a useful tool in the recognition of commingling, depending on the type of incident and preservation of the bodies (Goodman & Edelson 2002; Viner 2014). A preliminary radiographic evaluation of fleshed body parts (perhaps at an initial triage station) may be warranted to detect commingling through the identification of excessive number of body parts, for example, and to assist in the sorting process (for example, Blau, Robertson, & Johnstone 2008). This possibility is especially likely in regard to contemporary situations in which rapid scene response is possible, such as an aircraft crash or a terrorist bombing. In these situations every fragment of bone and soft tissue should be initially considered as a separate specimen unless it can be shown to be attached by soft tissue or to conjoin to another piece. Care should be taken to recognize soft tissue from different individuals that has become stuck together. The simple fact that portions are recovered together from the field and are bagged as a unit is not conclusive evidence that they originated from the same person.

Sorting Commingled Remains

In the sorting process it is commonly the job of the physical/forensic anthropologist to “rebuild” the individuals to the greatest extent possible. An early discussion of sorting that is still germane can be found in the article by Charles Snow (1948). Snow advocated a systematic approach to sorting that utilized gross methods such as pair matching, articulation, and process of elimination in a series of steps. Today the analysis of DNA profile data provides another powerful stage in the sorting process (Budimlija et al. 2003; Jin et al. 2014; Mundorff et al. 2014) that was not available to Snow. As DNA technology becomes more rapid and cost effective, it is proving to be more commonplace in the resolution of commingling. Without a doubt, one can imagine many examples of “unidentifiable” or “unassociable” human remains from past events that would today be resolvable thanks to the advent of DNA analysis.

The sorting guidelines exemplified in this chapter provide an objective and sound basis for gross, metric, and molecular analysis. It is important that systematic procedures are utilized and appropriately documented. Many scenarios, especially those involving completely skeletonized remains, will be amenable to several gross techniques (biological profile, visual pair matching, checking articulations, process of elimination, robusticity, and taphonomy), one metric technique (osteometric comparison), and, when appropriate and feasible, DNA analysis. The majority of these sorting procedures are not stand-alone techniques; for best results they should be used in conjunction with one another. For example, a combination of articulation, process of elimination, and taphonomy may provide strong evidence of association, but any of these alone may be insufficient. In addition, osteometric comparison (Byrd & Adams 2003; Byrd 2008; Byrd & LeGarde 2014) may provide an objective manner of segregating two elements hypothesized to originate from different individuals. It is worth reiterating that extensive fragmentation will hinder most gross techniques and necessitate a greater reliance on the use of DNA testing, regardless of the scale of the incident (Kontanis & Sledzik 2008, 2014).

The gross and metric sorting procedures can be accurately and objectively applied to most instances of small-scale commingling. They are also very useful for large-scale commingling situations, but discriminating power is likely to be reduced in many circumstances as the number of skeletal elements grows (for example, differences in size and shape may not be as apparent when the number of individuals increases). Large-scale commingling also introduces many logistical problems regarding analysis, such as laboratory space and data management issues (Byrd et al. 2003). Most of the procedures recommended in this chapter require considerable laboratory

bench space. These procedures also require the assignment of specimen numbers which need to be physically associated with each body part. The data generated during the analytical process must be compiled, stored, and then retrieved as needed in support of analyses. Data management and analysis are best done on computers, but there is still a need to develop software to automate the process. One example available to the public is offered by the International Committee of the Red Cross (2013).

Conjoining Fragmentary Remains

The first step of the sorting process involves determining element representation. As part of this step fragmentary remains should be conjoined (glued together) to the greatest extent possible, because this will assist in the overall segregation process. Bones should then be sorted by element type, side, and size (for example, all right femora should be organized from most smallest to largest). Grouping elements by age criteria (for instance, lack of epiphyseal fusion) may also be helpful at this stage of the sorting process. It is important to maintain all provenience information collected during the recovery effort, because this information may become critical during the analytical process. Furthermore, it is not unusual for articulated body portions to be recovered together (such as right arm and hand), and these associations should be maintained as a unit throughout the analysis as long as there is confidence in their association. Once these initial steps are completed, the formal sorting techniques can be systematically applied.

Biological Profile (Age, Sex, and Stature)

The human aging process is characterized by roughly 25 years of skeletal and dental development followed by decades of degradation, popularly referred to as “aging.” This aging process is reflected in numerous places in the skeleton (see Rogers, Chapter 20 this volume) and can be a critical clue in the sorting process (Schaefer 2014). Teeth erupt according to a relatively uniform schedule over the first 18 years of life (see Clement, Chapter 29 this volume). Epiphyses are open during the early periods of rapid growth but eventually close in a gradual manner. The closing of epiphyses, usually complete by the mid-20s, can be scored on an ordinal scale, as in the classic study by McKern and Stewart (1957). Other areas of the skeleton, including the pubic symphyses, the auricular surfaces, and the sternal ends of the 4th ribs, exhibit gradual degradation throughout life. This degradation has been studied and presented as series of stages by anthropologists (İşcan, Loth, & Wright 1984, 1985; Lovejoy et al. 1985; Brooks & Suchey 1990; Hartnett 2010). Advanced age is often reflected by the presence of arthritic lipping and resorption of bone in areas such as the joints.

Age estimates derived from various specimens can be used in the sorting process to separate bones of demonstrably different ages. For example, an innominate aged at 35 to 50 years can be confidently sorted apart from a humerus with a proximal epiphysis unfused. A cranium with the second molars fully formed and the third molars unerupted with incomplete root formation could be sorted apart from the innominate but not from the humerus.

In addition to the informative role that skeletal age markers may play in the sorting process, there may also be sorting clues based on the individual's sex (see Rowbotham, Chapter 19 this volume) or stature that can be of assistance. For example, a pelvis that is clearly female can often be segregated from all crania that are conclusively male. Similarly, it may be possible to objectively segregate long bones that have widely divergent stature estimates. Regarding stature (see Willey, Chapter 22 this volume), osteometric comparison (discussed shortly) will provide a more robust method of sorting based on metric data.

Visual Pair Matching

Visual pair matching refers to the association of homologous (left-right) elements based on similarities in morphology. In many instances the right and left sides are mirror images of each other. This concordance can be exploited in the process of sorting commingled remains through the recognition of paired bones from the same individual. For certain elements visual pair matching is among the most reliable and accurate methods available to the anthropologist sorting commingled remains, especially when the population size is of a small scale. The level of reliability is, however, contingent on the experience of the analyst. Regular training and proficiency testing are recommended.

Pair matching refers to the same element type (for example, right and left humeri). Visual matching of different skeletal elements (for instance, a humerus and a femur) based on morphology is not recommended owing to the subjective nature of the procedure. Visual matching of different element types using information such as robusticity and taphonomy may be possible in cases of small-scale commingling, as discussed shortly.

The basic procedure for visual pair matching is to hold the two specimens in question side by side and evaluate their concordance. The specimens should be observed from different angles. One should look at the comparison critically and attempt to note discrepancies that make their association untenable. This comparison can be done by formally comparing the size (length and width), followed by the overall shape, then the shape of any processes, then the shape of articular facets, and so forth. Figure 17.1 provides illustrations of the method at work. The more corresponding features there are, the greater the confidence that can be placed in the association. However, one distinct difference can lead to the segregation of two specimens. Note the differences in overall length, the development of the deltoid tuberosity, and the shape of the distal condyles in Figure 17.1c, which should lead to the conclusion that these are not a pair-match.

The reliability of visual pair matching was tested with an archaeological skeletal collection housed at the University of Tennessee, Knoxville (Adams 1996; Adams & Konigsberg 2004). Two commingled scenarios were simulated, one from a sample of 15 individuals and one from a sample of 30 individuals (note that only a 60% recovery was simulated in order to ensure that

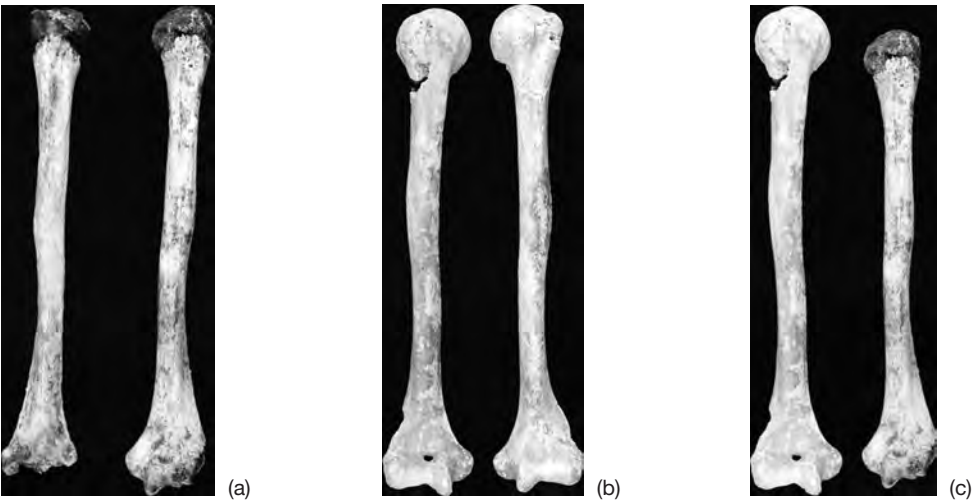


Figure 17.1 Two pairs of humeri depicted in (a) and (b), with a comparison between nonassociated bones in (c).

not every element would have a true pair represented). Only tibiae, femora, and humeri were tested, and the samples consisted of both complete and fragmentary elements from both adults and subadults. Results of the 15 individual group showed that all femora were matched correctly, all tibiae were matched correctly, and one pair of humeri was incorrectly identified. Results of the 30 individual test revealed that the following were not accurately recorded: one pair of humeri and one pair of tibiae. All femora were correctly pair-matched. While the limited results of this test are encouraging, one suspects that this high matching frequency may change if the sample size is substantially increased, since variation between individuals may not be as obvious. Furthermore, even minimal fragmentation can obliterate key areas used for identifying a match and be cause for errors.

Articulation

Skeletal specimens from adjoining elements may be associated or sorted by assessing their articulation, or formation of a congruent joint or juncture with another element. The basis for this form of analysis is the fact that articulating skeletal elements grow together as moving parts. Unless the individual suffers a pathological condition, the articulations will show a good fit in terms of size and shape. Some skeletal articulations require tighter concordance than others. While articulation can be a strong method for gross sorting, the confidence in an agreeable articulation as evidence of true association will vary according to how much concordance is actually required for the two bones to fit together. Table 17.1 provides a ranking of major skeletal articulations in terms of the confidence placed in a positive result (note that this table is based on the experience of the authors). Additional research (Doretto et al. 2014) found some slight differences regarding the reliability of certain articulations. There is an asymmetry in the interpretation of articulations: while an agreeable articulation does not guarantee a true association, a poor articulation is taken as proof of nonassociation.

Through articulation it may be possible to systematically sort much of a commingled assemblage, especially in small-scale incidents. As with most techniques, large-scale commingling will

Table 17.1 Table of articulations, with indication of degree of confidence in a fit. Articulations classed as “low” cannot serve as evidence of a good match but do have some potential for excluding very poor fits (from Adams & Byrd 2006)

<i>High</i>	<i>Moderate</i>	<i>Low</i>
Cranium, mandible	Cranium, atlas	Ribs, thoracic vertebrae
Vertebrae	Tibia, fibula	Manubrium, clavicle
5th lumbar vertebra, sacrum	Femur, tibia	Humerus, scapula
Humerus, ulna	Innominate, femur	
Innominate, sacrum	Patella, femur	
Tibia, talus	Navicular (scaphoid), radius	
Ulna, radius	Carpals [†]	
Metatarsals*	Carpals, metacarpals	
Metacarpals*		
Tarsals		
Tarsals, metatarsals		

*The 1st metacarpal and 1st metatarsal do not articulate closely with the others and are to be regarded as “low” confidence so far as their articulation with the others is concerned.

[†]The articular surface of the pisiform is too small to articulate with confidence.

greatly complicate the process. When feasible, the best area to initiate the “rebuilding” process is often with the pelvis or vertebrae. From here the various elements can be added. Problems with articulation arise from the lack of a close fit between some elements, such as between the arm and the torso. The articulation between the humeral head and the glenoid fossa of the scapula is not very diagnostic, nor is there an obvious way to articulate the scapula to the rest of the body. Linking arms, scapulae, and clavicles to torsos can be difficult or impossible based solely on articulation. Other elements, such as ribs, may also be challenging to associate based on articulation. As with all of the procedures described in this chapter, greater confidence is granted to results that lead to exclusions. The power of exclusion is based on the fact that in some circumstances one can definitively show that two specimens cannot have originated from the same individual, whereas consistency between specimens only demonstrates the *possibility* that they originated from the same individual.

Size and Shape/Osteometric Comparison

There are strong correlations among the sizes of the bones of the skeleton. Thus, a large humerus is associated with a large femur and a large metatarsal. This isometric reality can be exploited in the sorting process by formally comparing the sizes of two bones. Osteometric comparison is a technique that uses statistical models to objectively compare size and shape relationships between elements through measurement data (Buikstra, Gordon, & St. Hoyme 1984; Byrd & Adams 1999, 2003; Byrd 2008; Byrd & LeGarde 2014).

Osteometric comparison removes subjective judgment calls and provides a solid statistical basis for segregation based on size. The strength of this technique is that it can be used to sort remains that could not be segregated through other means, such as pair matching and articulation. It is also amenable to situations in which the remains are fragmentary. Note that the real strength of osteometric comparison is to recognize *inconsistent* relationships that lead to exclusionary sorting—that is, consistency between elements alone is often not sufficient evidence for association. The default (or null) hypothesis is always that the two bones being compared are from a person (or persons) of the same size. Naturally, some elements exhibit greater correlations in size with one another than with others. In most instances it is not possible to osteometrically segregate individuals with similar body proportions, which could prove problematic for large-scale incidents. Thus the power of the method is determined by the inherent allometric relationships among the skeletal elements as well as the size diversity of the commingled individuals (Byrd & Adams 2003).

Osteometric sorting utilizes a reference dataset composed of measurements collected from known individuals. The reference data used for osteometric sorting comprise primarily postcranial measurements. The measurements include the standard measurements found in the Forensic Databank at the University of Tennessee, Knoxville (Moore-Jansen, Jantz, & Ousley 1994), as well as new measurements designed specifically for fragmented bones. Details regarding the reference data and new measurements are presented in Byrd and Adams (2003) and Byrd and LeGarde (2014). The dataset is composed of pooled individuals representing both sexes and several ancestral groups. The reference dataset is continually growing as additional metric data are collected.

To apply the technique, statistical models are derived that provide the comparative means for assessing the relationship between two elements (Byrd & Adams 2003; Byrd 2008; Byrd & LeGarde 2014). Models have been provided for comparing different bones (Byrd & Adams 2003), paired elements (Byrd & LeGarde 2014), and articulating bones (Byrd & LeGarde 2014). Regression models were developed for comparing different bones (for example, humerus and femur). It has been found that the best regression models were created when the measurement

values were converted to natural logarithms. The available measurements on a bone are simply summed and the natural logarithm of this sum is the value used in statistical models. By performing the summation procedure, simple bivariate regression models can be utilized. Since length measurements typically show the highest correlations with one another, models including length measurements perform best. The addition of breadths and girth measurements into the indices offers a slight, but measured improvement in the statistical models. A surprising finding is that models utilizing several breadth and girth measurements, with no length measurements, often perform nearly as well as those including lengths (Byrd & Adams 2003). This fact has great significance when one is working with fragmented assemblages. Error rates for the method as a whole, using the 90% prediction interval, have been found to be approximately 5%. Models for comparing paired bones and articulating bones utilize the *t*-test and associated *p*-values. A more thorough discussion of these techniques is presented by Byrd and Adams (2003), Byrd (2008) and Byrd and LeGarde (2014), along with several regression models.

Currently, osteometric comparison is limited in its utility based on limited access to the reference data and the tedious process of customizing regression models. However, this method is superbly suited to computer automation. One hopes that software becomes available that allows all available measurement values for the case specimens to be entered in advance, and all relevant comparison results to be produced as the analysis proceeds, without one having to generate the statistical models for each comparison as separate steps. As specimens are sorted apart by the various methods described in this chapter, they can be eliminated from consideration in the software application.

Robusticity or “Build”

Snow (1948) mentioned body “build” as one of the characteristics used to individualize commingled skeletal remains. Indeed, every experienced osteologist recognizes that short, stocky bodies can be distinguished from tall, slender ones by observing the skeleton. Further, persons with heavy musculature, often described as robust, exhibit characteristics not shared with more gracile individuals. Bones showing the signs of hypertrophy (for example, larger girth, more pronounced muscle attachment sites) can be successfully sorted from their atrophied counterparts. Where a small number of individuals with widely divergent builds are commingled, this method alone has the potential to resolve the problem.

The challenge with this approach resides partly with the nature of human variation and partly with the lack of any systematic procedure to follow during its execution. Humans vary along a continuum from stout to thin, from tall to short, and from robust to gracile. Thus, where commingled assemblages include remains of numerous individuals, the likelihood of encountering ambiguous results during comparisons is great. Comparisons involving elements of the upper body with those of the lower body (for instance, the humerus compared to the tibia) are the most difficult to resolve. The method is further confounded by the lack of control over its application to an assemblage. Snow (1948) never elaborated on its use but rather left it up to the reader to decide how it should be used. Because the method is entirely subjective (in its current state), lacking explicit criteria for consideration, it does not lend itself to the determination of general error rates.

The authors advocate the use of this method under tightly controlled circumstances. Body build characteristics should be brought into consideration when the other primary methods have been exhausted, leaving multiple specimens yet to be resolved. This approach does not negate the subjectivity of the method but does limit the odds of drawing erroneous or inexplicable conclusions. Many of the features associated with robusticity will be picked up in the other procedures, such as pair matching and osteometric comparison.

Taphonomy

Skeletal remains are often commingled long after their initial deposition; one example is the relatively recent discovery by Vietnamese farmers of the wreckage of an aircraft that crashed during the Vietnam War (1959–1975). With the best of intentions the farmers gathered the bones they found in and around the wreckage, placed them in bags, and then turned them over to local government authorities (Adams & Byrd 2006). Another example involves the bones of United States servicemen killed during the Korean conflict, which were exhumed by the North Korean government, warehoused for an unspecified period of time, and then commingled (whether intentionally or not) at a later time (Pokines et al. 2002; Jin et al. 2014). A final example involves the remains of Bosnians disposed of in mass graves by their Serb neighbors, which were exhumed at a later date with mechanical excavators, loaded on dump trucks, and moved to new locations where they were redeposited with no attempt to keep individual sets of remains discrete (Skinner, York, & Connor 2002). In all these instances one expects that taphonomic processes could have left distinctive patterns on individual sets of remains during the period immediately following initial deposition. Where such patterns have occurred, they can be exploited during the sorting process.

Exposure of the skeleton to a range of variables at the microenvironment level creates the taphonomic patterns (see Nawrocki, Chapter 25 this volume) that can be used in the sorting process. Skeletons resting in different locations within a grave can be exposed to sediments with different micromorphological properties. Dark, fine-grained sediment tends to darken bones, whereas coarse-grained sands tend to produce lighter colors. Wet conditions leave bones with greater mass (owing to the lack of leaching, as well as the addition of moisture) than do dry conditions. Bones left on the surface are subject to weathering in a manner not observed in buried bones. Common effects of surface exposure are cortical exfoliation, loss of color (bleached appearance), cracking, and loss of bone mass (Blau *In press*). Proximity to artifacts or other non-bone materials can mark the skeleton. Deposition next to burning materials, for example, can cause color change owing to thermal alteration and/or exposure to charcoal and smoke (see Thompson & Ulguim, Chapter 26 this volume). The long-term deposition of metal artifacts next to bone can produce distinctive patterns. Copper artifacts, such as clothing zippers, tend to create a green stain and also tend to promote preservation of the bone. Steel artifacts tend to leave oxidation stains on bone. Although stains that are found on single bone specimens are not helpful in the sorting process, stains that were produced across multiple articulating bones often are. The alignment of such stains can be powerful evidence of an association of two or more bones.

However, there may also be drastic taphonomic differences observed on the remains of the same individual owing to traumatic disarticulation (such as may occur from dismemberment or an aircraft crash) and a variable burial context. In these situations portions of a single individual may be dispersed into very different contexts. The most significant point to be made concerning taphonomic patterns is that they are the result of idiosyncratic circumstances. The processes that produce these patterns can affect whole skeletons or only portions of a skeleton. Taphonomic patterns must be used with considerable caution in the sorting process, since the circumstances that create observable patterns can just as easily affect portions of adjacent skeletons as the elements of a single skeleton (all other things being equal).

Process of Elimination

Process of elimination suggests that bones may be assigned to a specific person, because that element is exclusively represented by an individual or can be conclusively excluded from all other potential individuals. This technique may be very useful in small-scale commingling, but

as the number of individuals increases it usually becomes problematic to narrow the list of potential candidates to a single individual. In most cases, one must complete all other methods of sorting before utilizing process of elimination. After these methods have been exhausted, duplicated elements may remain that can be associated with a specific individual through exclusion from all other possible options. An accurate account of the number of individuals involved in the incident, when possible, also greatly facilitates the use of process of elimination as a sorting technique. (See definitions of “open” and “closed” cases described in Buck & Briggs, Chapter 35 this volume, and Black, Chapter 34 this volume for their importance in defining the number of deceased.)

DNA Profile Data

More recently the ability to obtain DNA from skeletal remains has become a powerful tool for anthropologists sorting commingled remains (see Baker, Chapter 28 this volume). DNA typically derives from one of two primary sources, nuclear DNA (nucDNA) and mitochondrial DNA (mtDNA), which most often support three types of tests: autosomal STR, Y-STR, and mitochondrial DNA. Obtaining useful data from these sources involves the application of widely varying laboratory methods, and interpretation of the results requires awareness of the special considerations attached to each method. The reader is encouraged to utilize published resources (for example, Butler 2005) and to regularly consult with experts in the field of forensic DNA analysis.

For purposes of sorting commingled remains, nucDNA and mtDNA each has strengths and weaknesses; nucDNA is most commonly utilized by analysis of Short Tandem Repeat (STR) markers (Butler 2005). The development of commercial kits for STR analysis has made this form of DNA analysis relatively fast, inexpensive, and reliable. The analysis of autosomal STRs has the advantage of individualization when full profiles are obtained—random match probabilities can be low enough to merit only minimal concern. The autosomal STR profile from a set of remains can be compared to a sample from a missing individual, and a match is often grounds for a positive identification. This is one approach currently utilized by the United States Department of Defense, which collects blood samples from all active duty service members and stores them at the Armed Forces DNA Repository for future use (Department of Defense Directive No. 5154.24). Another nucDNA test commonly used in forensic DNA testing is the Y-STR, which is focused on the Y-chromosome inherited by sons from their fathers. This test requires a self-reference or a reference from a male relative (related through the father) for identification. Since it is not unique to the individual and is passed through the male line, it is considered an excellent complement to mtDNA results but considered alone will not necessarily prove sufficient for sorting remains. Perhaps the greatest weakness of nucDNA testing is the difficulty involved in obtaining a usable DNA profile when remains are poorly preserved, resulting in a partial or no DNA profile. In these cases analysts often resort to mtDNA testing.

The advantage of mtDNA over nucDNA is its preponderance in remains. Mitochondria are organelles found outside the nucleus of a cell. There may be up to 1,000 mitochondria per cell and several thousand copies of mtDNA in each mitochondrion (Bogenghagen & Clayton 1974). The higher copy number leads to a greater probability of obtaining a usable mtDNA sequence from poorly preserved remains. mtDNA testing has become routine for testing degraded or low DNA content samples such as hair, ancient bones, and teeth. The greatest weakness of mtDNA is that it is not individualizing and thus cannot be used as a unique identifier. Repeated types are commonly observed in large populations. Studies have shown that there are relatively common mtDNA types and that matches between unrelated people are not uncommon (Holland &

Parsons 1999; Melton et al. 2001). In cases where mtDNA testing is used, finding fewer discrete sequences than the number of individuals estimated by anthropological techniques in the laboratory analysis (see following section on Quantification) can possibly indicate the existence of one or more random matches.

Measures that can be taken to mitigate the risk of a false association during mtDNA testing include an accurate assessment of the number of individuals involved in the incident, prompt and comprehensive collection of family reference samples, and the utilization of multiple confirmatory lines of evidence when one is making initial sorting decisions. Utilizing a combined result from mtDNA and nucDNA testing can be extremely effective even when each DNA test result considered alone is not very powerful (for example, Hartman et al. 2014; Hartman et al. 2011). Regardless of which DNA testing method is used, sample selection is best assessed by the forensic anthropologist responsible for the case in conjunction with an expert in the field of forensic DNA analysis (Hines et al. 2014). One of the risks inherent in the use of either nucDNA or mtDNA is the chance of spurious matches resulting from sample contamination; strict protocols must be followed to prevent such occurrences (Mundorff et al. 2014). Samples should be carefully chosen so that they will (1) provide information relevant to the sorting process and subsequent identification; (2) not destroy evidence critical to the overall analysis (for example, gunshot wound or significant landmark needed for analysis); and (3) yield useful DNA data, given that some sample locations have better success than others (Mundorff, Bartelink, & Mar-Cash 2009; Doretti et al. 2014). Needless sampling or samples of excessive size are to be discouraged, because they often destroy evidence and waste the resources of the DNA laboratory.

Quantification

It is often the job of the physical/forensic anthropologist to determine the number of individuals represented in cases involving commingled human remains. This process usually occurs after the conjoining and sorting process is complete. The most common technique utilized for this assessment is the Minimum Number of Individuals (MNI) determined from skeletal elements. Regardless of the context (forensic or archaeological), anthropologists frequently use the MNI value in their reports as the estimate of individuals represented. Although the MNI may provide an accurate representation of the actual number of individuals, it is also subject to bias and misleading results. When the recovery of skeletal elements falls below 100%, the MNI may not be an accurate indicator of the true death population. When appropriate, a more accurate technique may be the Most Likely Number of Individuals (MLNI) for the quantification of commingled human remains (Adams & Konigsberg 2004, 2008; Konigsberg & Adams 2014). The main difference between the MNI and the MLNI is that the MNI provides an estimate of the recovered assemblage only. If the recovery of major body portions is less than 100%, the resulting number estimates associated with the MNI will reflect this bias and produce an underestimate of the actual number of individuals. The MLNI, in contrast, accounts for data loss and provides an estimate of the true population size. Because of their importance, specific details are provided here for the MNI and the MLNI.

Minimum Number of Individuals (MNI)

The MNI is the most popular method of quantification in any type of commingled osteological analysis. For interpreting population size from a skeletal assemblage, the MNI (as the name suggests) presents the minimum number of individuals that contributed to the sample. To deal with fragmentary body parts, specific segments of an element (for example, proximal humerus) can

be used for the calculation of the MNI. Every fragment must share a specific landmark to ensure that fragments of the same element are not counted as two distinct individuals. For example, an adult proximal humerus fragment and an adult distal humerus fragment cannot be counted as two different people unless they duplicate a landmark, such as the deltoid tuberosity, since they could otherwise be parts from the same person. An exception to this is possible if there are obvious age discrepancies between the two portions. The basic principle of an MNI estimate is to avoid counting the same individual twice.

Although there are variations involved with the calculation of the MNI, the most popular method employed by anthropologists is simply a report of the most frequently observed element. This report is obtained by simply sorting elements into lefts and rights and then taking the greatest number as the estimate. It is equivalent to assuming that all the less frequently observed bones are paired with the more frequently observed bones. For example, if there were 23 left humeri, 19 right humeri, 36 left femora, and 29 right femora, the MNI would be 36. This number indicates that a minimum of 36 individuals would have to be present in the commingled assemblage to account for this number of bones (based on the count of left femora).

In some instances the MNI will not provide an accurate estimate of the original population. The MNI simply states how many individuals would have been necessary to provide the *recovered* skeletal elements but may not be an indication of the *original* number of bodies. If the recovery of major skeletal elements nears 100% then the MNI will be an accurate representation; otherwise it may be of limited interpretive value. Consider a hypothetical scenario in which 100 individuals were placed in a mass grave. At some point the remains were disturbed (intentional or otherwise), resulting in commingling. Decades later the site was excavated in order to identify those that were killed, although the excavators do not know exactly how many individuals were originally interred. Taphonomic forces had acted on the site, and the recovery did not represent 100 complete skeletons (that is, there was commingling, unpaired elements, miscellaneous portions were missing, and so on). The MNI derived from this site was determined to be 80 individuals based on the most frequently encountered element (for example, the number of right femora). Based on this MNI estimate, 20 individuals are not accounted for, which could have serious consequences in the identification process.

Most Likely Number of Individuals (MLNI)

The Most Likely Number of Individuals (MLNI) provides a maximum likelihood estimate for the number of individuals represented by an osteological assemblage (Adams & Konigsberg 2004, 2008; Konigsberg & Adams 2014). The key feature for the use of the MLNI with skeletal remains is that accurate estimates of the original population can be derived from samples in which less than 100% of the major skeletal elements are recovered. This method is of particular utility with archaeological samples or in forensic situations when remains have been affected by taphonomic forces. In addition to providing point estimates, the MLNI can also calculate confidence intervals.

When one is working with skeletal elements, the MLNI is calculated based on pair matching (see earlier section on Sorting). Pair matching involves the comparison of right and left elements to determine if they are from a single individual. Since the pair-matching step should be completed during the sorting process, the data should be readily available for calculation of the MLNI. In theory any paired element in the body could be used for calculation of the MLNI. In practice, though, particular parts of the skeleton will be more useful than others. Important criteria to consider for choosing appropriate skeletal elements are their size, presence of distinct morphological traits, potential for age and sex determination, and likelihood of survival.

An estimate of the original death assemblage based on the MLNI represented by a specific skeletal element (for example, femora) is

$$\text{MLNI} = \frac{(L + 1)(R + 1)}{(P + 1)} - 1$$

where L = left bones, R = right bones, and P = pair-matches.

For example, take a scenario where there are 64 right femora, 51 left femora, and 44 femur pairs. Calculation of the MLNI indicates a maximum likelihood estimate of 74 individuals. In this same example the MNI would be only 64 individuals. Furthermore it is possible to present confidence intervals with the MLNI. According to the preceding example, an approximate 95% confidence interval is 71 to 79 individuals. The specifics involved in calculation of confidence intervals around the MLNI estimate using a hypergeometric probability function (available in most spreadsheet software programs) are thoroughly discussed by Adams and Konigsberg (2004). As might be expected, the confidence bounds get tighter as the recovery rate of elements approaches 100%, but the MLNI has been shown to perform very accurately when the recovery of elements exceeds 50%.

The primary danger involved with the use of the MLNI for quantification from skeletal elements is the misidentification of pairs. Because of the multiplicative nature of this technique, it is more vulnerable than other methods to fragmentation and misinterpretation of paired skeletal elements. In extremely fragmentary situations pair matching may be impossible, and the MLNI should not be calculated. Currently, the best option in highly fragmentary situations would be a MNI estimate, but it should not be considered a true count of the original death population.

Identification and Ethical Considerations with Commingled Remains

In any type of mass casualty event one of the critical analytical goals is the identification of the dead. When bodies are relatively complete and there is access to antemortem information, identification by traditional means (for example, radiographic and fingerprint) may be relatively straightforward and rapid. When bodies are highly decomposed, fragmentary and/or skeletal remains are commingled, this task becomes more difficult (Kontanis & Sledzik 2008, 2014). It may be possible to positively identify a fragment of a maxilla to a specific individual through dental records. It may also be possible to positively identify a fragment of a hand based on fingerprints. The identification of other very small, nondiagnostic fragments may be more challenging and may rely almost entirely on DNA analysis. Obviously the sorting process described here and the victim identification process are closely related. The linkage of an unidentified fragment with another portion that has been positively identified will, as a result, positively identify the newly linked piece.

At the onset of any analysis involving commingled remains, one should establish baseline parameters and protocols. Decisions need to be made early on in the process to determine the scope of the effort. With contemporary events there are also ethical considerations during the analysis and identification effort and in dealing with families of the deceased. Some complicated and sensitive issues to consider include these:

- Will every fragment of bone and soft tissue be analyzed, or is there a size parameter that will be used (for example, only fragments >1 cm)? Laboratory policies and procedural decisions will need to be made regarding the scope of DNA testing and to determine which remains

should be considered candidates for molecular analysis. If the decision is made to attempt identification of all fragments, regardless of their size, DNA testing will likely be the only means of reassociation and identification for many specimens.

- Is the goal to identify every person, to reassociate and identify every fragment, or to do both? These are complicated but related issues. For example, if some amount of remains can be positively attributed to every individual involved in a mass casualty incident, how much effort should then be expended to associate additional unidentified portions to these individuals?
- How will “unidentifiable” bones (for instance, calcined bones) and degraded soft tissue (such as, poorly preserved skin fragment) be treated? Will the decision be made to destroy certain material as medical waste, or will everything be retained? In many scenarios it will not be possible to positively link every fragment to a specific individual, regardless of the time and effort expended and funds available. One option is to retain everything and have some type of a group designation. This approach acknowledges the fact that the remains could have originated from any number of people involved in the incident and provides an option for their inclusion in a memorial or common grave.

Such decisions are crucial to the identification effort and, as such, will dictate the effort put into the process of sorting and reassociating fragments. There are serious and long-lasting implications for not only scientific endeavors but also victims’ next-of-kin, especially identifications related to mass fatality incidents (Wagner 2014). There are no universal answers to these questions, and decisions will be incident-specific, perhaps largely based on input by and wishes of the affected families as well as budgetary and other logistical constraints. In most mass fatality incidents it will usually fall to the medical examiner or coroner’s office with jurisdictional control to make the final determination regarding the identification effort.

Conclusions

The sorting of commingled skeletal remains a necessary step in the forensic identification process. The complexity of the problem requires that it be addressed by highly skilled physical/forensic anthropologists utilizing a careful, systematic approach. Under ideal conditions, the anthropologist will engage a combination of field, morphological, and DNA profile data such that each sorting decision is informed by multiple lines of evidence. Reliance on a single line of evidence, to include DNA profiles, is not recommended. Only through persistent application of multiple lines of evidence will the practitioner be able to maximize the accurate sorting of remains and subsequently support individual identification.

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The Assessment of Ancestry and the Concept of Race

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Physical anthropologists have long been interested in the biological relationships of past and present populations. In bioarchaeology, establishing biological affinity elucidates crucial historical processes, including migration patterns. Methods also exist for estimating population affinity of individual specimens—a process that is often useful in forensic anthropology. The assessment of ancestry, like the estimation of age, sex, and stature, is typically an expected component of a biological profile provided to law enforcement by a forensic anthropologist. Unlike sex, age, and stature, however, ancestry estimation is fraught with misunderstanding, misuse, and controversy. Underlying any discussion of the assessment of ancestry and its value to forensic anthropology is the concept of race. In this chapter we discuss the relationship between race and ancestry estimation in forensic anthropology, discuss the methods developed by anthropologists to determine ancestry, and address some relevant philosophical and ethical issues.

The conflation of ancestry and race is typical in the anthropological literature and has a long history. In fact, physical anthropology (the parent discipline of forensic anthropology) was instrumental in establishing the concept of race and entrenching it in the American and European worldview. As Brace (1982) so aptly points out, several personalities variously recognized as the founders of physical anthropology—John Fredrich Blumenbach, Paul Broca, Samuel Morton, Ernest A. Hooton, and Aleš Hrdlička—either defined the race classifications that have become so pervasive and accepted race as the natural condition of human variation or carried out research on human variation within the race framework. The fact that in the 1920s and 1930s the pages of the *American Journal of Physical Anthropology* were replete with articles describing the physical and behavioral characteristics of “Negroids,” “Caucasoids,” and “Mongoloids” is testimony to the continuation of physical anthropology’s fascination with the concept of race up to World War II.

In the 1940s it was M. F. Ashley Montagu who seriously began to question the concept of race for humans and recommended dropping the term (and associated notions) altogether (Montagu 1941, 1942, 1952). In the 1960s Frank Livingstone (1962) applied questions raised nearly a decade earlier by Wilson and Brown (1953) about nonhuman subspecies to the human-race question. Livingstone pointed out that the discordance of physical (genetic) traits made it impossible to partition humans in any biologically meaningful way. The number and type of races anyone generated from the basis of biological variation would depend on the number and types of traits selected. A scheme founded on skin color, for example, would have no resemblance to one based on blood groups. Livingstone (and Montagu, for that matter) suggested that a better understanding of human variation would be arrived at by studying traits (or genes).

Over the past few decades, the idea of human races has fallen into disfavor among most physical anthropologists (Lieberman & Reynolds 1996; Lieberman, Kirk, & Littlefield 2003). However, physical anthropologists are not alone in their rejection of the race concept applied to humans. Molecular geneticist Alan Templeton (2002) attempted to address the issue of human races using criteria that are typically applied by biologists to nonhuman animals. He set up his arguments by establishing that there are two basic models for viewing subspecies (or races): the lineage model and Sewell Wright's " F_{st} statistic." He then tested the applicability of the models using human DNA data. In the first model, according to Templeton, races are viewed as evolutionary lineages. If human races represent discrete evolutionary lineages, then there must be more interbreeding within members of each lineage than between lineages. The models test whether breeding frequency associates with major races or with proximity. The DNA data, he argues, are consistent with the proximity model (that is, humans interbreed more frequently with conspecifics, or other members of the same species, in their immediate proximity than with members of their own so-called race). The DNA evidence does not accord with the lineage model (*ibid.*).

Templeton focused on the eminent geneticist Sewell Wright's statistic of diversity (F_{st}) that zoologists use to gauge whether genetic variation among groups within a species exceeds "a minimum level of differentiation" (*ibid.*: 35) that is sufficient to divide the taxon into smaller groups, or subspecies. An F_{st} of 0 indicates that, although individuals differ, there is no diversity among populations. An F_{st} of 1 indicates that all individuals in each local population are identical but that each population is different from all others. The traditional criterion for the existence of subspecies is an F_{st} value of 0.25–0.30. Species with an F_{st} above 0.30 are divisible into subgroups, whereas, according to Templeton, species with an index below 0.25 are not. For illustrative purposes Templeton produces a table of sample species, some with accepted subspecies and others that cannot be subdivided. The F_{st} for humans is 0.156, which is well below the index generated for nonhuman species. Thus, according to Wright, the human species is not divisible according to this criterion either—there are no human subspecies, or races.

If races do not exist, how then can forensic anthropologists expect to provide estimates of ancestry in their research and case reports? (Sauer 1992). It is our contention that a problem exists only if ancestry is equated with race. We maintain that human variation is such that estimating a place of origin is not only reasonable but quite practical (Brace 1995). Anthropologists can often link unknown human remains to a known region of the world based on variation in skeletal morphology. The idea of race becomes relevant when this linking is associated with the assignation that is most likely in a particular cultural context. For example, one popular forensic anthropology textbook (Byers 2005: 158–59) advocates the use of "White," "Black," "Asian," "Native American," and "Hispanic" for the population of the United States.

Like attitudes toward the concept of race itself, the methods available for the assessment of ancestry have evolved. In the next section we review a number of the methods that have been and continue to be used by forensic anthropologists to identify ancestry. Decisions about the use of terminology in this review have been difficult. Despite our belief that ancestry does not equal race, we have left the term *race* and some of the group identifiers (for example, "Caucasoid") when we feel that changing terms would change the author's meaning or intent.

History of Methods

Most of the early studies on human variation were designed to document human biological diversity. Topics ranged from the "Physical Anthropology of the American Negro" (Cobb 1942), a thorough documentation of a host of physical attributes of African Americans, to population

variation among individual bones such as the scapula (Gray 1942) or vertebral column (Trotter 1929). Other early works include but are by no means limited to variation among rib lengths (Lanier 1944), sciatic notch measurements (Letterman 1941), cephalic indices (Michelson 1944), the morphology and closure of the superior orbital fissure (Ray 1955), various body dimensions (Todd & Lindala 1928; Thurstone 1947), cranial morphology (Todd & Tracy 1930), and long-bone lengths/stature (Trotter & Gleser 1952).

Many of the early publications were influenced by the 1885 introduction of anthropometry by Alphonse Bertillon, a French law enforcement officer. Anthropometry originally involved 11 measurements: (1) the individual's height, (2) reach, (3) length of trunk, (4) length and (5) width of head, (6) width of cheeks, (7) length and (8) width of right ear, (9) length of left middle finger, (10) length of left little finger, and (11) length of left forearm (Bertillon 1896). Bertillon also outlined multiple other bases for comparison among people, ranging from hair texture and skin pigmentation to alveolar prognathism. Although his methods were aimed at identifying criminals who had been arrested and were likely to be repeat offenders, they set the stage for future metric analyses of the human body.

While most early physical anthropologists focused their attention on research concerning growth, development, nutrition, and other descriptive analyses of skeletal populations, a handful of pioneers began applying their knowledge of the skeleton to forensic cases (İşcan 1988). Aleš Hrdlička began assisting the FBI with cases in 1936 (Ubelaker 2000), and Wilton M. Krogman, with his 1939 publication *Guide to the Identification of Human Remains* in the *FBI Law Enforcement Bulletin*, brought the importance of anthropological skeletal analysis to the attention of the law enforcement community (Rhine 1990a). In addition to determining age at death, sex, and stature, anthropologists often provided opinions as to the possible ancestry of unidentified skeletal remains. Momentum continued to build, leading Ellis Kerley to comment in 1978: "the list of physical anthropologists who have been engaged in medico-legal activities is a long and impressive one that includes most of the major physical anthropologists of the first half of the twentieth century" (Rhine 1990a: xix).

Alice Brues (1958) highlighted some of the key skeletal features that are commonly examined by physical anthropologists in the context of a forensic investigation, including some that are used to estimate race. According to Brues, because there is no one feature on all skulls in any given racial group, the anthropologist must examine multiple features in order to accurately assess an individual's ancestry. She based her analysis on three aspects of the face: (1) soft tissue; (2) areas where soft tissue closely follows bone contours; and (3) aspects visible only on the skull itself (Brues 1958: 559). Brues was careful to point out the potential for incongruity between ancestry assessment based on skeletal remains and the "racial" category with which the individual would have identified during life (ibid.).

One of the most definitive works published during the early period of forensic anthropology involving human identification was Krogman's publication, *The Human Skeleton in Forensic Medicine* (1962). Knowing that an anthropologist would not always be called to assist with cases, Krogman authored this book as a reference for law enforcement to become acquainted with bones and the information they can provide. Although this volume also includes information on bone growth and development, time since death, and identification techniques such as skull image comparisons and comparative radiography, most of the book focuses on establishing the biological profile. Krogman relied on early studies that described population differences in the pelvis, scapula, long bones, and other parts of the skeleton to develop methods for race identification. He concluded that the long bones, scapula, and mandible could not be racially classified, that the pelvis had only limited applicability (70%–75%), and that morphological and metric analyses of the skull tended to be useful 85%–90% of the time (Krogman 1962: 206).

A number of individual studies were carried out, and several books were published on the subject of forensic anthropology during the 1970s and 1980s (for example, Rathbun & Buikstra 1984; Krogman & İşcan 1986; Reichs 1986). However, 1990 brought about the publication of *Skeletal Attribution of Race* (Gill & Rhine 1990), the most comprehensive guide available for race identification from human skeletal remains. *Skeletal Attribution of Race* arose from a symposium at the 1984 meeting of the American Academy of Forensic Sciences that had been inspired by annual meetings of the Mountain Desert and Coastal forensic anthropologists (Rhine 1990a). Most of the methods included in the volume represent improvements on or critiques of previous research; others are presented for the first time.

We now move to a discussion of the traditional methods available to forensic anthropologists for determining ancestry from skeletal remains. The methods are grouped into metric and anthroposcopic analyses (methods that utilize visual assessment as opposed to measurements) of cranial and postcranial elements.

Cranial Morphology

The Gill and Rhine volume (1990) describes several methods that involve visual assessment of the skull. Among them is Alice Brues’s technique for evaluating the shape of the nasal root. According to Brues, “Negroids” tend to have nasal roots shaped like “quonset huts” (buildings with a semicircular arched roof), “Mongoloids” have “tented” nasal roots, and the nasal roots of “Caucasoids” resemble “a church with a steeple” (1990). Although this method is appealing, because it appears to be straightforward and provide immediate results, the terminology is problematic because of the potential relationship between it and racial stereotypes (Figure 18.1).

Rhine (1990b) presents a “nonmetric skull racing” technique, an anthroposcopic method that incorporates a suite of cranial traits. He examined 87 complete skulls (“Anglo,” “Hispanic,” “Modern Amerind,” Prehistoric “Amerind,” “Black,” and “Black casts”), all of known identity except for the prehistoric skulls and all from the Maxwell Museum’s collection (1990b: 9). Rhine’s chapter includes lists of common and rare features or traits, along with illustrations, that he attributes

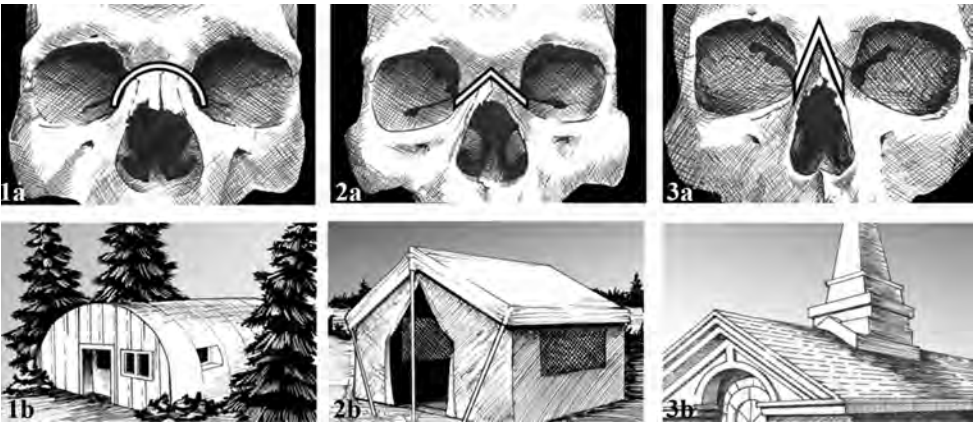


Figure 18.1 Illustrations of Brues’s scheme for assessing race based on the morphology of the nasal root (Brues 1990; original illustration by J. Wankmiller). (1a) Depicts the stereotypic morphology of a Negroid over an illustration of a Quonset hut (1b); (2a) Depicts the stereotypic morphology of a Mongoloid over an illustration of a tent (2b); (3a) Depicts the stereotypic morphology of a Caucasoid over an illustration of a church with a steeple (3b).

to crania representative of each of the three groups he encounters most frequently as a forensic anthropologist working in the American Southwest (“American Caucasoid,” Southwestern “Mongoloid,” and American Black) (1990b). For example, a large nasal spine, parabolic dental arcade, sloping orbits, and retreating zygomatics are associated with the “American Caucasoid”; a small nasal spine, hyperbolic dental arcade, rectangular orbits, and vertical zygomatics are associated with the “American Black”; and a small nasal spine, elliptic dental arcade, rounded orbits, and projecting zygomatics are associated with the Southwestern “Mongoloid” (ibid.).

Several new methods for anthroposcopic analysis of the cranium are also presented in the Gill and Rhine volume. For example, Napoli and Birkby studied the morphology of the external auditory meatus in skulls of “Caucasoids,” “Mongoloids,” and individuals of mixed “Caucasoid/Mongoloid” ancestry. Their “Mongoloid” sample consisted of 35 prehistoric crania from three Western Pueblo archaeological sites in east-central Arizona, and the “Caucasoid” and mixed “Caucasoid/Mongoloid” sample consisted of 36 modern crania from forensic cases (Napoli & Birkby 1990: 28). They concluded that the shape of the external auditory meatus differs to the extent that in “Caucasoids” and “Caucasoid/Mongoloid” admixed individuals, the oval window inside the ear canal is visible, whereas “Mongoloids” tend to have a morphology that does not allow visual inspection of the oval window (Napoli & Birkby 1990) (Figure 18.2).

Angel and Kelley (1990) studied the mandibles of 375 females and 406 males from the Terry Collection and forensic cases, evaluating them for the extent of ramus inversion and gonial flaring (Angel & Kelley 1990). Their test populations were expanded to include Blacks from a late 18th- to early-19th-century slave cemetery in Maryland, an early-19th-century cemetery of free Blacks from Philadelphia, and several African and American (Plains) Indian mandibles. According to Angel and Kelley (1990) both ramus inversion and gonial flaring are more pronounced among Blacks than among Whites, and these differences are more pronounced among males than among females. They also note that based on morphological differences between the American Black mandibles and grouped American Indian and African mandibles, the American Black mandibles appear to exhibit some racial admixture.

Brooks and colleagues report on a nonmetric assessment of alveolar prognathism (Brooks, Brooks, & France 1990). Their sample included skulls or maxillae from a number of regions: 3 skulls from India; 17 from various Southeast Asian countries; 53 North American Indian maxillae from several sites in Nevada; 40 Arikara skulls from South Dakota; 51 American Black and 49 American White skulls (primarily from the Terry Collection); and 20 Sudanese Nubian skulls (ibid.: 42). According to the authors alveolar prognathism is marked in all their sample populations except for the American Whites. American Black and Nubian skulls are the most prognathic, but prognathism is also pronounced in North American Indians and Southeast Asians. Other methods for distinguishing among American Indians, Blacks, and Whites using facial features

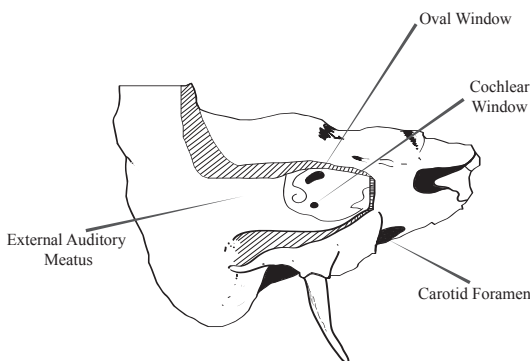


Figure 18.2 The cross-section of a right temporal bone showing the location of the oval window inside the auditory canal from Napoli and Birkby (1990)

include visual assessment of the transverse palatine suture, the zygomaticomaxillary suture, and the shapes of the mastoid process and palate (Gill 1998).

Throughout the 1990s and into the early part of the 2000s the assessment of ancestry using cranial nonmetric traits remained subjective and relied heavily on the experience of the observer. In light of the Daubert decision (*Daubert v. Merrell Dow Pharmaceuticals, Inc.* 1993) and other federal court rulings guiding judges on the evaluation of expert witness testimony, the methods used to establish ancestry by forensic anthropologists require (1) empirical support, (2) estimated error rates, (3) method standardization, and (4) validation of the method through the peer review process. The final component of the Daubert guidelines—general acceptance—has been met by cranial nonmetric traits; however, such acceptance without validation was unfortunate and represented a gap in best practice. The lack of a quantified approach to assess ancestry using cranial nonmetric traits and more important, the lack of known error rates associated with ancestry prediction using the visual approach, suggests these traits have not been investigated with appropriate scientific and legal considerations in mind.

Minimizing subjectivity is certainly one of the goals of the scientific method (Rao 1989), but in light of the Daubert ruling, forensic anthropologists are required to standardize and test the methods used for all aspects of skeletal analysis. Hefner (2009, 2014), Hefner and Ousley (2014), and Hefner and colleagues (2012, 2014) and others (Hughes et al. 2011; Hurst 2012) have been working to reduce the subjectivity associated with scoring these traits using clear definitions and illustrations. These researchers are also quantifying assessments of ancestry based on cranial nonmetric traits using a variety of parametric and nonparametric classification statistics. For example, Hefner and Ousley (2014) examined the utility of frequently cited cranial nonmetric traits (predominantly from the Rhine 1990 article) using 11 novel classification statistics with mean classification accuracies nearing 85% in 3- and 4-group analyses. Their results demonstrate cranial nonmetric traits can be quantified and used successfully to assess ancestry without relying only on the experience of the observer.

The importance of this level of research is three-fold. First, it removes some of the inherent subjectivity of scoring the traits (and various character states) through standardized illustrations and anatomically based definitions. Second, these methods provide probability models and likelihood statements to the individual assessments, quantifying the seemingly unquantifiable. And finally, and perhaps most important, these methods diverge from the traditional (and perhaps typological) 3-group models focusing on White, Black, and Asian/Native Americans, moving to population-level assessments of geographic ancestry and a deeper understanding of human variation.

Cranial Metrics

Several anthropologists have noted variation in facial indices and head measurements among different groups of people (Cameron 1929a, b, c, 1930; Michelson 1944; Woo 1949; Iyer & Lutz 1966; Gill 1984; Gill et al. 1988). The discriminant function analysis introduced by Giles and Elliot (1962) provided a mechanism for cranial analysis that went beyond measurements and indices. Their work was pioneering (Kerley 1978; İçsan 1988), and it continues to inspire research.

Giles and Elliot (1962) based their work on eight cranial measurements: (10) glabello-occipital length, (2) maximum cranial width, (3) basion-bregma height, (4) maximum bi-zygomatic diameter, (5) prosthion-nasion height, (6) basion-nasion, (7) basion-prosthion, and (8) nasal breadth. From these measurements, Giles and Elliot developed four discriminant functions that would distinguish between: (1) White and American Negro males; (2) White and American Negro

females; (3) White and American Indian males; and (4) White and American Indian females. Five of these cranial measurements were also used to develop formulae for determining the sex of an individual if that is also in question (Giles & Elliot 1962: 148). The American Negro and White crania ($n = 408$) are from the Terry Collection (currently housed in the Department of Anthropology at the National Museum of Natural History of the Smithsonian Institution) and the Todd Collection (currently housed at the Cleveland Museum of Natural History). The prehistoric Indian Knoll site, for which age and sex were first assessed and published by Clyde Snow in 1948, provided the American Indian sample (Giles & Elliot 1962: 148). According to Giles and Elliot, the Indian Knoll remains were reexamined to verify the age and sex assessments in Snow's earlier work, before the data collection for their 1962 article. All 408 American Negro and White crania from the Terry and Todd Collections were subjected to the 8 aforementioned measurements. Subsequently the measurements of 75 males and 75 females from each of the three groups were used to create the discriminant functions. When applied to the 225 males and 225 females used in the calculations, and to 326 other individuals (not used in the initial calculations), the discriminant functions provided an accuracy rate of 82.6% for males and an 88.1% rate for females (Giles & Elliot 1962: 156). To use the method the analyst measures an unknown skull, subjects the measurements to two algorithms, then places the resulting values along two axes on a graph (Figure 18.3). Placement on the graph indicates the most likely ancestral group. The method operates under the assumption that the skull under examination derives from one of the three populations involved in the study (Giles & Elliot 1962: 150).

In 1966 Walt Birkby tested the Giles and Elliot method against Southwestern American Indian and Labrador Eskimo populations in order to assess whether the discriminant functions could be applied to populations other than those from the original study. Birkby found that the Indian Knoll sample was not representative of all American Indians and "the determination of race by discriminant functions based only on a single American Indian sample cannot be suited with any degree of confidence on any other American Indian population" (1966: 26). Echoing Giles and Elliot, Birkby pointed out that statistical methods may have substantially less utility when applied to populations that were not part of the sample on which the calculations or techniques were originally developed.

A further test of the Giles and Elliot discriminant functions was published by Snow and associates (1978). Where Birkby's analysis focused on the four functions designed to determine ancestry, Snow and associates tested the discriminant functions that were developed to determine race and sex where both are unknown. They applied the method to a series of 52 forensic cases (individuals with known identities), and found that the functions were useful for distinguishing between White and Black skulls but that they misclassified 6 out of 7 Indian crania. They concluded that the Giles and Elliot method is useful, despite its population limitations, and that the limitations may actually be minimized with further refinement of the functions (Snow et al. 1978).

The Giles and Elliot functions resurfaced in the Gill and Rhine edited volume. Fisher and Gill (1990) applied the functions to a sample of Northwestern Plains Indians. Their findings indicate that the discriminant functions are useful for determining sex, but again their utility diminishes when they are used to ascertain the ancestry of individuals from populations other than the ones in the original study. Ayers and colleagues (1990) further tested the discriminant functions by applying them to 191 modern forensic cases (representing White, Black, and Amerindian males and females). They found that their modern forensic sample was different enough from the material used to calculate the original functions to suggest a possible secular change in the United States. According to Wescott and Jantz (2005) a secular change in the cranial shape of Americans has in fact occurred over the last 150 years. They noted shifts in the

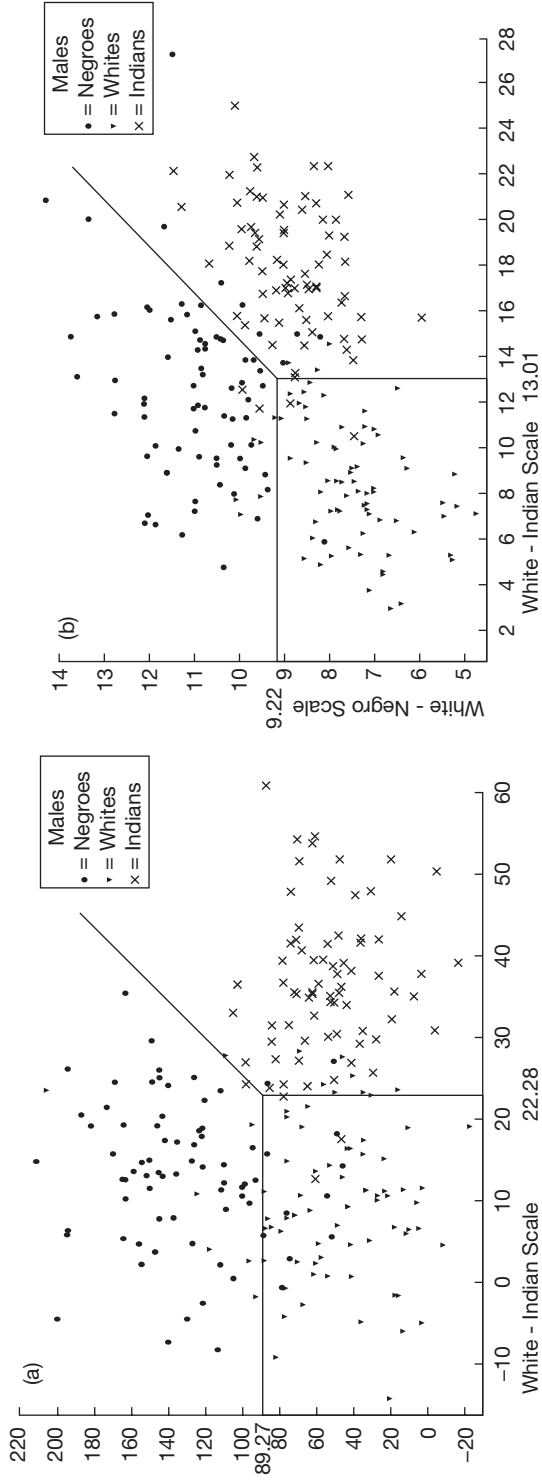


Figure 18.3 The sectioning points for males (left) and females (right) that resulted when Giles and Elliot applied their discriminant functions to the 225 males and 225 females used in the calculations (Giles & Elliot 1962: 153–54)

locations of anatomical landmarks on the skull and concluded that the changes are likely the result of “genetic changes, improved health and nutrition, and biomechanical responses to a more processed diet” (2005: 240).

Other cranial metric analyses include the work of Gill and Gilbert (1990), Curran (1990), Gill and associates (1988), and Howells (1973, 1989, 1995). Drawing on earlier research (Gill 1984; Gill et al. 1988), Gill and Gilbert (1990) present a method for measuring the midfacial skeleton of American Blacks and American Whites, with the hope of circumventing some of the problems inherent in the Giles and Elliot functions. Incorporating a simometer (modified coordinate calipers first developed by Howells in 1973), Gill and Gilbert took six measurements of midfacial dimensions from 100 American Blacks, 125 American Whites, and 173 Amerindians. Eventually they arrived at three indices they believed were most useful for determining ancestry: maxillofrontal index, zygoorbital index, and Alpha index (1990). They concluded that Whites scored differently on all three indices than did Blacks and Indians, and the last two groups produce very similar values (*ibid.*: 48–49).

Although Gill and Gilbert used a large American Indian sample for their study, Curran (1990) points out that their sample from the Southwest is relatively small ($n=27$). He tested the ability of the midfacial indices to distinguish among “Caucasoids,” “Negroids,” and a larger sample ($n=100$) of Southwestern American Indians. Curran reports that although the functions separate “Negroid” and “Caucasoid” crania and “Caucasoid” and Indian crania, they fail to reliably differentiate between “Negroid” and Indian crania (1990: 56).

In 1973 and 1989 W. W. Howells conducted and published two extensive studies of craniometrics variation among thousands of males and females from a number of the world’s populations. Subjecting the data from these studies to various statistical analyses, he concluded that subjects tend to cluster with one another by region. Howells expanded on his earlier work in 1995 by subjecting test crania to statistical analysis to see how closely they fit with selected groups from his 1973 and 1989 studies. These test crania were of known provenience and population affinity; however, he treated them as unknown in order to assess the predictive value of having large amounts of data on so many populations from around the world (1995). Howells’s method and data have been major contributors to some of the most recent and progressive discriminant function analytical tools, such as FORDISC.

Now in its third version, FORDISC is an interactive computer program that allows an investigator to compare measurements of unknown remains to as many as 11 groups using 1 to 34 cranial measurements or 1 to 39 postcranial measurements (Freid & Jantz 2005). A major advantage of FORDISC is its capability to customize discriminant functions to a particular specimen when, for example, it is too damaged to take all of the prescribed measurements or if it is not from a population already in the database (Ousley & Jantz 1996).

Although it is based on the same principles as the Giles and Elliot discriminant functions, FORDISC takes into account a number of new measurements in addition to having a much larger data bank from which to draw comparisons. The data bank used to generate FORDISC is composed of known, contemporary samples from the Forensic Data Bank at the University of Tennessee in Knoxville, the Howells world sample, and several archaeological populations (Freid & Jantz 2005; Ousley & Jantz 2005). Ousley and Jantz (2005) contend that having data from numerous populations from various time periods may enable the program to account for secular change.

In addition to FORDISC there is another computer program, CRANID, which calculates a linear discriminant and nearest neighbor discriminant analysis with 29 cranial measurements. The cranium is classified after comparison with 64 samples that include 3,163 crania from around the world (Wright 1992, 2008, 2012).

Dentition

In many cases the more fragile bones of the skeleton are lost to taphonomic forces (see Nawrocki, Chapter 25 this volume). However, teeth tend to survive the elements very well and can assist anthropologists in assessing the ancestry of unknown human remains (see Clement, Chapter 29 this volume). Shovel-shaped incisors, for example, are among the most recognizable traits that can be associated with a particular ancestral group. Aleš Hrdlička brought shovel-shaped incisors to the attention of physical anthropologists with his 1920 publication on the trait (Hinkes 1990). He noted varying degrees of shoveling and varying frequencies of the trait among Chinese, Mongolian, Japanese, Eskimo, American Indian, American White, and American Black dentitions and concluded that American Indians tend to exhibit the trait to a greater degree than do any of the other groups (Hrdlička 1920). Hinkes cites a number of other researchers who reported on observations of shovel-shaped incisors, both before and after Hrdlička's 1920 publication (see Hinkes 1990). Her 1990 chapter in the Gill and Rhine volume synthesizes all the other studies into one table, which contains a list of the samples along with the frequencies and varying degrees of shovel-shaping.

A recent publication by Lease and Sciulli (2005) discusses metric and morphological analyses of the deciduous teeth of African-American and European-American children to assess differences between these two groups. Lease and Sciulli used casts of dental arcades from children aged 2–6 years: 110 (males and females) for metric analyses and 117 (males and females) for morphological/nonmetric analyses (2005: 57). They concluded that, on average, African-Americans' deciduous teeth are approximately 7% larger than those of European-Americans and that although European-Americans show higher frequencies and more extreme expressions of nonmetric traits on their anterior teeth, African-Americans show such variation on the posterior teeth (*ibid.*: 60). According to Lease and Sciulli, although children could be placed into ancestral groups as identified by their parents, those categories are not derived from the continent of origin; rather, they are social categories and are dependent on how the parents categorize themselves and their children. They also cite Dahlberg (1951), identifying other aspects of dentition that are known to be population-related, including third-molar agenesis and molar cusp pattern variation. Recent research reports population variation in the thicknesses of the enamel, dentine, and pulp of deciduous teeth (Harris, Hicks, & Barcroft 2001).

Postcranial Metrics

Historically the femur is among the most thoroughly studied human postcranial bones. Consequently several of the methods available for evaluating ancestry based on the postcranial skeleton involve the femur. T. Dale Stewart claimed that his publication on the anterior curvature of the femur was the first to involve the postcranium for assessing ancestry. Until that time, "squatting facets" on the anterior margins of the tibiotalar joint were the "nearest thing to such a criterion so far reported" (1962: 49). He credits Aleš Hrdlička with the observation that "skeletons of Negroes are always to be distinguished from those of other races by the straightness of their long bones" (*ibid.*). Stewart's method involved leveling the bone using a wooden wedge beneath its proximal end and then measuring the heights above the table of (1) the leveling points, (2) the point on the diaphysis (shaft) of the greatest anterior curvature, (3) the highest point on the cervical tubercle, and (4) the highest point on the head (Figure 18.4) (*ibid.*).

Together these four measurements place values on both the anterior curvature of the diaphysis and the torsion of the proximal end of the bone (*ibid.*). Stewart found that Indians have the most pronounced curvature, Negroes have the least, and values for Whites fall somewhere in

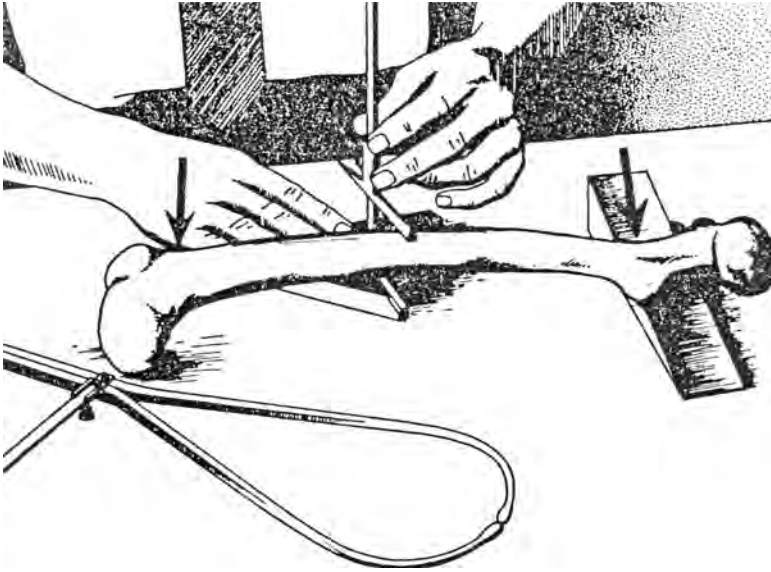


Figure 18.4 Stewart's method for measuring the anterior curvature of the femur. The bone is leveled by placing a wooden wedge beneath the proximal end (Stewart 1962: 51).

between. He indicated that assessing anterior femoral curvature alone is not as efficient as using it in combination with the degree of torsion for determining an individual's ancestry (*ibid.*: 58). One must keep in mind that variation such as this may be attributable to differences in diet or activity levels and may not, in fact, reflect genetic differences.

According to Gilbert and Gill (1990) American Indians tend to have a noticeably flattened (anteroposteriorly) subtrochanteric region when compared to American Blacks and Whites. In 2005 Wescott tested the Gilbert and Gill subtrochanteric (platymetric) index, evaluating its usefulness for distinguishing among five different populations: American Indians, Polynesians, Hispanics, American Whites, and American Blacks (2005: 286). He noted several limitations of the application of the platymetric index to the assessment of ancestry: (1) the shape of the proximal femur is more likely related to activity than it is to ancestry; (2) considerable intragroup variation can be attributed to sex differences rather than to population differences; (3) different groups of Native Americans may exhibit very different indices; and (4) the potential for interobserver error exists in the taking of measurements (*ibid.*: 287). After pooling the American Blacks and Whites into one sample, Wescott found that although the subtrochanteric index can be useful for differentiating Native Americans from American Blacks and Whites, its utility ends there, because the differences among Hispanics, American Blacks and American Whites are not statistically significant, and Native Americans frequently classify as Polynesian (*ibid.*: 289).

A third study involving metric analysis of the femur was introduced by Baker and colleagues (1990). They examined the anterior outlet of the intercondylar notch of the femur, concluding that "American Negroids" tend to have higher maximum notch heights than do "Caucasoids." Baker and associates refer to Trotter and Gleser (1952) and suggest that part of the difference in notch height may be due to the fact that "American Negroids" tend to have longer limbs than "Caucasoids" do (Baker, Gill, & Kieffer 1990: 94).

The pelvis has been found to be among the most reliable postcranial predictors of ancestry. İşcan (1983) measured three aspects (biliac breadth, antero-posterior height, and transverse

breadth) of 400 reconstructed pelvises from the Terry Collection (100 of each sex-race group: American Black and White, males and females). Using the discriminant function method, İşcan found that accuracy of ancestry identification was high, 88%, in the sample used to generate the functions. This method has the same potential limitation as do the Giles and Elliot cranial metric functions in that it will not reflect secular change. The method requires complete pelvises, which could be problematic if remains are poorly preserved. It is also age dependent, so that the age of the individual must be known or estimated to make the best use of the method.

In 1983 DiBennardo and Taylor introduced a method that combined measurements of the pelvis and femur. They took a series of 32 measurements of pelvis and femora of 260 North American Whites and Blacks (65 males and females of each race) from the Terry Collection. The measurements were then subjected to multiple discriminant function analyses to test their utility in predicting the race and the sex of unknown individuals. Race and sex were taken together to provide insight as to how racial and sexual variation affect each other (DiBennardo & Taylor 1983: 306). DiBennardo and Taylor (*ibid.*: 308) report an accuracy rate of approximately 95% for predicting both sex and race. They also developed a method for assessing ancestry via discriminant function analysis of the central portion of the pelvis in isolation, with a substantially lower success rate (average of 61.2%) than when the innominate and the femur are analyzed together (*ibid.*).

İşcan and Cotton (1990) expanded on this methodology by adding the tibia to the analysis of the pelvis and the femur. According to İşcan and Cotton (1990: 83), until 1990, the Schuller-Ellis and Hayek (1984) method, focusing on the acetabular region and the pubis, was the only method in the literature that did not require measurements of a complete pelvis, femur, or tibia. The İşcan and Cotton method involves discriminant function analysis of 21 measurements in all: 6 from the pelvis, 7 from the femur, and 8 from the tibia (1990: 83). Because this technique requires fewer measurements of the same elements used in previous methods and includes the analysis of an additional element, the authors suggest it is more applicable to incomplete remains (*ibid.*). Whereas the pelvis and the femur are often considered the most accurate postcranial predictors of ancestry, other postcranial elements (for example, the scapula) have been analyzed for their utility in determining ancestry (Krogman & İşcan 1986).

Since the publication of *Skeletal Attribution of Race* (Gill & Rhine 1990), several authors have included ancestry estimation sections in laboratory or field manuals (Krogman & İşcan 1986; Buikstra & Ubelaker 1994; Bass 1995; Burns 1999; White & Folkens 2005).

Ethics of Race/Ancestry Estimation in Forensic Anthropology

Forensic Anthropology has often been called upon to substantiate typological thinking and to reinforce the type concept itself.

(Williams, Belcher, & Armelagos 2005: 344)

Anthropologists have established the obvious fact that people from different parts of the world look different from one another. In fact this systematic variation often allows anthropologists and others to be able to suggest a person's place of ancestry by looking at him or her. Physical anthropologists have expanded this understanding of human variation to the skeleton such that forensic anthropologists, by observing suites of morphological characteristics or applying measurements to various algorithms, are able to estimate place of ancestry from skeletonized human remains, particularly the skull.

At the same time, the majority of anthropologists have rejected the concept of race applied to humans. According to Lieberman, Kirk, and Littlefield (2003: 112), 80% of cultural

anthropologists and 69% of physical anthropologists disagreed with this statement: “there are biological races in the species *Homo sapiens*.” Some anthropologists, most notably Goodman and Armelagos (1996), have argued that anthropologists should discredit the idea of human races and reject the notion that there are human groups that are definable by physical characteristics. They have criticized forensic anthropologists for adding credence to the idea of human races by including information about ancestry or race in their reports. To the contrary, some authors (see Gill 1998; Cox, Giles, & Buckley 2006) contend that it is essential to include the assessment of ancestry or race in a report and that it may in fact be unethical or irresponsible not to do so.

George Gill, an outspoken champion of the race concept, states that, unlike other kinds of anthropologists, forensic anthropologists do not have the luxury of ignoring the “the traditional concept of race” (1998: 295). Because they work in a context where traditional schemes of race have “clear meaning,” he believes that forensic anthropologists must translate their findings into terms such as “Caucasoid” and “Black.” He is strongly critical of those forensic anthropologists who deny the existence of race and who avoid using it in forensic cases.

Cox and associates (2006) present an interesting and novel justification for the identification of ancestry by forensic anthropologists. They point out that in New Zealand, the Maori believe that the remains of their ancestors “retain special importance” and that the physical remains of these ancestors need to be identified so that they can be handled in culturally prescribed ways (ibid.: 870). They state: “forensic anthropologists who refuse to identify ‘race’ could be seen to be placing their own beliefs over those of an indigenous group. Identification of the race and therefore ancestry of human physical remains by forensic anthropologists could be seen as an *ethical responsibility*” (emphasis added ibid.: 869). Presumably, their arguments are relevant to other Indigenous peoples.

Controversy about the existence of race in the field of anthropology and beyond presents practicing forensic anthropologists with a dilemma. Although most forensic anthropologists include some mention of ancestry (or race) as a key part of a biological profile, critics point out that this reifies an outdated and demonstrably harmful concept (see Albanese & Saunders 2006).

Williams, Belcher, and Armelagos (2005) and Goodman (1997) are among the anthropologists who believe that forensic anthropology should avoid attempts to identify either ancestry or race, because the methods used to do so are flawed and inaccurate. Williams, Belcher, and Armelagos (2005) applied discriminant function analyses using FORDISC 2.0 to a sample of 42 ancient Nubian crania dated from 350 B.C.E. to 350 C.E. Using 12 measurements, the Forensic Data Bank series identified 12 of the 42 crania as White, 11 as Black, 3 as Japanese, 1 as Hispanic, and 1 as Native American. The remaining 14 crania “were significantly different from the population specified by FORDISC 2.0 (typicality $p < 0.05$)” (Williams, Belcher, & Armelagos 2005: 342) and were considered inadequately classified. The authors conclude: “skeletal specimens or samples cannot be accurately classified by geography or by racial variation” (ibid.: 345). These authors support their argument with an earlier published study of Spanish crania.

In 2002 Ubelaker, Ross, and Graver reported on a study that applied FORDISC 2.0 to a sample of crania from 16th- and 17th-century Spain. Twenty standard measurements were taken on 95 crania, 58 of which were believed to be male and 37 female. FORDISC 2.0 analysis using the Forensic Data Bank option classified the crania as follows: 44% as White; 35% as Black; 9% as Hispanic; 4% as Japanese; 4% as American Indian. Williams and associates (2005) refer to this study as a second illustration of how FORDISC 2.0 performs poorly when asked to identify specimens from samples not already in the system.

Are forensic anthropologists faced, as Williams and associates (2005) contend, with applying methods that do not work to ascribe individuals to races that do not exist? Not necessarily. First,

no forensic anthropologists we know of uses discriminant functions as the sole or primary tool for determining ancestry. In our laboratory, and from personal experience, we know that our practice is the norm: FORDISC 2.0 and 3.0 are used to help to confirm or to raise doubts about conclusions based on morphology and context (see also Ubelaker, Ross, & Graver 2002). To critique the practice of ancestry estimation based on an application of discriminant function in a vacuum is naïve and unwarranted. Second, as Ubelaker and colleagues (2002) and Ousley and Jantz (1996) point out, FORDISC does not perform well on individuals or samples that are not adequately represented in the database. In other words, lacking a Nubian or Spanish reference sample in the FORDISC database, the program is neither expected nor designed to perform well.

Brace (1995), Kennedy (1995), and Sauer (1992) have all supported the no-race position yet argue that identifying place of ancestry is a legitimate and useful goal when trying to generate a biological profile and identify unknown human remains. Using estimations of region of ancestry can be a useful tool when applied to missing person cases. How the information is communicated to various agencies must depend on the circumstances of the individual case and its context.

Conclusion

In this chapter we have briefly discussed the concept of race from an historical perspective to illustrate that, despite the contributions that anthropology made in the past to the establishment of traditional views of race, the prevalent view among contemporary anthropologists is that races do not exist. Having established that point, we argue that current techniques are useful for assessing the region of ancestry for many individuals (Sauer 1992; Brace 1995) and that this information has potential value for identifying decomposed or otherwise unrecognizable human remains. Although it should be clear that identifying an individual's place of ancestry is not tantamount to identifying his or her race, identifying place of ancestry does allow anthropologists to predict to which race a missing person was most likely assigned (see Sauer 1992).

Ancestry evaluation is an integral part of the forensic examination. Assisting investigators with human remains identification by adding information about ancestry may facilitate and accelerate the process. Of course, caution is essential when one is offering any judgment about an individual from his or her remains, but many decades of research have shown that an understanding of systematic human variation allows the accurate (although not perfect) estimation of ancestry from the skeleton. It is our position that when reporting on ancestry investigators should avoid loaded archaic terms. However, if it is clear that an individual's ancestors are highly likely to have come from Europe, for example, then that fact should be communicate to the proper authorities.

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Anthropological Estimation of Sex

Samantha K. Rowbotham

The anthropological assessment of sex involves the use of skeletal indicators to provide an estimation of whether or not an individual was biologically male or female. Estimating the biological sex of an individual is one of the four components of the biological profile and is of interest in all human osteology-based disciplines. Physical anthropologists and biological archaeologists are interested in estimating sex because it provides demographic information; forensic anthropologists are interested in sex estimation because knowing an individual's sex contributes to the preliminary identification process for law enforcement agencies. For forensic anthropologists, knowing the sex of an individual effectively narrows missing-person searches by 50% and provides a potential way of differentiating commingled skeletal remains (Barker et al. 2008). Given that the conclusions provided by a forensic anthropologist have legal implications with potentially serious repercussions, the forensic anthropologist has an ethical obligation to ensure that the methods he or she employs have been extensively tested, validated, and widely accepted in the discipline and that they produce the most reliable results. In undertaking an estimation of sex two approaches are possible; morphological and metric. *Morphological* refers to the visual assessment of the shape of specific skeletal elements, and *metric* refers to the measuring and quantifying of anatomical parts of skeletal elements. Both methods are typically concerned with the pelvic girdle and the skull.

This chapter provides an overview of the anthropological estimation of sex. *Sexual dimorphism* is defined, followed by an outline of the historical developments of scientific research into sexual dimorphism. The key morphological and metric techniques currently utilised in forensic anthropology are presented, the limitations associated with estimating sex are highlighted, and the contribution of deoxyribonucleic acid (DNA) to determining sex is described. Finally, the limitations and future directions for research in this area are discussed.

Sexual Dimorphism

The phenotypic differences between the male and the female skeleton are referred to as *sexual dimorphism*. These differences are attributed to the chromosomal structure and hormonal productions at two stages in human development. First, the sex of an individual is determined from his or her chromosomal structure, which is established at conception. The structure of chromosomes differs between the sexes, with males having an XY structure and females an XX structure (Mays 2010). The X is considered the initial chromosome, and so the female is regarded as the “original” sex—meaning that all foetuses will develop into females unless they are redirected by the male hormones produced as the result of a Y chromosome (Wilson, George, & Griffin

1981). The second stage of the development of sexual dimorphism is the extent and duration of hormone production during the pubertal period. The quantity of hormones produced, testosterone in males and oestrogen in females, directly affects the extent of male and female features manifested in the adult skeleton (Scheuer & Black 2000). Essentially, the greater hormone production of testosterone in males and oestrogen in females, the greater the development of sexually dimorphic skeletal features. Therefore, although chromosomal structure determines the first stage of sexual dimorphism, it is the second stage that has the greatest impact on the extent of male or female skeletal characteristics.

White, Black, and Folkens (2012) noted that the variation in sexual dimorphism between males and females can produce between 0 and 20% difference in skeletal dimensions. Compared to the variation in most other primate species, this is a relatively small variation difference. Consequently, it is possible to differentiate between the sexes using the small dimorphic variations only in the most sexually dimorphic skeletal elements: the pelvis, skull, and select long bones.

Historical Development

Scientific anatomical interest in human skeletal sexual dimorphism has been a developing field since the Renaissance. This development is documented in the gender studies of Schiebinger (1986) and Stolberg (2003), in which they interpreted the original Latin anatomical texts that discussed female skeletal characteristics.

The concept that skeletal morphology differed between the sexes, particularly the pelvis and its function for parturition in females, was first discussed in the late 15th century medical writings of Alessandro Benedetti and Giacomo Berengario da Carpi (Stolberg 2003). This idea of skeletal anatomical differentiation was then expanded and further detailed by physician Felix Platter in his 1583 work *De Corporis Humani Structura et Usu Libri III*, where the first comprehensive skeletal analysis of sexually dimorphic traits was provided (Platter 1583). Platter's work included the first illustration of a female skeleton with 13 skeletal markers noting sexually dimorphic traits in the pelvis (ilium, pubis, and coccyx), lumbar vertebrae, ribs, sternum, clavicles, and cranial sutures (Platter 1583). These skeletal traits were further developed and refined by his colleague Caspar Bauhin (1597) in the publication *Anatomica Corporis Virilis et Muliebris Historia*. The collaborative studies of these two physicians produced the first anatomical and scientific understandings of the biological variations in the skeleton. By the mid-18th century these observations had become well documented in European anatomical texts (Schiebinger 1986). With the exception of Platter (1583) and Bauhin's (1597) notations on cranial sutures, sexual dimorphism in the skull remained undocumented until the late 18th century, when Ackermann (1788) and Soemmerring (1796) first noted and documented dimorphic variations in facial skeletal characteristics and cranial sizes and shapes, respectively.

The scientific biological process behind these physically manifested skeletal changes was not wholly understood until the concept of sexual dimorphism was introduced by anatomist John Barclay (in Mitchell, Albinus, & Barclay 1819) and expanded by Posner (1847). They proposed that male and female skeletons were initially the same and that skeletal differences did not develop until puberty. Thus by the end of the 18th century the contemporary understanding of which features are morphologically sexually dimorphic in the skeleton, and how and when these are produced, was established.

Anthropological interest in developing techniques to scientifically differentiate male and female skeletal remains began around the turn of the 20th century. Currently the earliest known recording methods of morphological techniques assessing sexual dimorphism was in Broca's (1875) work on the skull, and the first application of metric techniques to estimate sex in

postcranial elements was undertaken by Pearson (1915). These studies mark the commencement of over a century of extensive osteological research in identifying sexually dimorphic skeletal features, particularly from the pelvis and skull, using morphological and metric applications. This scientific interest in developing and validating techniques continues in the 21st century.

Morphological and Metric Techniques

The visual assessment of skeletal morphology and the collection of osteological measurements have typically been undertaken on the pelvis and the skull, because these are the most sexually dimorphic skeletal elements and thus provide the most reliable estimations. There has been some debate in the literature regarding which of these methodological approaches, metric or morphological, is superior. It has been argued metric techniques provide more robust results because they deliver more precise statistical conclusions and do not require a high level of osteological expertise (Moore 2012). However, morphological applications have been found to be easier and faster to use and provide equally reliable results (Barker et al. 2008; Mays 2010). Although the choice of technique may be dictated by the preservation and the condition of the skeletal remains, the general consensus is that both approaches are of equal value, and, regardless of an individual's preference, both should be utilised in order to provide the most holistic and reliable estimation of sex.

The next two sections discuss the key morphological and metric techniques used within forensic anthropology. Refer to the original sources for detailed methodologies on technique application and the guidelines of the Scientific Working Group of Anthropologists for implementing best practices when making these assessments (SWGANTH 2011).

Morphological Techniques

Research undertaken using morphological techniques to estimate sex indicates that variation occurs in the reliability of results; techniques are generally considered to produce between 90% and 98% accuracy (Krogman 1962; Meindl et al. 1985). This variation depends on which skeletal elements are preserved and therefore available to examine. The most reliable sex estimations can be achieved if the pelvis and the cranium are collectively examined and all characteristic features on those skeletal elements are assessed (Rogers & Saunders 1994). Overall this level of reliability for morphological techniques is high; however, as Littleton and Kinaston (2008) note, there will always be intrinsic variation between males and females, and so 100% accuracy will never be achieved.

Morphological methods are the more traditional and commonly employed approach. However, it needs to be taken into consideration that they are subjective techniques and so are dependent on the assessor's training and experience, and knowledge of, the variation in sexual dimorphism in human skeletal remains. Ideally the pelvis should be assessed first, because its evolutionary predisposition to parturition and absence of ancestral traits lead to greater reliability than is possible from assessing the skull, which should be assessed second.

Pelvis

The pelvis, as previously detailed, constitutes the most sexually diagnostic skeletal elements. Variation between the female pelvis and the male pelvis is seen in the overall pelvic morphology and within the individual bones making up the pelvic girdle. Overall pelvic girdle dimorphic differences are generally characterised by a pelvis that is low and wide with a rounded pelvic

inlet in females and a pelvis that is high and narrow with a heart-shaped pelvic inlet in males. These differences are denoted by greater flaring of the ilium blades, less curvature of the sacrum, nonintrusive ischial spines, and wider subpubic angles in females compared to males.

Sexually dimorphic characteristics are also evident among the individual bones of the pelvis. (Refer to Figure 19.1 for the osteology features and Table 19.1 for the corresponding qualitative scoring criteria.) Of these bones the pubis has been found to be particularly accurate for sex estimation, because it is the most responsive skeletal element to hormonal changes and thus produces the greatest diversity in sexual dimorphism (Washburn 1948; Phenice 1969). Skeletal features indicative of parturition, particularly the presence of dorsal pubic pitting and extended pubic tubercles, may also be utilised for estimating sex. Caution has been advised by Ubelaker

Table 19.1 Qualitative scoring criteria for the sexually dimorphic traits of the adult pelvis

Bone	Number	Feature	Female	Male
Ilium	1	Overall	Significant flare (lateral), low, broad	Minimal flare, high, narrow
	2	Greater Sciatic Notch*	Wide, shallow	Narrow, deep
	3	Auricular Surface	Elevated	Flat
Pubis	4	Ventral Arc*	Elevated ridge	Absent/slight ridge
	5	Subpubic Concavity*	Concave	Convex
	6	Ischiopubic Ramus Ridge*	Narrow, crest like	Broad, flat
	7	Overall	Long, square	Short, rounded
Sacrum	8	Overall	Small, wide, tapered	Large, narrow, elongated
	9	Body Proportions	1/3 body, 2/3 ala	1/2 body, 1/2 ala
	10	Curvature	Minimal	Significant
Os Coxae	11	Obturator Foramen	Triangular, small	Oval, large
	12	Acetabulum	Lateral facing, small	Anterior facing, large

*Standard traits referenced in the literature
Adapted from Barker et al. (2008); Buikstra & Ubelaker (1994); Ferembach, Schwidetzky, & Stloukal (1980)

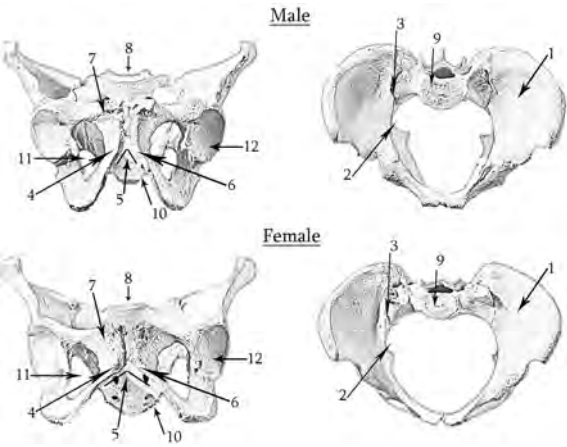


Figure 19.1 Sexual dimorphism in the adult human pelvis indicates male (top) and female (bottom); anterior and superior views (images of skeletal elements adapted from photographs in White, Black, & Folkens 2012: 417, fig. 18.26)

and De La Paz (2012) when using these features, however, since their reliability has been found to be extremely questionable.

Skull

Sexual dimorphism in the skull follows the principle that, in general, males are larger and more skeletally robust than females. This is seen in the sexual dimorphism expressed in the occipital and most facial bones (Figure 19.2). The extent of this dimorphism is qualitatively documented using Inforce Foundation's five-point scoring system as detailed in Barker and associates (2008) (Table 19.2). Five classifications are recommended to score skull traits because the sexually dimorphic variation in the skull is often more ambiguous than the pelvis' more strictly "male" or "female" categories. Caution should be taken when assessing the mandible in isolation as it is the most environmentally adaptable bone. It has been found to remodel throughout life, from diet and tooth loss, and this can alter the shape and thus potentially affect the subjectivity of sex estimations (Meindl et al. 1985).

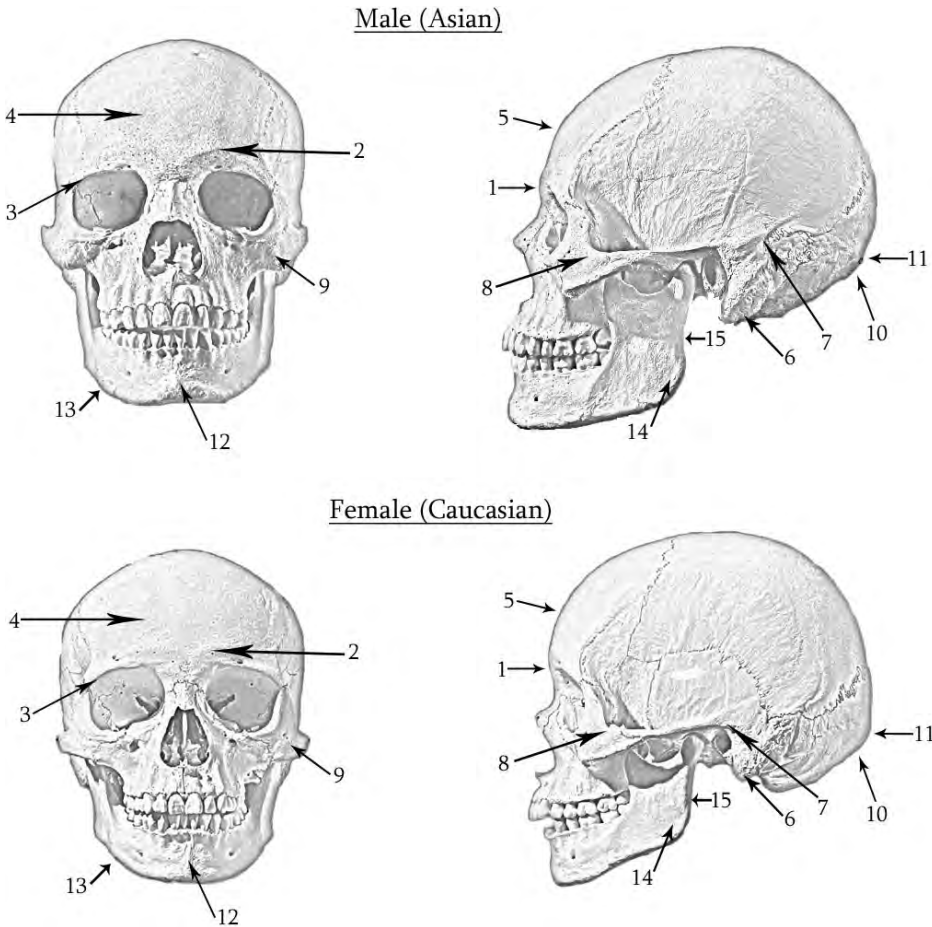


Figure 19.2 Sexual dimorphism in the adult human skull indicates male (top) and female (bottom); frontal and lateral views (images of skeletal elements adapted from photographs in White, Black, & Folkens 2012: 409, fig. 18.20)

Table 19.2 Qualitative scoring criteria for the sexually dimorphic traits of the adult skull

Bone	Number	Feature	Female	Probable Female	Indeterminate	Probable Male	Male
Frontal	1	Glabella*	*Smooth	Slight	Moderate	Marked	Prominent
	2	Superciliary Arches	Smooth	Slight	Moderate	Marked	Prominent
	3	Upper Orbital Margin	Very round, sharp border	Round, sharp border	Transitory form,	Quadrangle, round border	Very quadrangle, round border
Temporal	4	Frontal Bossing	Very distinct (double)	Distinct	Slight	Indistinct	Absent
	5	Profile	Very steep incline	Steep incline	Medium incline	Slight incline	Very slight incline
	6	Mastoid Process*	Very small	Small	Medium	Large	Very large
	7	Mastoid Crest	Close to external auditory meatus	Almost reaches external auditory meatus	At point of external auditory meatus	Extends beyond external auditory meatus	Extends well beyond external auditory meatus
Zygomatic	8	Zygomatic Process*	Very low, smooth surface	Low, smooth surface	Medium, irregular surface	High, irregular surface	Very high, very irregular surface
Occipital	9	Malar Rugosity	Smooth	Slight	Moderate	Marked	Prominent
	10	Nuchal Plane Rugosity*	Smooth	Slight	Moderate	Marked	Prominent
	11	External Occipital Protuberance	Smooth	Slight	Moderate	Marked	Prominent
	12	Mental Eminence*	No projection	Small projection	Medium projection	Large projection	Very large projection
Mandible	13	Chin shape	Rounded or pointed	Moderately rounded	Transitory form	Moderately square	Square, protuberant
	14	Gonial Angle	Flaring absent, no rugosity	Slight flaring, no rugosity	Medium flare, possible rugosity	Distinct flare, minimal rugosity	Very distinct flare, marked rugosity
	15	Ramus Flexure	No angulation	No angulation	Possible angulation	Moderate angulation	Distinct angulation

*Standard traits referenced in the literature
Adapted from Barker et al. (2008); Buikstra & Ubelaker (1994); Ferembach, Schwidetzky, & Stloukal (1980); Walrath, Turner, & Bruzek (2004)

Metric Techniques

Metric techniques involve measuring sexually dimorphic skeletal elements and comparing the results with measurements of individuals of known sex. These techniques have been established for, and implemented on, a large range of skeletal elements, with a particular focus on the post-cranial. Measurement dimensions are defined with osteological landmarks, or the maximum or minimum dimensions of a skeletal element, and they are typically used for univariate or multivariate analyses. The metric approach has increased in popularity over the last 10 to 15 years—probably because of the technique’s statistical nature, lack of subjectivity, and high degree of reliability with inter-observer errors (Adams & Byrd 2002).

Metric techniques are not without their limitations, however. First, these techniques are population specific and so can be applied only to skeletal remains of the ancestral population the technique was developed from (Blau 2014)—thus they cannot be applied successfully to fragmentary remains where diagnostic features indicating ancestry are not available. Second, it can be difficult to measure different skeletal elements and features. Often the landmarks may be ambiguous or difficult to determine owing to poor preservation, and measurements may not be possible if remains are fragmentary.

Metric techniques for the skull typically use discriminant functions (uni- or multivariate statistics), which were first applied by Giles and Elliot (1963), who established a criterion of nine cranial metric measurements. According to the statistical analysis of the measured variables, the individual will be assigned to a sample that is classified into a minimum of two groups; in this case, male and female (Giles & Elliot 1963). Use of this approach led to the development of statistical software programs such as FORDISC (Ousley & Jantz 2013) and CRANID (Wright 1992; Hughes, Wright, & Barry 2005). FORDISC, now in its third generation, uses linear discriminant function analyses and is widely utilised by anthropologists to estimate the sex of an individual (Ousley & Jantz 2013). CRANID uses linear discriminant analyses and nearest neighbour analyses to estimate an individual’s ancestry and sex (Wright 1992). These original measurements are still the accepted cranial metric approach today; however, recently research has begun establishing alternative techniques that utilise sizes and angles to estimate sex from other cranial features, including the frontal sinuses (Belaldavar et al. 2014), dentition (Yuwanati, Karia, & Yuwanati 2012), and the petrous portion (Akansel et al. 2008). These alternative techniques are still new, however, and so should be used with caution.

Developments of indices for the pelvis generally use the isolated os coxae (Patriquin, Steyn, & Loth 2005), with a specific focus on the pubis, because it is proportionally longer in females than in males so is ideal for metric studies (Washburn 1948; Albanese 2003). Other studies have focused on combinations of the isolated os coxae, sacrum, and the complete pelvic girdle (Steyn & İşcan 2008). However, some of these indices (for example, Washburn 1948) have been found to be less reliable than their comparative morphological analyses (Drew 2013).

Postcranial metrics, particularly those of the long bones, have been found by Spradley and Jantz (2011) to provide greater reliability than the cranial metrics. There is a multitude of post-cranial studies, and some, such as femoral and humeral dimensions as detailed in Bass (1995), are more commonly utilised than others. In the last decade research has focused on estimating sex using small or fragmentary skeletal remains for cases where the pelvis, skull, and long bones are not recovered or are poorly preserved. The diversity of these postcranial metric studies include, but are not exclusive to, the hyoid (Urbanová et al. 2013), individual vertebrae (Marlow & Pastor 2011), phalanges (Eshak, Ahmed, & Abdel Gawad 2011), fourth ribs (Macaluso et al. 2012), patellae (Akhlaghi et al. 2010), and metatarsals (Mountrakis et al. 2010). Accuracies of these studies range from 76% to 96%. In addition, research by Albanese (2003,

2013) has developed non-population-specific metric techniques for a number of postcranial skeletal elements. Accuracy ranges from 87% to 97% for the humerus, radius, ulna, and clavicle up to 98% for the pelvis. Certainly non-population-specific techniques are ideal for the forensic anthropologist, because when estimation of ancestry is not possible the estimation of sex can still be assessed. However, Albanese (2003, 2013) and the aforementioned postcranial metric techniques for small or fragmentary skeletal elements are recent developments, and so further validation work is required before they are used in isolation to estimate sex. Both morphological and metric techniques have advantages and disadvantages that indicate that a combination of the two approaches should always be implemented to attain the most reliable sex estimation.

Things to Consider When Estimating Sex

One needs to consider three issues when estimating the sex of an individual: (1) the development of sexually dimorphic features is biased; (2) overlap exists in features that are used for ancestry and sex estimations; and (3) age can alter sex characteristics.

Natural bias in sex estimations of the pelvis and skull can develop from the pubertal hormone growth period. As previously noted prepubescent skeletons are “gracile” and present no sexual dimorphism until the onset of puberty. During this pubertal period the male pelvis does not change form, whereas the female pelvis adapts to prepare for parturition. Paradoxically, the remainder of the female skeleton, particularly the skull, maintains the gracile characteristics of a neonate, whereas the male skeleton develops larger and more robust skull features. The level of hormone production needed to create these characteristics varies with each individual, and so if an individual’s hormone production is low, sexual characteristics may potentially retain some of their neonatal features, which may result in misclassification. For example, a female pelvis may retain some of the prepubescent male traits and potentially be misclassified as male, and the male skull may retain some of the original prepubescent female traits and potentially be misclassified as female. To account for this bias when making sex estimations, one should give more weight to female characteristics when assessing the pelvis and to male characteristics when assessing the skull.

Another concern is that sexual dimorphism is population specific. To be more precise, the robusticity of an individual’s skull is the product of both ancestral and sexual dimorphic development. Subsequently, sex estimation using the skull should not be made without first estimating ancestry; otherwise there is the potential for misclassification of the sex. Estimating the ancestry first is necessary, because some ancestral groups are relatively robust (for example, Indigenous Australian Aboriginals), and so both sexes exhibit robust sexual traits, while other groups are gracile (for instance, Europeans), and so both sexes exhibit gracile traits. Thus once the individual’s ancestral origins are established, the examiner can then assess the robusticity produced from sexual dimorphism relative to what is considered robust or gracile for that ancestral population. If ancestry is not estimated first, the potential exists for sex estimation to be misclassified. For example, a gracile male who would be considered robust within his gracile population may be incorrectly classified as female if his limited robusticity was attributed only to his sexual dimorphic development and not to his ancestral development.

Last, one must consider the age of the individual when estimating sex. For example, in the case of an elderly female who has passed menopause, cranial features may have slightly regressed to their neotenous masculine form owing to the reduction in oestrogen hormone production, and pelvic features, including dorsal pitting and the preauricular sulci, may have lost their characteristic appearances (Rogers & Saunders 1994; Mays & Cox 2000). Currently Mays and Cox (2000) and Rogers and Saunders (1994) have not found these manifestations to be a significant

concern in sex estimations; however, they note that they should be taken into consideration and that further investigation in this field is required.

Contribution of DNA

There have been significant advancements in the use of DNA to determine sex. Molecular biologists use proteins referred to as amelogenin, a gene involved in tooth formation, to amplify the X- and Y-chromosomes and distinguish between them by using gel and capillary electrophoresis (see Baker, Chapter 28 this volume). Determination of sex is made based on the number of products in a sample; two different products, X- and Y-chromosomes, are expected to be seen in males, and only one product, X-chromosome, is expected in females (Stone 2008). The method is revolutionary, because it can confirm the traditional anthropological techniques, but, most significantly, it is able to determine sex for juvenile and differentially preserved skeletal remains—thus DNA has been widely used to determine sex in skeletal materials of both archaeological and forensic contexts. DNA is not without its limitations, however. DNA samples may be contaminated or degraded, the process is time consuming and expensive, and occasionally false results can be produced (Mays 2010). For these reasons DNA analysis is typically used to complement the traditional estimations of sex but tends to be employed in cases of juvenile and differentially preserved remains where there are no other satisfactory methods.

Limitations

The greatest limitation for anthropological estimations of sex is the lack of reliable sexing techniques for juvenile skeletal remains (Blau & Hill 2014). This limitation has significant repercussions for establishing a child's biological profile to aid in identification in forensic cases—because if the sex is unknown, the precision of the age ranges is also limited as these are sex-specific.

The stage at which sexual dimorphism is distinguishable is a contentious topic. There is general agreement that sexual dimorphism is present from the intrauterine stage onward (Wilson, George, & Griffin 1981); however, differences are not satisfactorily distinguishable in the skeleton until puberty is completed (Scheuer & Black 2000; Baker, Dupras, & Tocheri 2005). Thus it is generally accepted that there are no reliable methods to estimate sex in cases of juvenile skeletal remains (Blau & Hill 2014). Consequently, considerable research has been conducted into differentiating male and female juveniles using the same skeletal elements sexually dimorphic in adults. Examples of these skeletal elements include the skull (Molleson, Cruse, & Mays 1998; Loth & Henneberg 2001), dentition (Black 1978; Cardoso 2008), pelvis (Mittler & Sheridan 1992; Holcomb & Konigsberg 1995; Vlak, Roksandic, & Schillaci 2008), and long bones (Rissech, Schaefer, & Malgosa 2008; Stull & Godde 2013). This research has produced varying levels of reliability; it is limited by a lack of large juvenile osteological samples of known sex from which to establish, and validate, techniques. Subsequently, DNA is still considered the only accurate means to determine sex in juvenile skeletal remains.

Future Directions

Based on current developments and areas of particular interest in the literature, it is anticipated that the estimation of sex in human skeletal remains will continue to develop and expand in two research avenues. First, there will be further developments in metric techniques. The recent explosion of postcranial metric techniques will require rigorous validation studies before they can be applied in forensic anthropology casework. It is likely that these

techniques will also further develop and focus on estimating sex from fragmentary skeletal elements of the less well documented skeletal regions, such as hands and feet. Also, there will likely be a stronger focus on developing the non-population-specific metrics initiated by Albanese (2003, 2013); the potential benefits from these are momentous. Second, research will continue into establishing morphological and metric sex techniques for juvenile remains. Since one of the major difficulties working with juvenile remains of known sex is sample size, the application of computed-tomography-imaging samples, either medical or postmortem, may be useful, because they are typically large sample sizes with known sex data (for example, Decker et al. 2011).

Conclusion

The anthropological estimation of sex in human skeletal remains forms an important part of the biological profile, which is important for establishing an individual's identification in forensic cases. Sex is estimated from an assessment of sexually dimorphic parts of the skeleton, specifically the pelvis, cranium, and selected postcranial elements, using traditional, well-established, and scientifically validated morphological and metric techniques. Owing to the valuable contribution that sex estimation provides forensic practitioners, continual validations and improvements of techniques are required to ensure the accuracy and robustness of findings. Although the estimation of sex can be a somewhat complex process for the untrained practitioner, particularly considering the subjectivity involved with morphological techniques and the population limitations with metric techniques, combining the two approaches increases the reliability of results. Ideally the anthropologist should, after accounting for concerns of hormonal bias and the other biological profile components, employ both morphological and metric techniques to the pelvis and cranium to achieve the most reliable estimation of sex.

In addition to traditional techniques, the improvement of metric techniques, the development of methods for juveniles, and advances in DNA applications mean that the anthropologist's ability to accurately estimate sex in human skeletal remains will only continue to improve.

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Skeletal Age Estimation

Tracy L. Rogers

Age estimation is a critical component of the biological profile, as even the broadest age ranges can help focus the investigation into the identity of unknown human remains. For example, as of February 2015 in Canada there were 774 missing adults listed on the publicly accessible website Royal Canadian Mounted Police (RCMP) National Centre for Missing Persons and Unidentified Remains (NCMPUR) (RCMP 2014). Of those, 251 (32%) were between the ages of 20 and 50 years. If a forensic anthropologist in this example could provide a broad skeletal age-at-death estimate of 20–50 years for found remains, 68% of prospective matches could be eliminated. The narrower the age estimate, the more useful the skeletal analysis is in reducing the number of potential missing person matches and expediting the process of positive identification.

Although restricted age ranges are desirable, they are not always feasible. The difficulty in estimating the age at death of a skeleton stems from the fact that our chronological age (how old we are in years) rarely corresponds exactly to our physiological age (how old our bodies appear as a result of development and subsequent degeneration). Skeletal aging is a variable and nonlinear process, resulting from individual health, nutrition, genetics, mechanical wear, and exposure to environmental stressors. To encompass the scope of individual variability inherent in the aging process, skeletal age estimations are always reported in ranges, for example, 23–57 years. Depending on the technique used to approximate age at death, the recommended age ranges will include the majority of individuals in the test sample (Gilbert & McKern 1973), 95% of the range of individual variation (McKern & Stewart 1957; Suchey, Wiseley, & Katz 1986), prediction intervals of varying magnitudes (Samworth & Gowland 2007), or some other measure of inclusiveness (Lovejoy et al. 1985a).

In a forensic context it is necessary to balance a restricted age estimate, capable of eliminating some members of the missing persons list, with a broad age range that accounts for individual variation and encompasses the true age of the deceased. If the estimated age range is too large, then greater time, effort, and money will be needed to test all the potential matches for DNA identification. If the age-at-death evaluation is too narrow, the true age of the deceased may not be included in the estimate, causing the police to incorrectly eliminate that individual as a potential match to the remains. Either problem can have serious repercussions for a medico-legal investigation.

Comprehensive overviews and summaries of skeletal age indicators are available in several texts, including Bass (2005), Buikstra and Ubelaker (1994), Byers (2010), Christensen, Passalacqua, and Bartelink (2014), DiGangi and Moore (2013), Dirkmaat (2012), and White, Black, and Folkens (2011). Juvenile remains are given detailed consideration in Fazekas and Kósa (1978),

Schaefer, Black and Scheuer (2009), and Scheuer and Black (2000, 2004). Two of the most complete treatments of skeletal age estimation are İşcan's *Age Markers in the Human Skeleton* (1989), and Latham and Finnegan's *Age Estimation of the Human Skeleton* (2010); and a detailed bibliography relating to skeletal age estimation can be found in Black and Ferguson (2011). The Scientific Working Group for Forensic Anthropology (SWGANTH 2013), in contrast, provides guidelines for selecting and implementing appropriate methods of age estimation.

This chapter addresses the theoretical implications of macroscopic age-at-death estimation of both human skeletal remains and living individuals in a forensic context. It outlines the primary themes and concerns associated with skeletal age indicators, summarizes major historical developments that have led to significant advances and influenced current trends, and concludes with an examination of the future of skeletal age-at-death estimation.

Main Issues and Concerns

Estimating the age of skeletal remains introduces several theoretical and practical problems: (1) subadult versus adult age estimation, including estimating age in living individuals; (2) chronological versus physiological age; (3) side asymmetry; (4) statistical analysis of age-related changes in the skeleton; (5) combining information from multiple age indicators; and (6) admissibility.

Subadult versus Adult—Age Estimation of the Dead and the Living

Because the techniques used to assess juvenile age-at-death differ from those applied to adults, skeletal age estimates generally begin with a brief evaluation of maturational stage to determine which methods are most appropriate. Distinguishing infants and children from adults poses no difficulty, but separating adolescent from young-adult skeletons can be challenging owing to sexual and individual developmental variation. Adolescence is both a biologically variable period and a culturally heterogeneous experience. In a physiological sense an adult skeleton is one in which the growth process is complete; all epiphyses are fused. Yet epiphyseal union is a gradual process that occurs primarily throughout the teenage years for long bones but extends into the mid-20s and early 30s for the iliac crest (Webb & Suchey 1985) and sternal clavicle (Webb & Suchey 1985; Bassed et al. 2011). Not surprisingly, in a review of 200 osteology articles from 2004 to 2009, Falyas and Lewis (2011) found inconsistencies in the minimum age at which a skeleton is deemed an adult; ranging from 14–25 years of age.

In a cultural sense “adult” can mean the legal determination of adulthood as established by the state, province, or country; a cultural or ethnic recognition of adulthood; or an informal acknowledgment of adult status by family or peers. One cannot assume a skeletal assessment of “adult” will be universally or correctly interpreted by medico-legal investigators. Thus a minimum age-at-death estimate should be provided for all cases in which only a broad distinction between adult and subadult skeletal remains is possible.

Because subadult age indicators reflect only the developmental stage in which they are active (that is, dental formation in young children, tooth eruption in middle childhood, epiphyseal fusion in later childhood and adolescence, and diaphyseal length up to the point of epiphyseal union) the progressive nature of growth and development generates more precise age ranges than is possible with adult age indicators, which are rooted in remodeling and degenerative changes (İşcan & Loth 1989). Maturational changes during development are largely under genetic control, although health, nutrition, and other environmental stressors do have the capacity to stunt and/or slow these processes (Johnston & Zimmer 1989; Stinson 2000; Cardoso 2011). Teeth are less susceptible than bone is to environmental disturbances, making teeth the preferred tissue

for estimating juvenile age (Demirjian 1986; Cardoso 2007, 2009, 2011; SWGANTH 2013). Dental formation is favored over eruption, because eruption rates vary by population and can be negatively affected by disease and poor nutrition (Saunders 2008).

Recent research in subadult age estimation has focused on testing existing growth standards (for example, Maresh 1955; Greulich & Pyle 1959; Moorrees, Fanning, & Hunt 1963) for use in skeletal/dental age estimation (Graham et al. 2010; Schillaci, Sachdev, & Bhargava 2012; Suri et al. 2013; AlQahtani, Hector, & Liversidge 2014; Tomás et al. 2014), as well as developing purpose-built standards to estimate fetal gestational age (Carneiro et al. 2013) and juvenile skeletal age (Crowder & Austin 2005; AlQahtani, Hector, & Liversidge 2010; Rissech, Márquez-Grant, & Turbón 2013). Comprehensive reviews of subadult osteology, growth, and growth research can be found in Baker, Dupras, and Tocheri (2005), Saunders (2008), and Scheuer and Black (2000).

Distinguishing adults from subadults becomes more problematic when it is necessary to determine the legal status of living individuals who lack documentation. This issue arises in cases of refugees, asylum seekers, perpetrators or victims of human trafficking, and targets of child pornography (Schmeling & Black 2011). Forensic anthropologists, odontologists, and radiologists, working independently and in teams, have approached the problem of ascertaining legal adulthood using a variety of modalities (most commonly radiographs and CT scans), and growth indicators (for instance, dentition, epiphyseal union, facial measurements). Some success has been reported for the medial clavicle (Bassed et al. 2011) and facial proportions from photographs (Cattaneo et al. 2012). One of the most comprehensive texts on this subject (Black, Aggarwal, & Payne-James 2011) recommends a four-pillar approach (social and psychological evaluation, external physical estimation of age, skeletal estimation of age, and dental estimate of age). Experts in each discipline work together to combine their results following the guiding principles of balance of probability, logic, robustness of methodology, and transparency of procedures (Black, Aggarwal, & Payne-James 2011). Ethical and legal considerations and permissions must remain in the forefront of any such analyses.

Chronological versus Physiological Age, Statistical Solutions, and Side Asymmetry

Estimating the age of adult skeletons is based on bone remodeling and degenerative changes that result from complex interactions between mechanical stress, health, nutrition, and time. The challenge in developing a technique to estimate adult skeletal age is to identify and quantify the pattern, sequence, and rate of age-related changes, while allowing for the contributions of genetics, individual circumstances, and lifestyle that influence each person's aging process (İşcan & Loth 1989). Some researchers have argued that all skeletal age indicators are inherently unreliable owing to poor correlation between physiological and chronological age (Bocquet-Appel & Masset 1982). Jackes (2000) suggests that age may account for as little as 30% of the total amount of morphological variability observed on joint surfaces. See Nawrocki (2010) for a detailed discussion of this issue.

Traditional attempts to associate bone change with senescence use regression analysis to identify the best age-associated trend in the data, from which age-at-death ranges are produced (Aykroyd et al. 1997). This process results in techniques of skeletal age estimation that are moderately successful when applied to individuals but demonstrate systematic bias when tested on large samples; under-aging older individuals and over-aging younger individuals, with the transition occurring at approximately 40–50 years of age (Aykroyd et al. 1997). For examples of test results see Merritt (2014), Hens and Belcastro (2012), and Saunders and colleagues (1992). Similar results have been reported for some dental techniques (Ferrante et al. 2015). Applying these age indicators to archaeological populations in paleodemographic analyses produces age

profiles that overtly mimic the reference sample (Hoppa & Vaupel 2002; Jackes 2011), prompting several authors to recognize age estimation as “one of the most thorny problems facing human osteoarchaeology” (Mays 1998: 50). Recently, Samworth and Gowland (2007) utilized a regression approach to produce two-way “look up” tables that provide 90% prediction intervals for the Brooks and Suchey (1990) pubic symphysis, and Lovejoy and colleagues (1985) auricular surface methods, used individually or in combination. Passalacqua (2010) reports that the tables were as accurate, or slightly more accurate, than the original methods when tested on a North American sample, although the tables also had a tendency to overage younger individuals and underage older individuals.

To reduce the bias toward the middle and “age mimicry” of the target sample to the reference sample caused by regression analysis, alternate approaches to data processing, such as Bayesian prediction using prior probabilities and classical correlation, are recommended (Aykroyd et al. 1997; Hoppa & Vaupel 2002). Transition analysis can be used for phase-based techniques to determine the probability of exhibiting a specific age phase at a particular age. Following a Bayesian approach, a probit model is used with known age-at-death and phase scores from documented individuals (an informative prior) to generate these probabilities. Maximum likelihood analysis can then be used to establish the mean and standard deviation for the distribution of ages (the coverage) at which individuals transition from one phase to the next (Boldsen et al. 2002). Reference tables for conducting transition analysis using common age estimation techniques are available (Uhl 2013), as are computer programs such as ADBOU (Boldsen et al. 2002), which can be used to combine the results of multiple age indicators. (ADBOU is available as a free download from <http://math.mercyhurst.edu/~sousley/Software/> and will soon be incorporated into *FORDISC*; Mercyhurst Archaeological Institute 2014. More information about the statistics involved in transition analysis and additional free software downloads can be found at <http://konig.la.utk.edu/nphases2.htm>.) Several tests of transition analysis for use in forensic and bioarchaeological contexts have found that it outperforms age estimation methods used in the traditional manner and is useful for individuals over 50 years of age (Hoppa & Vaupel 2002; Schmitt et al. 2002; Langley-Shirley & Jantz 2010; Godde & Hens 2012). Choosing an informative prior can have a significant impact on the success of transition analysis (Godde & Hens 2012, 2015), which may limit use of ADBOU (Uhl 2008; Milner & Boldsen 2012).

Side asymmetry introduces another complication for skeletal age estimation. In their analysis of 130 white males from the Hamann-Todd Osteological Collection, Overbury and colleagues (2009) found 63% of individuals exhibited side asymmetry in their Suchey-Brooks pubic symphysis age phase. For those in which asymmetry produced categorical asymmetries (the left and right side scored as different phases), accuracy was reduced to 68%, compared to 86% for those with no side asymmetry. Their study found no significant directional asymmetry, and, contrary to expectation, it is the older scoring phase that is most accurate. The degree of asymmetry in adult aging is notably higher than that reported for developmental asymmetry in the third molar and medial clavicle of modern Australians (Bassed, Briggs, & Drummer 2012). For developmental asymmetry Bassed and associates (2012) recommend combining the age estimates from both sides in order to increase accuracy.

Combining Information from Multiple Age Indicators

Todd (1920) endorsed the use of more than one indicator to assess age. His advice has been repeated over the decades as a solution to the problems of inaccuracy and bias that can result from the use of individual indicators (Lovejoy et al. 1985a; SWGANTH 2013). Yet McKern's (1957)

analysis of the pubic symphysis, epiphyseal union, and cranial sutures reveals that random pooling of observations produces variable results, not all of them successful. Few physical anthropologists would argue the importance of evaluating all age-related criteria and combining the results in a biologically meaningful manner. Unfortunately, no common standardization, calibration, or evaluation procedures currently exist (Ritz-Timme et al. 2000; Garvin & Passalacqua 2012), leaving the issue of combining indicators open to debate.

Gustafson's technique (1950), which scores six variables of a longitudinally sectioned tooth, was the first to combine age criteria. Several ensuing improvements were made, after testing and recalculation of Gustafson's data revealed errors in his analysis (Rösing & Kvaal 1998). Lamendin and colleagues (1992) introduced a nondestructive method using tooth translucency and periodontosis, eliminating the need for tooth sectioning. Subsequent tests on modern populations have produced results equal or superior to skeletal techniques of age estimation (Prince & Ubelaker 2002).

Acsádi and Nemeskéri (1970) proposed the "Complex Method" of combining age indicators (recommended by the Workshop of European Anthropologists 1980). Their approach utilizes four indicators: endocranial sutures, proximal humerus trabecular involution (increased marrow space at the expense of trabecular bone), proximal femur trabecular involution, and the pubic symphysis. Observers using the Complex Method must assess the pubic symphysis to determine if the individual was younger or older than 50 years. If younger, the lower limit of the age range for each indicator is selected; if approximately 50 years of age, the mean of each range is used; and, if older, the upper limit of the range is selected. The resultant values are then averaged. According to Acsádi and Nemeskéri (1970) the complex method produces age assessments that are 80%–85% accurate with a ± 2.5 -year margin of error.

Lovejoy and colleagues (1985a) use seriation to refine age estimates and systematically combine the results of age indicators using the multifactorial approach to produce a summary age. Their study includes the pubic symphysis (Todd's method and the authors' revisions of Todd), auricular surface, proximal femur trabecular involution, cranial sutures, and dental wear. In the multifactorial approach all indicators are applied separately to a population, and the results are used to create an intercorrelation matrix. Principal components analysis determines the correlation of each age indicator to the first factor (assumed to represent chronological age). The correlation is the indicator's weight, with the final age of an individual determined as the weighted average of all indicators available for that specimen (Lovejoy et al. 1985a).

The authors report success with the multifactorial approach (all ages normalized inaccuracy was 7.5 and bias -5.4), as do Bedford and colleagues (1993), who used it to combine the results of four age indicators: pubic symphysis, auricular surface, proximal femur trabecular involution, and radiographic analysis of the clavicle. They conclude the multifactorial approach is superior to any single indicator. In contrast, Saunders and colleagues (1992) found that summary age essentially averaged the results they obtained from analyses of the auricular surface, sternal rib end, ectocranial sutures, and pubic symphyses. The complexity of the multifactorial approach and its failure to demonstrate an improvement over averaged results prompted Saunders and associates (1992) to conclude there was no compelling reason to use the multifactorial approach. Applying the multifactorial approach in a forensic context is problematic unless the observer uses the same indicators as Lovejoy and associates (1985a), because weightings for each indicator are derived from population data. When examining a single skeleton, a forensic anthropologist is limited to using published weightings (*ibid.*), which may not be appropriate given the population variability observed in several age indicators, for example, pubic symphysis (Katz & Suchey 1989). Factor analysis is most effective when weightings are calculated using the population from which the unknown remains originate (Saunders et al. 1992).

Baccino and colleagues (1999) examined the accuracy of the Suchey–Brooks pubic symphysis technique, the sternal end of the fourth rib, the Lamendin dental method, and histology of the femur, individually and in combination. They considered three means of combining data: (1) averaging the results of the four techniques; (2) a two-step procedure whereby the Suchey–Brooks age is used if the symphysis scores in one of the first three phases and the Lamendin age is used if the pubis is in one of the later Suchey–Brooks phases; and (3) a “global” approach taking all results into consideration and drawing on the experience of the observer. The study produced single-year age estimates to facilitate comparisons, and the results demonstrated that all three combined methods produced better age estimates than did any single method. Of the three comprehensive approaches, averaging was the least successful.

Brooks and Suchey (1990) and Saunders and colleagues (1992) agree that indiscriminant averaging is not useful in estimating skeletal age. According to Saunders and associates (1992) there are no shortcuts in age estimation. Combining information from several techniques involves (1) evaluating the accuracy, range, and applicability of each method; (2) selecting the most appropriate method based on sex, population, and preservation; and (3) using the overlapping areas of the resulting age phases to identify the most likely age range, given the limitation of the techniques. Uhl and Nawrocki (2010) tested two methods of overlapping age ranges, along with simple averaging of the results from multiple methods, and linear regression. They found that all complex methods were better than the techniques used individually, but linear regression has the advantage of providing statistically derived prediction intervals.

Transition analysis is currently gaining ground as an effective method of combining age indicators. As noted, it has undergone testing for both bioarchaeological and forensic use and is now being routinely incorporated into forensic anthropology and osteology textbooks (Dirkmaat 2012; DiGangi & Moore 2013; Christensen, Passalacqua, & Bartelink 2014). Uhl (2013) provides a case study demonstrating how reference tables are generated through transition analysis and how to use the tables to produce an estimated age range that combines results from the 4th rib, auricular surface, and pubic symphysis techniques.

Less controversy surrounds subadult age estimation. Dental development, eruption, epiphyseal appearance, and fusion are commonly used. Nevertheless, Pfau (1991) examined the relationships among dental development, diaphyseal length, epiphyseal closure, and age at death, specifically examining sex and population variation, to determine the validity of combining results obtained from these variables. He concluded that dental development and long-bone development are independent phenomena. The three variables are separately useful as age indicators and are complementary when combined. He has created a tripartite graph that may be used to predict chronological age from these traits. Although he recommends the use of both dental and long-bone development to assess age, he does not specify how to combine results. Based on a comprehensive examination of subadult dental age estimation Liversidge and colleagues (1998) recommend using as many teeth as possible and calculating a mean value from the individual results. Langley–Shirley and Jantz (2010) recommend transition analysis for subadult age estimation—an approach that readily lends itself to combining age indicators.

Admissibility in Court

There is no definitive way to produce a skeletal age estimate. In a forensic context the determining factor must always be how well the analysis will stand up in court. It must be admissible, accurate, and logical. If not, opposing counsel will attempt to have the evidence rendered inadmissible or will encourage the jury to disregard the testimony by implying that the techniques are unreliable, not generally accepted, or illogically applied. Although a forensic anthropologist may not

be subpoenaed to testify strictly about age at death, his/her report will be a matter of record and will be open to review. Poorly implemented techniques, assumptions, and contradictory or illogical summaries can be used to discredit other aspects of the analysis, some of which may be crucial to the case.

Judges use several criteria to rule on the admissibility of expert testimony, including general acceptance of the technique. In the United States the *Daubert* factors (*United States Supreme Court in Daubert v. Merrell Dow Pharmaceuticals, Inc.* 1993) provide additional guidelines for judges to consider: (1) expert testimony, which must be based on reliable principles and methods; (2) the theory or technique in question, which must have been subjected to peer review and publication; and (3) the potential or known error rates of the technique, as well as the standards controlling the operation of the technique. The research that provides the basis for the testimony must be conducted independent of the litigation and should not be undertaken expressly for the purposes of the trial (Giannelli & Imwinkelried 1999). The Canadian legal system has found these criteria useful (Rogers & Allard 2004), and similar requirements exist in other jurisdictions (Ritz-Timme et al. 2000).

Statistical means of combining age indicators provide a mathematically sound approach that is defensible, if not entirely comprehensible, to a jury. Jury comprehension of expert testimony is, however, vital: if jury members cannot understand the nature of the evidence, they will disregard it and its significance entirely (Ayd & Troeger 1999). Keeping in mind that the average jury member has a high school education, forensic anthropologists must be able to explain why and how the final age estimation was established in a manner that is clear and engaging (Ayd & Troeger 1999). Each forensic anthropologist must decide how she/he is most comfortable conveying and defending the science and conclusions of the analysis.

Major Historical Developments

İşcan (1988), İşcan and Loth (1989), Katzenberg and Saunders (2008), Kemkes-Grottenthaler (2002), and Ubelaker (2010) provide excellent historical reviews of the development of techniques used to assess skeletal age-at-death. This chapter examines the paradigm shifts responsible for key advances in the study of age-at-death assessment of the human skeleton.

The history of skeletal age estimation mirrors theoretical developments in physical anthropology. From 1900 to 1939 the prevailing approach to research in physical anthropology was historical-descriptive and typology-driven, seeking to understand culture history and the history of human races (Armélagos & Van Gerven 2003). Although both qualitative and quantitative methods were utilized, the literature from this period consists largely of non-analytical anatomical studies (Lovejoy, Mensforth, & Armélagos 1982). Armélagos and Van Gerven (2003) define analytical analyses as those that (1) propose and test specific hypotheses, (2) address issues of process or function, or (3) attempt to place analyses into a broader theoretical context. Descriptive publications discuss sorting methods, or identification without placing results into a broader context or anatomical description (see Ubelaker, Chapter 8 this volume).

Todd (1920) laid the foundation for systematic analysis of skeletal age indicators with his groundbreaking study of the pubic symphysis (İşcan & Loth 1989), followed shortly afterward by an examination of cranial sutures (Todd & Lyon 1924, 1925a, b, c). Although his analysis of the pubic symphysis is descriptive in its formulation of age phases, Todd (1920) situated his analysis within the larger context of growth and development of the pubic bone and the potential for variation in growth rates/patterns in different ancestral groups. Taking a functional approach, he aimed to understand the nature of pubic symphyseal modification to better appreciate the applicability and limits of his newly proposed technique of age estimation. The result is a 10-phase

system of evaluating age-related morphological changes of the pubic symphysis, and proof that such modifications are not growth related. Unfortunately, in defining developmental phases and corresponding age ranges, Todd based his descriptions on what he considered normal variation. Divergent symphyseal faces were deemed “anomalous” and were eliminated from his sample (Todd 1920). By artificially truncating the range of variability observed for each age, Todd introduced a bias into his technique that was not fully understood for more than 60 years (Meindl et al. 1985).

The prevailing descriptive paradigm prevented a critical examination of the nature of skeletal age indicators for almost 30 years (İşcan & Loth 1989). Physical anthropology embraced this new tool in the belief that age is correlated with skeletal changes in a predictable manner that is uniform across time and space, despite Todd’s recognition of individual and population variability. In 1951 Sherwood Washburn introduced “The New Physical Anthropology,” emphasizing evolutionary processes and mechanisms and arguing for a dynamic analysis of functional anatomy, in place of static descriptions. Process, theory formulation, and hypothesis testing were all part of the equation (Armelagos & Van Gerven 2003). Shortly afterward, physical anthropology saw many of its assumptions questioned. The study of skeletal age estimation was no exception.

By the 1950s physical anthropologists had identified a perplexing trend in their skeletally based demographic data but were at a loss to explain it. Few archaeological populations exhibited mean ages of death over 30 years of age (Brooks 1955). Finally acknowledging a potential problem with their two primary age indicators, the pubic symphysis and cranial sutures, physical anthropologists embarked on a testing and revision spree that lasted more than 40 years. Brooks, encouraged by the “dynamic approach now introduced into anthropometrical analyses” (Brooks 1955: 567), initiated the process with two questions: (1) can age estimation methods be applied to populations other than the test sample; and (2) how well do the pubic symphysis and cranial suture techniques correlate to each other? Her conclusions would not be out of place in the literature of the 1980s; the pubic symphysis has a statistically significant correlation with known age, although it has a tendency to underage older individuals, whereas cranial sutures are poorly correlated with age. McKern and Stewart (1957: 72), concerned with the “static” nature of Todd’s (1920) technique, introduced a new method of evaluating the pubic symphysis based on component scoring. Emphasis was on process and a means of recognizing and incorporating variation.

During the 1960s and 1970s a functional approach to the skeleton began to emerge, and skeletal population studies and multivariate statistical analyses were common (Armelagos & Van Gerven 2003). Physical anthropology became data driven, rather than problem directed, as exemplified by research produced during the 1970s (ibid.). The lack of predominantly theoretical papers was a glaring omission in the pages of the *American Journal of Physical Anthropology*.

The creation of a Forensic Anthropology section of the Academy of Forensic Sciences in 1972 marked the beginning of modern forensic anthropology, and both the role and the scope of forensic anthropology began to change (İşcan 1988; Ubelaker, Chapter 8 this volume). The need for more exact methods of skeletal age estimation increased as forensic anthropologists became more active in casework. Although Bocquet-Appel and Masset did not bid farewell to paleodemography until 1982, physical anthropologists were accumulating sufficient evidence to recognize problems with the raw data of demographic analysis, in particular, age estimation. The belief in a single method applicable through time and across space was beginning to fade (Workshop of European Anthropologists 1980). As Stojanowski and Buikstra (2005) observe, there is value in descriptive research. The accumulation of raw data for synthesis and validation studies can lead to a complete reevaluation of current thought and, ultimately, a paradigm shift.

In 1977 Buikstra coined the term *bioarchaeology*, introducing a holistic approach to the study of past populations. According to Armelagos and Van Gerven (2003), North American bioarchaeology incorporates three primary features. It (1) takes a population perspective, (2) views culture as a force both affecting and interacting with bioadaptation, and (3) provides a method for testing hypotheses involving interaction between the biological and the cultural elements of adaptation. Three themes linked to the comprehensive approach of bioarchaeology began to emerge in the literature of age estimation: (1) testing/triangulating data, (2) phase (holistic) versus component analysis of age criteria, and (3) population variation.

Triangulating data from several sources was the cornerstone of a pivotal series of articles published by Lovejoy and colleagues in 1985 (Lovejoy et al. 1985a, b; Meindl & Lovejoy 1985; Mensforth & Lovejoy 1985; Walker & Lovejoy 1985). The authors advocate a systematic, objective means of combining information from several age indicators, blind testing of techniques, and a more informative method of expressing the relationship between chronological and skeletal age that states the degree and direction of bias (inaccuracy and bias, respectively). Their work, and the critiques of Bocquet-Appel and Masset (1982), ushered in the statistical revolution that marked skeletal age-estimation research of the 1990s.

Introduction of the auricular surface method of age assessment (Lovejoy et al. 1985b), which explicitly recognizes the superiority of some features at particular stages, such as the appearance of striae that signals a change from phase 1 to 2, reopened the question of how best to score age indicators. Kemkes-Grottenthaler (2002) describes two systems of scoring: phase and component. I recognize three: phase, component, and revised phase or holistic—based on the manner of coping with atypical individuals. The earliest methods were phase analysis (Todd 1920), consisting of descriptions that corresponded to particular age ranges. The phase system was criticized for its inability to include individuals who do not fit phase descriptions.

Condemning the static nature of the phase system, McKern and Stewart (1957) introduced component analysis of pubic symphyseal age assessment for male, and later female, standards (Gilbert & McKern 1973). Component systems focus the observer's attention on particular details that are scored progressively. Features are examined independently with the resultant stage scores for each feature added together to produce a final value that equates to a particular age range. Component scoring is not dependent on archetypes, making it possible to evaluate atypical individuals. In 1990 Suchey and Brooks introduced an alternative version of the phase system that is flexible and holistic in its application. Along with descriptions, observers utilize casts depicting early and late stages of each phase. Rather than matching a rigid set of criteria such as traditional phases, holistic phase methods encourage users to seek patterns that can include a dynamic range of possibilities for each phase. By observing the trajectory of change that occurs within a phase, the observer is able to assign atypical individuals appropriately.

Proponents of component scoring argue that it is a flexible alternative to phases that permits correct age assessment of "atypical" individuals (McKern & Stewart 1957; Gilbert & McKern 1973). Components capture the changes inherent to complex biological structures better than phases and facilitate statistical analyses (Boldsen et al. 2002). Advocates of a holistic approach stress the importance of patterns in revealing true age, simplifying methodology, and reducing interobserver error (Suchey, Wiseley, & Katz 1986; Suchey & Brooks 1990). They are concerned about the complexity of component scoring, particularly in the field (Suchey 1979; İçsan, Loth, & Wright 1984, 1985; Suchey, Wiseley, & Katz 1986). Recently, however, Shirley and Ramirez Montes (2015) found that component systems actually reduce interobserver error, providing the coding systems do not exceed three states of expression per trait.

Acknowledging the role of intra- and interpopulation variation was another hallmark of 1980s' skeletal age-at-death research. Although Todd observed differences between male and

female pubic symphyses and noted the rate of metamorphosis varied among populations, he did not consider the distinctions to be significant (İşcan & Loth 1989). He did, however, produce separate sex- and population-based methods for the cranial sutures. By the 1950s the need for distinct male and female pubic symphyseal age criteria was apparent (Stewart 1957). Gilbert and McKern (1973) offered a solution, but problems quickly became evident (Suchey 1979). Tactics for coping with inter- and intrapopulation variation fell into two camps: (1) establish separate methods for each sex and population (İşcan, Loth, & Wright 1984, 1985), or (2) devise a technique that is not sex or population dependent, either because of its nature or because it uses a sufficiently diverse sample (Lovejoy et al. 1985b).

It appears there are significant sex differences in the aging process, making it necessary to devise independent scoring criteria and age indicator stages for many regions of the skeleton (Todd & Lyon 1925a, b, c; İşcan, Loth, & Wright 1984, 1985; Katz & Suchey 1986; Igarashi et al. 2005). A few techniques are not sex specific (Lamendin et al. 1992; Kunos et al. 1999), and some bones only demonstrate sex differences depending on how they are scored (Lovejoy et al. 1985b; Buckberry & Chamberlain 2002; Igarashi et al. 2005).

Population differences are less well understood. Sample limitations and lack of funding for travel make it difficult for a single researcher to conduct comparative studies of collections worldwide. Instead, techniques are proposed by one research group and are independently tested on other populations by different teams of investigators, often incorporating slight modifications. Although independent blind testing is desirable, a coherent program of research devoted to the analysis of population differences would make it easier to tease out the variables that are contributing to these mixed results. Suchey and colleagues are among the few who have been able to examine a diverse sample. They found it necessary to produce separate casts and descriptions for males and females, but addressed population differences by using slightly altered phase values for each ancestral group (Katz & Suchey 1989).

The dearth of large-scale population studies leads to the question: is it merely rate of change that differs, as indicated by Katz and Suchey (1989), or are there detectable differences in the pattern of aging? Using transition analysis in historic Italian populations, Godde and Hens (2012) demonstrated that different populations do transition from one stage to the next with varying timing. Lam and Rogers (In preparation) found that the auricular surface method (Lovejoy et al. 1985) performed poorly when applied to Japanese samples—to the point that many could not be assigned a phase—while Gocha and colleagues (2014) note that the 4th rib method (İşcan, Loth, & Wright 1985) is similarly ineffectual for Southeast Asian samples. These results suggest that different populations may actually express different patterns of aging, not simply differential age progression through otherwise uniform changes.

Research in the 1980s demonstrated the variable nature of aging. Bone loss with age is highly site specific, each bone behaving as an individual organ (Walker & Lovejoy 1985). Radiographic analysis demonstrated differences in adjacent anatomical sites (for example, humerus and clavicle), differences unassociated with locomotor habits or activity levels (for instance, the femur and calcaneus exhibited different patterns of change), and sex-specific differences between individual bones (ibid.). Skeletal aging was shown to occur at different rates in different populations (Katz & Suchey 1989). The link between skeletal metamorphosis and years lived became more tenuous as factors such as health, mechanical wear, and nutrition gained prominence.

Trends

Throughout the 1980s Meindl and colleagues changed the way in which skeletal age estimation was approached. During the 1990s Suchey and colleagues were at the forefront of change,

introducing 95% confidence intervals to age ranges (Katz & Suchey 1986, 1989; Brooks & Suchey 1990), anticipating future developments in forensic science that initiated a reevaluation of best practice policy in the United States following the *Daubert* ruling on the admissibility of expert testimony in 1993 (*United States Supreme Court in Daubert v. Merrell Dow Pharmaceuticals, Inc.* 1993).

On reviewing the state of skeletal age estimation Ritz-Timme and colleague (2000) made an explicit demand for accurate and precise techniques of age estimation to meet the requirements of forensic practice, stating that techniques should be (1) transparent, provable, and published in a peer-reviewed journal; (2) tested using appropriate statistical procedures; (3) sufficiently accurate to fulfill the demands of a single case, meaning that 95% ranges must be considered; and, (4) in cases of age estimation of living individuals, practitioners must abide by medical ethics and legal regulations (Ritz-Timme et al. 2000). Ritz-Timme and colleagues (2000) advocated the use of dental methods, bone histology, and multifactorial methods for all adult ages. Their conclusions foreshadowed a shift in forensic anthropology aimed at improving and standardizing the science in accordance with medico-legal requirements (Rogers & Allard 2004; Christensen 2005), a practice that has now become routine (Passalacqua 2010; Godde & Hens 2012; Rissech, Márquez-Grant, & Turbón 2013).

The 1990s saw increased involvement of forensic anthropologists in casework, teaching, publication, and research. Greater emphasis on the court aspects of forensic anthropology (in particular, admissibility), fostered increased testing of existing techniques to validate results, including the use of Bayesian statistics (Lucy et al. 1996), as well as innovative technology to capture data. Three-dimensional imaging and computed tomography (CT) scanning was introduced into forensic anthropology at that time and continues to be a productive research avenue (Lottering et al. 2013; Villa et al. 2013). A similar need for standardization in the sub-field of paleodemography resulted in the “Rostock Manifesto,” (Hoppa & Vaupel 2002), an outline of paleodemography’s goals and expectations with respect to skeletal age. Two of the key concerns were to develop and validate age indicator stages through improved osteological methods, better reference samples, and the use of Bayesian statistics (*ibid.*). Although the need to improve skeletal age estimation was initiated in response to issues particular to each sub-field, the resultant theoretical and practical convergence benefits both forensic anthropology and paleodemography.

The last decade has seen the introduction, modification, and testing of several new techniques for skeletal age estimation, including some that have focused on anatomical surfaces and structures not yet fully explored (Rissech et al. 2006; Passalacqua 2009; Calce & Rogers 2011; Calce 2012; Chandrakanth et al. 2012). Alternate approaches to age estimation that rely on biomechanical or elemental properties of bones and teeth are also garnering interest, particularly as they appear to produce small age ranges that cannot be reproduced by macro- and microscopic methods. Artificial, or bomb carbon, for example has a reported mean error of 1.9 years (Wang et al. 2010), or 1.9 ± 1.4 years before the bomb spike (1955–1963) and 1.3 ± 1 year after the bomb peak (Alkass et al. 2011). Similarly, a biomechanical and analytical method utilizing wet and dry apparent density, porosity, organic/mineral/water fractions, collagen thermal degradation properties, ash content, Ca/P ratios, osteonal and matrix microhardness of bone sections from 12 donors was used to produce a series of regression equations capable of estimating age within ± 1 year (Zioupou et al. 2014).

Future Directions and New Interpretive Paradigms

According to İşcan and Loth (1989) the study of age-at-death estimation suffers from two primary oversights: (1) the inability of researchers to recognize that individual bones are part of a larger functional system, and (2) specialization leading to a methodological division among

morphological, histological, and radiological techniques. They recommended future research focus on age-related changes in different parts of a single skeleton using a combination of analytical techniques (İşcan & Loth 1989), with the goal of developing better methods of age estimation by identifying: (1) regions of the skeleton that best reflect chronological age; and (2) approaches capable of capturing age-related changes in a meaningful manner. They suggested establishing modern skeletal collections of documented age, sex, and ancestry in order to clarify the biological and cultural factors influencing the aging process (İşcan & Loth 1989).

A review of the literature since 1989 reveals limited progress in fulfilling İşcan and Loth's recommendations. Testing and modification of existing skeletal techniques continue to outpace the number of newly explored anatomical regions and modes of analysis being developed. Functional-based examinations of skeletal age indicators, such as cranial sutures (Hershkovitz et al. 1997) and cortical bone loss (Mensforth & Lovejoy 1985), and research into the confounding effects of pathological or metabolic conditions on aging (Crewes 2007) are even more rare. While it is necessary to test and improve techniques for use in court, the limitations of current approaches to skeletal age-at-death estimation are becoming evident, as revisions to existing techniques fail to produce broadly applicable (not age or population specific) age indicators confined within small age ranges at every stage of the life course. Part of the problem is inherent—chronological age and physiological age are measures of different variables (Nawrocki 2010). The solution is to return to the fundamentals of skeletal aging.

The discipline is currently approaching skeletal age-at-death estimation from two different perspectives: maximizing available information and utilizing statistics to generate the most useful age ranges. This is a positive trajectory, but the overarching goals are perhaps not as coherently defined as İşcan and Loth envisioned. Combining information from multiple sites of the skeleton has become a proxy for targeted functional analyses of skeletal aging and the development of methods that might result. Similarly, emphasis on statistical approaches, although productive, diverts attention from efforts to seek sites and modalities that best capture age-related changes. In contrast, biochemical, molecular, and biomechanical analyses provide insight into the properties of aging bone, which may lead to more refined age-at-death estimates when combined with morphologically based skeletal changes. The positive outcome of the discipline's two-pronged approach is the realization that single techniques of age estimation are less effective than combined methods.

New generations of forensic anthropologists and bioarchaeologists are being taught to incorporate multiple lines of evidence to increase the accuracy of their skeletal age estimates (Latham & Finnegan 2010; DiGangi & Moore 2013; Christensen, Passalacqua, & Bartelink 2014), although the best techniques to use and most effective method for combining results are still under debate (Garvin & Passalacqua 2012). Overspecialization and regionalization continue to plague the study of skeletal age-at-death, affecting the way in which age indicators are combined. There are collective dental analyses (Gustafson 1950; Lamendin et al. 1992), techniques that include multiple aspects of skeletal morphology (Hoppa & Vaupel 2002; Schmitt et al. 2002; Uhl 2013), those that amalgamate histological characteristics (Thomas et al. 2000), and even those that combine dental and skeletal sites using a single modality, such as CT (Bassed et al. 2011). Research that integrates dental, skeletal, radiological, histological, biomechanical, and analytical indicators, or combinations thereof, are less common, and the resulting methodologies integrate the data sets quite differently (Lovejoy et al. 1985a; Baccino et al. 2014; Zioupos et al. 2014). Validation studies demonstrate that some combined techniques are more successful than others; the addition of some methods actually reducing the efficacy of the estimate (Milner & Boldsen 2012).

Negotiating the revisions, tests, lack of standardization and consensus can be challenging in forensic practice. Updates to Ritz-Timme and colleagues' (2000) assessment of the state of the art

have produced practical recommendations for estimating the age of the living and the dead (Cunha et al. 2009), while recent textbooks have conveniently collected and organized scoring criteria and reference tables for skeletal age-at-death estimation (DiGangi & Moore 2013; Christensen, Passalacqua, & Bartelink 2014). Access to a growing number of modern skeletal collections (L'Abbé, Loots, & Meiring 2005; Alemán et al. 2012; Ferreira et al. 2014; Ubelaker 2014) will aid our efforts to develop research frameworks capable of examining skeletal aging more broadly.

Armelagos and Van Gerven (2003) mourn the failure of the “New Physical Anthropology” to take hold in osteology. They question the relevance of applying innovative methods to old questions. Similarly, Buikstra and colleagues (2003) caution that advanced methods of analysis are “far outstripping our ability to generate contextually sensitive research designs in which to ground anthropologically significant questions,” and they express a concern that forensic anthropology and bioarchaeology are becoming so specialized they are losing relevance to anthropology as a whole. The special knowledge required to master new technology and analytical approaches encourages researchers to limit themselves to histological, morphological, biochemical, or diagnostic imaging when age is seen as a means to an end. It is only by viewing the process of aging as an end in itself that a fully integrated approach to skeletal aging will be developed and the best methods of assessing the age of human remains will be defined. Engaging in a dialogue on the functional correlates of aging and the manner in which senescence is experienced by the individual and the population through time and cross-culturally offers an additional forum for integrating anthropological thought.

Conclusion

The historical-descriptive approach of early anthropology engendered descriptive anatomical analyses that produced static techniques of assessing skeletal age (Todd 1920; Todd & Lyon, Jr. 1925a, b, c). The dependence on a single criterion for age estimation was established before Todd and continued for the next 30 years (Brooks 1955). Following the inception of the New Physical Anthropology (Washburn 1951), with its emphasis on function, theory, and processual methodology, independent testing of age indicators became commonplace (Hanihara 1952; Brooks 1955). Newly introduced techniques emphasized variability, scored through a dynamic component analysis of each feature (McKern & Stewart 1957; Gilbert & McKern 1973). Analytical approaches, such as bioarchaeology, combined with Bocquet-Appel and Masset's (1982) critique of paleodemography and its raw data, prompted physical anthropologists to look at age estimation in a new light. A new era of critical analysis, with an emphasis on populations, testing/triangulating data, and a broader theoretical perspective introduced the faint glimmer of a functional approach to skeletal age assessment.

Understanding the physiology of aging is essential to devising meaningful skeletal age indicators. Examination of large skeletal samples revealed the nonlinear nature of aging, with its significant interbone (Walker & Lovejoy 1985), sex-specific (Suchey 1979; Katz & Suchey 1986), and interpopulation variability (İşcan, Loth, & Wright 1984, 1985; Katz & Suchey 1989). Biomechanical factors did not become an explicit consideration in the literature of skeletal age estimation until histomorphometric analyses began to receive greater attention (Stout 1989; see also Crowder, Heinrich, & Dominguez, Chapter 21 this volume). Previous researchers had examined sites other than the traditional pubic symphysis, and cranial sutures, but did so in an effort to increase the number of available age indicators (Acsádi & Nemeskéri 1970; İşcan, Loth, & Wright 1984, 1985), for reasons of preservation (Lovejoy et al. 1985b), and to develop methods capable of assessing older adults (İşcan, Loth, & Wright 1984, 1985; Lovejoy et al. 1985a, b), rather than for biomechanical reasons.

The 1990s to the present day have seen a greater emphasis on validation studies relating to admissibility issues in forensic anthropology, which incorporate Bayesian statistics introduced by paleodemography. New technologies, such as 3D imaging and micro CT scans, are becoming commonplace in an effort to refine and potentially replace traditional methods of skeletal age estimation. The problems inherent to skeletal age assessment have turned some researchers toward dental age estimation, including macroscopic techniques (for example, Lamendin et al. 1992), examination of enamel microstructure (FitzGerald 1998), cementum annulation (Wittwer-Backofen, Gampe, & Vaupel 2004), and amino acid racemization in dentin (Ohtani & Yamamoto 1991). For a review of chemical and molecular approaches to estimating age-at-death see Zapico and Ubelaker (2013).

Biological anthropology, in particular paleodemography and forensic anthropology, has made valuable contributions to our understanding of skeletal aging and age evaluation, addressing significant methodological and theoretical concerns relating to various themes: subadult versus adult aging and age estimation; chronological versus physiological age, including intra- and interpopulation variability; statistical analysis; and scoring and combining age indicators. Although age estimates are ultimately put to different purposes in paleodemography than in forensic anthropology, and the level of analysis—that is, population versus individual—often differs, we share the goals of increased accuracy, reliability, and reduced bias in skeletal age assessment. Improving the validity of our techniques produces more realistic representations of past populations and defensible biological profiles of modern human remains.

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Histological Age Estimation

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Since the introduction of the first histological method of age estimation by Ellis Kerley in 1965 numerous methods by various researchers have followed. Despite the attention that histological age estimation has received in the literature, histological methods tend to be used when no other methods can be applied or for the sole purpose of distinguishing human bone fragments from nonhuman. This chapter reviews well-established histological methods of age estimation and explores the tribulations in the acceptance of these methods as a conventional tool for the estimation of age at death. Furthermore, it describes the biological factors that one must consider when developing and applying microscopic methods of age estimation. Finally, this chapter discusses contemporary research and future directions in cortical bone histomorphometry.

The Dynamics of Bone and Histological Age Estimation

Bone is a dynamic, metabolically and mechanically active tissue that varies in composition and structure throughout an organism's life. As cortical bone remodeling occurs over time, the relative density of secondary osteons in the cortex increases (Wu, Jett, & Frost 1967; Wu et al. 1970). In other words, as chronological age increases, the cortex becomes crowded with intact and fragmentary osteons (Figure 21.1). Histological age estimation is based on the assumption that the replacement of primary bone with secondary bone and a continual turnover of osteons will occur at a predictable rate (Pfeiffer 1992). The development and interpretation of histological methods for age estimation, therefore, requires an extensive understanding of the microstructure and physiology of skeletal tissue. Because the information provided in this chapter focuses on methods and not the biological basis for histological age estimation, we recommend that professionals who wish to apply or to develop such methods take time to appreciate the nuances of bone microstructure.

Methodology is strongly emphasized in this chapter primarily because methods of age estimation used in the forensic context must meet specific demands owing to the evidentiary nature of analytical results. Furthermore, understanding the methodological constraints will guide anthropologists in method selection and indicate to researchers where standardization is needed for future histological methods. The preferred methods for adult age estimation involve assessing gross bone morphology. In the absence of preferred gross age indicators one turns to less reliable morphological age indicators that exhibit changes loosely correlated with age, have higher levels of method subjectivity, and typically lack large contemporary datasets.

Owing to the nature of biological variation, large age intervals are expected for the estimation of adult age at death regardless of the method employed. Despite discussions within the early



Figure 21.1 Rib cross-section depicting the five patterns of lamellar bone: (1) concentric, (2) outer (periosteal) circumferential, (3) inner (endosteal) circumferential, (4) primary interstitial, (5) osteonal interstitial lamellae. Examples of intact and fragmentary osteons are noted by numbers 1 and 5, respectively.

literature, histological methods do not avert this constraint. Crowder (2005) determined that both the Thompson (1979) and Cho and colleagues (2002) histological methods of age estimation demonstrate levels of inaccuracy and bias comparable to preferred morphological methods. A point of contention, however, is the high observer error associated with histological analysis despite the indication that these methods are less subjective than the evaluation of gross morphology. Evaluation of this issue suggests that reliability analysis has been performed using poor variable definitions or inadequate statistical methods, such as student *t*-tests and correlation coefficients, which hinder a clear assessment of precision/accuracy for histological methods.

Methods and Comparison Studies

Early Studies and Their Evaluations

Ellis Kerley (1965) applied the first quantitative histological approach to the estimation of age at death. Kerley evaluated the absolute counts of intact and fragmentary secondary osteons, the percentage of circumferential lamellar bone, and the number of non-Haversian canals in 88 males, 29 females, and 9 individuals of indeterminate sex.¹ This method involves the evaluation of these variables from complete transverse cross-sections of the femur, tibia, and fibula. One circular microscopic field from the outer third of the anterior, posterior, medial, and lateral aspects of the bone's cross-section is evaluated. Regression equations for each variable and bone are then used to develop an age estimate profile chart, in which an age interval is developed. Kerley and Ubelaker (1978) revised the original method to rectify an incorrectly published microscopic field size through the introduction of a correction factor to offset microscope field size differences. Stout and Gehlert (1982) suggest that the use of the correction factor to adjust osteon counts may be of limited value due to the spatial variation of microstructures within the cortex.

Ahlqvist and Damsten (1969) reported difficulties in discerning between intact and fragmentary osteons using Kerley's definition, which defines an intact osteon as having 80% or more of its area intact with a complete Haversian canal. Instead of recording absolute osteon counts, they suggest using a square eyepiece grid to determine the percentages of remodeled and primary bone per field. The percentages are then averaged for four microscopic field locations. Recognizing the greater variation in remodeling at the linea aspera, they avoided this area for analysis by rotating the location of the fields to where they fall between the original Kerley fields. Regression equations to predict age at death were generated from only 20 femoral samples.

Following Kerley (1965) and Ahlqvist and Damsten (1969), two distinct approaches to histological age estimation were developed. One trajectory focuses on quantifying the percent remodeled bone tissue (Figure 21.2A) and the other on quantifying the number of remodeling events (Figure 21.2B). Debate over these two methodological approaches continued over several decades.

Bouvier and Ubelaker (1977) compared the accuracy and the precision of the Kerley and Ahlqvist and Damsten methods using 40 femoral sections taken from the original Kerley sample. They found that precision was similar, but the Kerley method was more accurate for the younger individuals and less accurate than the Ahlqvist and Damsten method for the older individuals. These results were attributed to the skew toward older individuals in the reference sample from which the Ahlqvist and Damsten method was derived. Stout and Gehlert (1980) questioned results from the Bouvier and Ubelaker study, noting problems in testing the accuracy using a sample from which the predictive equation was derived. Despite the use of an independent test sample, Stout and Gehlert reported similar results in the accuracy of the two methods. In another study Stout and Stanley (1991) compared Kerley's method, which uses absolute osteon counts, to Ahlqvist and Damsten's method, which employs the percentage of osteonal bone. Evaluating a small sample of 35 long bones, excluding the femur, they determined that the best predictor of age was absolute osteon counts from the fibula.

Singh and Gunberg (1970) evaluated histological age-related changes in a sample of 59 mandibles and 40 femora and tibiae anterior midshafts. For analysis of the long bones, two microscopic fields were selected at random within the anterior periosteal region, and the following variables were collected: the sum of the intact osteons counted in both fields; the average number of lamellae per osteon; and the average Haversian canal diameter. They attempted to avoid the potential error in discerning the number of osteon fragments among the interstitial

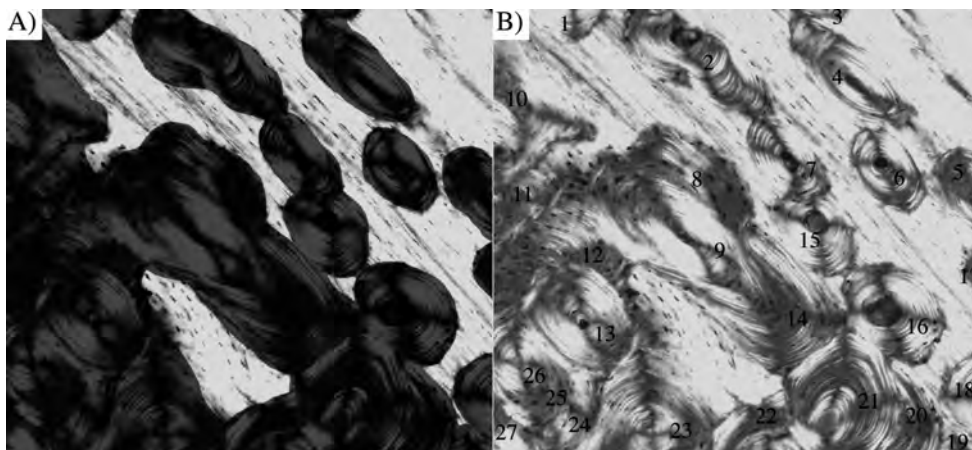


Figure 21.2 Graphical representation of the two general approaches to histological age estimation: (A) The quantification of percent remodeled bone tissue, where remodeled bone tissue is represented by dark grey. (B) The quantification of individual bone remodeling events represented by counts.

bone; however, osteons that were partially obscured by the periphery of the microscopic field, cut obliquely, or seen only as fragments were included if they represented a complete Haversian canal. Regression analysis indicated that nonlinearities occurred in later ages with all three variables. Regardless of this observation, a linear model was assumed for the remainder of the analyses.

Crowder (2005) evaluated the reliability of the Singh and Gunberg method with a sample of 184 individuals from the Spitalfields' skeletal collection. Results indicate that the method grossly overestimated age. Although a strong correlation between the number of intact osteons and chronological age exists, the inaccuracy of the method indicates a problem with the technique or the prediction equation. Crowder (2005) further noted that the method produced high observer error, likely associated with counting microstructures using an open microscopic field technique (one without a counting reticule).

Further Development and Testing of Methods

Ribs and Clavicles

Stout (1986) introduced a histological method using cross-sections from the middle third of the 6th-rib based on research performed by Harold Frost and various colleagues spanning several decades (Pirok et al. 1966; Jett, Wu, & Frost 1967; Santoro & Frost 1967; Frost 1969; Wu et al. 1970). This method sought to eliminate issues such as sampling error due to field location and the influence of biomechanical factors on weight-bearing bones. Intact and fragmentary osteon counts per grid area are summed producing a variable referred to as osteon population density (OPD), solving the problem of differentiating between intact and fragmentary osteons. Background information pertaining to the creation of the regression equation, sample descriptive statistics, and the accuracy and precision of the method was not presented.

Pursuing the use of non-weight-bearing skeletal elements, Stout and Paine (1992) introduced a revision of the Stout (1986) 6th-rib-method and explored the use of the clavicle for histological age estimation. Equations were generated from a sample of 40 individuals

derived from a forensic context with an age distribution skewed toward younger individuals. No sex differences among the histological variables were noted, although only 8 of the 40 individuals were female. In a validation sample of 12 ribs and 7 clavicles differences between the known and predicted mean ages were not significant. Stout and colleagues (1996) applied the clavicle equation to a sample of 83 individuals of known age from a 19th-century Swiss cemetery, producing inaccurate age estimates for subjects older than 40 years of age. There were no differences noted in OPD between sexes, indicating that the inclusion of 42 females in the test sample is most likely not the cause of the inaccuracy. The researchers hypothesized that the inaccuracy in age estimates was due to disparity in sample age distributions and the occurrence of the OPD asymptote (see section on Remodeling Variation). A new prediction equation for the clavicle was generated through the combination of the original sample and the Swiss cemetery sample.

Dudar and colleagues (1993) assessed the accuracy of the rib-age prediction equations from the Stout (1986) and Stout and Paine (1992) studies on an independent sample of 55 individuals derived from cadavers and archaeological remains of known age. Results indicate that the Stout and Paine method significantly underestimates age, whereas the Stout method produced fairly accurate age estimates. The tendency of the Stout and Paine method to underestimate age was also reported in Pratte and Pfeiffer's (1999) study on 62 individuals of mixed ancestry. In contrast to Dudar and colleagues' results the Stout method did not produce accurate age estimates. Pratte and Pfeiffer noted a weak association between OPD and known age and hypothesized that extrinsic factors affecting bone remodeling (for example, alcoholism or malnutrition) may be the cause. Neither validation study produced sex-related differences.

In an attempt to combine histological methods with morphological methods, Stout and colleagues (1994) analyzed rib cross-sections and sternal rib end morphology from the 4th rib of 60 individuals (11–88 years of age) taken at autopsy. Histological methods from Stout and Paine (1992) and gross morphological methods from İşcan and colleagues (1984, 1985) were followed. The authors concluded that because the correlation between histological and morphological age estimates is lower than desired, the methods reflect different age-associated factors. They stated that combining the two methods using multiple regressions might improve accuracy. Dudar and colleagues (1993) had reported similar results in their analysis of histological age estimates from the 6th rib and morphological age estimates from the 4th rib.

In 2002 Cho and colleagues presented a modification to the Stout (1986) and Stout and Paine (1992) rib methods. Sixth-rib cross-sections from 69 African-Americans and 34 European-Americans were used as a developmental set, with 34 African-Americans and 17 European-Americans forming the validation sample. In addition to the variables described by Stout and Paine (1992), mean osteonal cross-sectional areas were calculated. Results indicate that age-related changes in histological structures, namely osteon area and relative cortical area, differ among ancestral groups, whereas sex differences within the groups are negligible. Ancestry-specific equations were developed. The validation sample produced results that were not significantly different from the developmental sample.

Crowder (2005) compared the reliability of the 6th-rib methods using 215 individuals from the Spitalfields collection. The Stout (1986) and Cho and colleagues (2002) equations performed similarly in all statistical tests, but the Stout and Paine (1992) equation grossly underestimated age. This bias has been noted in several of the aforementioned studies and indicates a possible problem with the regression equation. Analysis of observer error indicates that the OPD variable appears to reduce error compared to evaluating the OPD constituent variables separately.

Kim and colleagues (2007) applied the Cho and colleagues (2002) methods to 4th-rib sternal end samples. Rib cross-sections were from 64 Koreans, including 36 males (22–67 years of age)

and 28 females (20–60 years of age). This study found a high correlation between OPD and osteon area with age. Similarly, Pavón and colleagues (2010) applied the Cho and colleagues method to 4th-rib sternal end samples. Rib cross-sections were from 36 individuals of Maya origin (34 males and 2 females) between 28 and 78 years of age. This study found high differences in remodeling rates between their samples and those of Stout and Paine (1992) and Cho and colleagues (2002). They argued that unique histological age estimations algorithms should be developed for different ethnic groups.

Upper and Lower Extremities

Thompson (1979) developed a method designed to minimize the amount of destructive sampling and explore the utility of both the lower and the upper extremities for age estimation. Thompson sampled bone cores (0.4 cm in diameter) from the femora and tibiae of 116 cadavers and the humeri and ulnae of 31 cadavers. Various histomorphometric measurements were recorded through point counting using a 10×10 grid eyepiece disk micrometer. Overall, Thompson explored 19 variables, including a number of gross measurements (for example, core weight, cortical thickness, and cortical density). One variable, referred to as the percentage of osteonal area, was determined to be the single best indicator of age. Histological structures were recorded in four contiguous microscopic fields along the core's anterior periosteal surface. Both sex- and side-specific regression equations were developed.

Thompson (1981) tested the accuracy of the core method on 54 forensic cases consisting of different ancestral groups. The results indicated that the femur produces the most accurate age estimates with a trend for increased accuracy in individuals of European descent.² The other skeletal elements produced age estimates that were determined to be too inaccurate for forensic science application. Further analysis of the tibia by Thompson and Galvin (1983) indicated that the tibia-based method is less accurate than the femur owing to differences in osteon area (size) between the elements. Osteon area was removed from the equation, and age estimates comparable to those from the femur were then obtained for individuals younger than 55 years. Thompson and Galvin proposed that two regression equations might be needed for the tibia: one to estimate age in individuals younger than 55 and one to estimate age for individuals over 55 years.

The method proposed by Thompson in 1979 has been evaluated by a number of researchers. Narasaki (1990) concluded that the Thompson method is less accurate than previously reported, especially among males, when applied to a sample of 52 modern Japanese cadavers. Proper method validation was not performed, in that Narasaki introduced two new variables into the method before evaluation. Furthermore, the test sample was heavily skewed with over half of the sample older than 80 years. The geriatric nature of the sample increases the susceptibility for altered cortical bone remodeling by factors associated with advanced age and chronic diseases. Pfeiffer (1992) estimated age at death for 29 individuals from historical cemeteries, concluding that the Thompson method could be applied with reasonably high repeatability despite variations in bone preservation. Age estimates were accurate in only half of the cases; however, subperiosteal erosion may have caused the overestimation of age. Crowder's (2005) test of the reliability of the Thompson method resulted in age estimates with deviations from chronological age that were not significantly different from zero, but age estimates for individuals younger than 50 years generated larger inaccuracy values. The lack of younger individuals in Thompson's reference sample may explain the difference in inaccuracy for the younger age cohorts. Crowder notes that the Thompson method generates low observer error, likely attributed to the use of the point count grid method and more objective variable definitions.

Femur

Continuing with the exploration of the anterior femur as a histological age indicator, Ericksen (1991) introduced a method using the largest and most diverse sample compared to all the aforementioned studies. Cortical bone samples were removed from 328 individuals (154 males and 174 females) collected from George Washington University Medical School cadavers, cemeteries from the Dominican Republic, and autopsy specimens from Chile. Much like the Thompson (1979) method, Ericksen's method recorded histological structures from the periosteal region of an anterior wedge using an eyepiece grid. The method evaluated five fields both microscopically and through photographs. Histological variables include counts of secondary osteons, type II osteons, osteon fragments, resorption spaces, and non-Haversian canals. The sum of the variables for the five fields is divided by the total area to determine the count per square millimeter. The remaining variables are collected using a 100-space grid superimposed on the field photographs to count the predominant microstructure per grid-square. These variables include unremodeled circumferential bone, osteonal bone, and fragmentary osteonal bone. Sex differences were prevalent within the sample; thus, sex-specific equations were developed in addition to a pooled sex equation.

Although the heterogeneous nature of the Ericksen sample may produce more widely applicable equations, Crowder (2005) suggests that the method introduces higher levels of observer error than does the Thompson (1979) method. The Ericksen variable definitions are extremely detailed, yet it is difficult to identify the nuances of certain bone microstructures, especially when diagenesis is present. This can be most problematic when discerning osteon fragments from crowded interstitial bone and resorption spaces from diagenetic destruction. Furthermore, higher error levels can be expected as a result of the subjectivity in determining the predominant microstructure per square in a 100-square grid. Interestingly, the Ericksen method produced significantly high observer error values for the individual variables, whereas the calculated ages did not. This suggests that the combination of the variables in the predictive equations reduces the individual variable error. Despite observer error issues, the accuracy of the Ericksen (1991) method is similar to the Thompson (1979) method (Crowder 2005).

Maat and colleagues (2006) applied a modification to the Thompson (1979) method for a sample of anterior femur cross-sections from 162 Dutch individuals (86 males and 76 females) between 15 and 96 years of age. The percentage of remodeled bone tissue was determined from three fields: one point at the most anterior aspect of the femoral cortex and points 25° to the left and right of this point. This study found a high correlation between the percentage of non-remodeled tissue and age at death, but also recommended a qualitative catalogue of age related change in bone microstructure.

Han and colleagues (2009) introduced an additional histological age estimation method for Korean adults using anterior midshaft femur cross-sections. Seventy-two Koreans, including 44 males (41–86 years of age) and 28 females (35–94 years of age), were included in this study. Five subperiosteal fields were selected: one field at the anterior point, fields at $\pm 10^\circ$ from center, and fields at $\pm 20^\circ$ from center. Han and colleagues found a high degree of correlation between OPD, osteon area, and cortical width with age, and further suggest the importance of using population specific methods.

Humerus

Yoshino and colleagues (1994) analyzed histological thin-sections from the diaphysis of the humerus of 40 Japanese males at a location near the surgical neck. Following the Ericksen (1991) method, Yoshino and colleagues evaluated histological structures using micrographs

and direct observation in cases of doubtful interpretation. Results demonstrated a high multiple correlation coefficient and a standard error of estimate similar to Thompson's (1979) study of humeral samples. The authors validated the method with samples from the reference population, which produced a mean absolute difference of 5.1 years between known and estimated ages. However, the fact that the method was tested on the reference sample from which the method and equations were derived is problematic as this might result in a false impression of accuracy.

Skull

In an attempt to improve age estimation methods for the skull, Cool and colleagues (1995) investigated occipital bone histomorphometry using cores extracted from 17 Australian cadavers. This study found the amount of histomorphological variation in occipital bone tissue is too great for accurate age estimation. Clarke (1987) had reported similar results in an earlier study evaluating the parietal bone. Curtis (2004) analyzed the microstructure of the left and the right frontal bone from a sample of 92 European-American cadavers, concluding that the histological structure does not appear to be as influenced by age-related changes when compared to postcranial elements.

Factors Affecting Histological Age Estimation

Microscopic age changes in cortical bone are a universal phenomenon, yet biological variability in bone remodeling rates owing to intrinsic and extrinsic factors affects histological age estimates. The following sections briefly discuss these factors as they relate to nonpathological bone.

Remodeling Variance

The onset and magnitude of bone turnover varies at different anatomical locations throughout the skeleton. Significant sampling error can occur within (spatial variance) and between (incoherence) cross-sections, with the latter's sampling error increasing dramatically as the amount of cortical area evaluated decreases (Frost 1969). Frost (1969) recommends that a minimum of 50 mm² of cross-sectional bone in non-pathological individuals should be evaluated to minimize sampling error. Crowder (2005) notes that incoherence between rib cross-sections is more pronounced in older individuals owing to the higher fragmentary OPD values. Pfeiffer and colleagues (1995) demonstrated the relation of spatial variance in bone remodeling to mechanical loading: the anatomical axes (the anatomical planes of a bone) of the femur mid-shaft exhibited greater variability in bone remodeling than did the mechanical axes (the locations of mechanical loading owing to the mechanical environment of the bone). Spatial characterization of rib cortical microstructure demonstrates that bone remodeling processes are consistent with heterogeneous point processes; OPD at different regions of interest may not characterize the OPD for an entire cross-section (Heinrich 2015). In an attempt to control for spatial variance, Iwaniec and colleagues (1998) determined that the smallest amount of the anterior femur should be evaluated to accurately predict the variation in the entire anterior wedge of the femoral midshaft. The study produced a promising sampling strategy that was further explored by Crowder and Dominguez (2012) but has yet to be developed into an age estimation method.

Chan and colleagues (2007) evaluated sampling error in long-bone diaphyses using the Thompson (1979) method. According to the results, the inter- and intrasection variation that

occurs in bone remodeling within the femoral cortex has the potential to produce significant differences among age estimates taken from various femoral diaphyseal locations compared to the age estimated from the anterior midshaft. However, the sampling location is not necessarily confined to the anterior midshaft but can be applied with similar accuracy to locations along the anterior diaphysis.

A larger obstacle than sampling error is an OPD asymptote³ that occurs when new osteon creations remove all evidence of older ones (Wu et al. 1970). This phenomenon is predicted to occur around the 6th decade of life in the ribs; however, this time period is not static. It is unclear if the onset of the asymptote varies between skeletal elements that remodel more slowly or that have larger cortical areas. Heinrich (2015) suggests that the peak asymptotic value of OPD is likely a multifactorial product of bone remodeling, osteon area, mean tissue age, periosteal apposition, and endosteal expansion. Differences in the asymptotic nature of fragmentary and intact OPD indicates that future histological age-estimation methods will benefit from keeping intact and fragmentary OPD distinct during analysis.

Population Variation

The literature has produced conflicting reports regarding variation in bone remodeling among ancestral groups. Although bone mass, quality, and turnover rates have been shown to differ among ancestral groups, it is unclear how age estimates are affected. If bone turnover is increased in a specific region (for instance, the endosteal surface) then current methods of histological age estimation that evaluate fields at the perisoteal surface may not demonstrate significant remodeling differences. For example, Kerley (1965) determined that ancestry has no effect on histological age changes, whereas Pratte and Pfeiffer (1999) and Cho and colleagues (2002), evaluating entire rib cross-sections, note differences in bone microstructure between groups. Differences may or may not be revealed, depending on the histological variables, sample size, and sample demographics. Comparisons using archaeological remains of unknown ages of death often demonstrate population differences in bone remodeling (Ericksen 1973; Richman, Ortner, & Schulter-Ellis 1979; Mulhern & Van Gerven 1997; Mulhern 2000). The unknown age and sex distributions of the archaeological populations being compared may differ significantly, producing variations in bone microstructure that can be mistaken as population differences. For example, it has been suggested that osteon area exhibits population differences (Pfeiffer 1998; Watanabe et al. 1998; Cho et al. 2002; Curtis 2004; Pfeiffer et al. 2006), albeit in most cases, these differences are not statistically significant. Furthermore, it has been postulated that age and sex differences exist in osteon area (Landeros & Frost 1964; Takahashi, Epker, & Frost 1965; Ortner 1975; Stout & Simmons 1979; Burr, Ruff, & Thompson 1990; Mulhern & Van Gerven 1997). These perceived differences in osteon area may be an artifact of the sample age and sex distributions or dependent on the histomorphometric technique. Rather than focusing on population-level differences that conflate genetics, subsistence activity, physical activity, and general life conditions, these authors suggest a better understanding of the underlying life conditions (such as physical activity, nutritional status, and physiological stress), population demography, and sex-related differences will prove more beneficial in accurately estimating age-at-death.

Sex-Specific Variation

It is well documented that bone density and the rate of bone remodeling differ between adult males and females (Kerley 1965; Thompson 1979; Ericksen 1991; Robling & Stout 2000; Agarwal et al. 2004). Sex-related differences in timing and magnitude of skeletal growth

during adolescence should be reflected in differences in mean tissue age and subsequent osteon accumulation. Pregnancy, parity, lactation, and menopause are biological factors that may affect bone turnover in the female skeleton (Agarwal & Stuart-Macadam 2003). Although sex-specific equations for histological age estimation have been developed (Thompson 1979; Ericksen 1991), most of the aforementioned studies did not demonstrate sex differences in histomorphometric variables. This fact could be the result of small samples producing skewed sex and age distributions, the intracortical location of the microscopic field, or choice of statistical models. Sex differences in histomorphometric variables observed in archaeological populations could be the result of bone's response to mechanical loading owing to a gender division of labor. Sex differences have been suggested to manifest in osteon area; however, other studies disregard sex as a factor (Dupras & Pfeiffer 1996; Pfeiffer 1998; Cho et al. 2002). Although sample size and distribution should be a concern, these discrepancies suggest that other factors affect osteon area, such as differences in bone-formation rates, physical activity, and age at death.

Physical Activity

Biomechanical strain levels may vary within and between populations depending on the general patterns of physical activity. Strain-related differences in bone mass have also been documented within paired skeletal elements of an individual (Daley et al. 2004). Lack of activity on weight-bearing elements, such as that which occurs with prolonged bed rest or quadriplegia, has been shown to alter bone resorption and formation rates, leading to lowered remodeling thought to result from decreased strain (Inque et al. 2000; Schlect et al. 2012). Controlled experiments using nonhuman mammals have demonstrated the effects of loading history on cortical bone modeling and remodeling (Skedros et al. 2003; Skedros, Hunt, & Bloebaum 2004). Research indicates that responses to weight-bearing exercise are specific to the loaded bone and do not appear to produce systemic effects (Tommerup et al. 1993; Robling 1998). Specifically, loading sufficient to generate microdamage that results in compromised osteocyte viability leads to remodeling (Herman et al. 2010). The question remains: how do levels of activity affect the accuracy of histological age-estimations in humans? The magnitude or duration of physical activity that is needed to produce significant differences in microstructure and, in turn, age estimates remains unknown. More research is needed comparing multiple skeletal elements from the same individual of a known sample.

Nutritional Status and Physiological Stresses

Researchers have suggested that diet, chronic undernutrition, and various physiological stresses can alter bone remodeling rates and affect age-estimation (cf. Richman, Ortner, & Schuler-Ellis 1979; Pfeiffer & King 1983; Paine & Brenton 2006; Karinen 2009; Keough, L'Abbé, & Steyn 2009). However, the biological process for these changes is poorly described. In general, undernutrition, substance abuse, and chronic disease are thought to reduce bone remodeling rates (Pfeiffer & King 1983; Paine & Brenton 2006; Karinen 2009); however, small sample sizes and age-distributions negatively affect the significance of this research. Recent research by Heinrich (2015) suggests that adult bone remodeling processes are robust to undernutrition and general physiological stresses. This research demonstrates that chronic undernutrition, chronic infectious disease, and poor life conditions can alter growth and developmental trajectories, mean tissue age, and subsequently reduce the amount of remodeled bone tissue.

Methodological Issues

While the intrinsic and extrinsic variables affecting bone histomorphometry are not controllable in the forensic context, methodological error can be limited. The evaluation technique determines the amount of subjectivity introduced. To improve histological methods, researchers need to adhere to a common set of more objective variable definitions. Variable definitions that require one to visually assess a percentage of bone present, absent, or remodeled are more subjective and produce higher levels of observer error. Dempster and colleagues (2013) standardized the nomenclature for hard-tissue histologists to relieve confusion and to reduce the semantic barriers that they must cross within the field; however, few researchers in anthropology have adhered to the protocol.

Sampling procedures are needed to adequately evaluate skeletal elements that have larger cortical areas (for example, femur, humerus) to limit the effect of spatial variance and to reduce observer error. In the histological method developed by Maat and colleagues (2006), only three 1 mm² fields were evaluated from the anterior femoral midshaft. Although the inherently “destructive” nature of histological sampling is a concern for archaeological remains and museum skeletal collections, this trepidation in removing larger sections of bone should not exist in forensic analyses. Recent research on spatial variation demonstrates the heterogeneous nature of intact osteon density (Heinrich 2015). The importance of evaluating an adequate amount of cortical bone is paramount in reducing remodeling variance error, which will improve the accuracy of the age estimate and assist with the overall identification process.

Sample sizes and age distributions need to be more carefully considered. Since age related trends are being evaluated, it is crucial for all ages to be equally represented. Small sample sizes and skewed age distributions can heavily bias resulting age-estimations. This fact may heavily contribute to the perceived histological differences between populations. It is not surprising that researchers have discovered significantly different remodeling rates between samples with substantially different age distributions. It is equally important to choose appropriate statistical models. Research demonstrates that many histological variables do not demonstrate linear relationships with chronological age; therefore, non-linear models need to be considered.

Conclusion

The advancement of microscopy technology has enormous potential to significantly enhance histological analyses. Relatively simple to use are digital cameras, automated microscope stages, capturing software and analytical programs. Viewing microscopic structures on a large monitor with software that can improve visualization can greatly decrease observer error, enable observer accountability, and assist with multiperson analysis. The ability to mark structures that have been counted or to measure features on a screen with a digitizing tablet improves histomorphometric data collection; however, the budding forensic anthropologist or seasoned professional deciding to perform histological age estimation should be warned that digital imaging does not replace direct microscopic analysis through the eyepiece. The nature of a 2D evaluation of a 3D structure requires the observer to continuously focus up and down and adjust polarization and lighting. Recent application of geographic information system (GIS) methodologies to histological analysis has enabled true spatial characterization and spatial analysis of bone tissue. These emerging methods show promise in elucidating the underlying etiologies of observed population-level differences and producing more accurate age-estimation methodologies (Rose et al. 2012; Gocha 2014; Heinrich 2015). Other technical advances include the use of microcomputed tomography (μ CT), which is the first nondestructive imaging technology for histological analysis (Cooper

et al. 2003, 2004). Currently, this technology is capable only of resolving Haversian canals, making it mostly suitable for the analysis of cortical porosity and not appropriate for use with established methods of histological age estimation.

It is apparent that existing histological methods of age estimation differ from one another in regard to skeletal element, sample location, and histomorphometric variables. Despite the general consensus that age-related changes are reflected to some degree in the microstructure of bone, the numerous difficulties in reproducing and evaluating results from previous histological studies have been a deterrent in their use as a standard method for the estimation of adult age at death. Furthermore, the macro- and micromorphological age-related changes within the skeleton are a complex interaction of intrinsic biological factors, extrinsic environmental factors, and inherent method biases that must be systematically examined. Adapting more rigorous procedures for developing and evaluating histological methods will aid researchers in generating more reliable methods of age estimation.

Notes

- 1 N.B.: Kerley does not report the origin of the samples used.
- 2 The Thompson (1981) sample included only six individuals of non-European descent.
- 3 The asymptote refers to the point where one is unable to quantify the accumulation of the density of remodeling events over time because preexisting events are being erased.

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Stature Estimation

P. Willey

An individual's stature is a readily observable and frequently measured biological trait. Along with age, sex, ancestry, and weight, stature is one of the first things we notice about a person and is included in many antemortem medical, civilian, and military records. Among other useful information, stature estimations from skeletal remains or body parts assists authorities' efforts to identify remains of unknown individuals. Along with the other biological parameters just mentioned, stature of the deceased is one of the biological assessments that may prove critical in establishing the possible identity of remains.

This chapter describes the process of estimating adult stature from skeletal remains and comparing that estimation with antemortem height. Stature is estimated in two ways: (1) measuring all bones constituting the components of stature, summing those measurements, and adding a soft-tissue component; and (2) employing regression formulae with the measurement of a complete bone or bone fragment. Beyond the estimations, several issues affect the accuracy of stature comparisons. These problems include decreasing stature associated with adult aging and the reliability of antemortem records. Topics requiring additional research are also presented.

Complete Skeletons

The method proposed by Dwight (1894) employs all skeletal elements constituting height and is sometimes called the "anatomical" method. Applications of this approach traditionally employ the techniques of Fully (1956) or Fully and Pineau (1960). Using these techniques has been supported in recent decades by numerous studies (for example, Berg, Casey, & Raasch 1985; Lundy 1985, 1988a; Bidmos 2005), and Raxter, Auerbach, and Ruff (2006) and Raxter, Ruff, and Auerbach (2007) revised and expanded this method.

The Fully method of stature estimation is more intuitive and understandable than the other principal approach. When using the method, one measures all the skeletal elements constituting stature, then sums those measurements and adds a soft-tissue "correction" to that sum (Box 22.1). These steps are presented shortly in more detail.

First, measurements are taken. The measurements (Figure 22.1) consist of cranial height (basion-bregma), heights of the anterior vertebrae bodies (cervical 3 through lumbar 5), anterior height of the first sacral segment, bicondylar femoral length, physiological tibia length (excluding the superior tibial spines and including the medial malleolus), and height of the articulated talus-calcaneus (oriented to include the angle of the foot's longitudinal arch). One deviation from this straightforward procedure concerns the atlas and axis measurements; the atlas is omitted and the axis's body, including the dens epistrophe (odontoid process), is measured (for

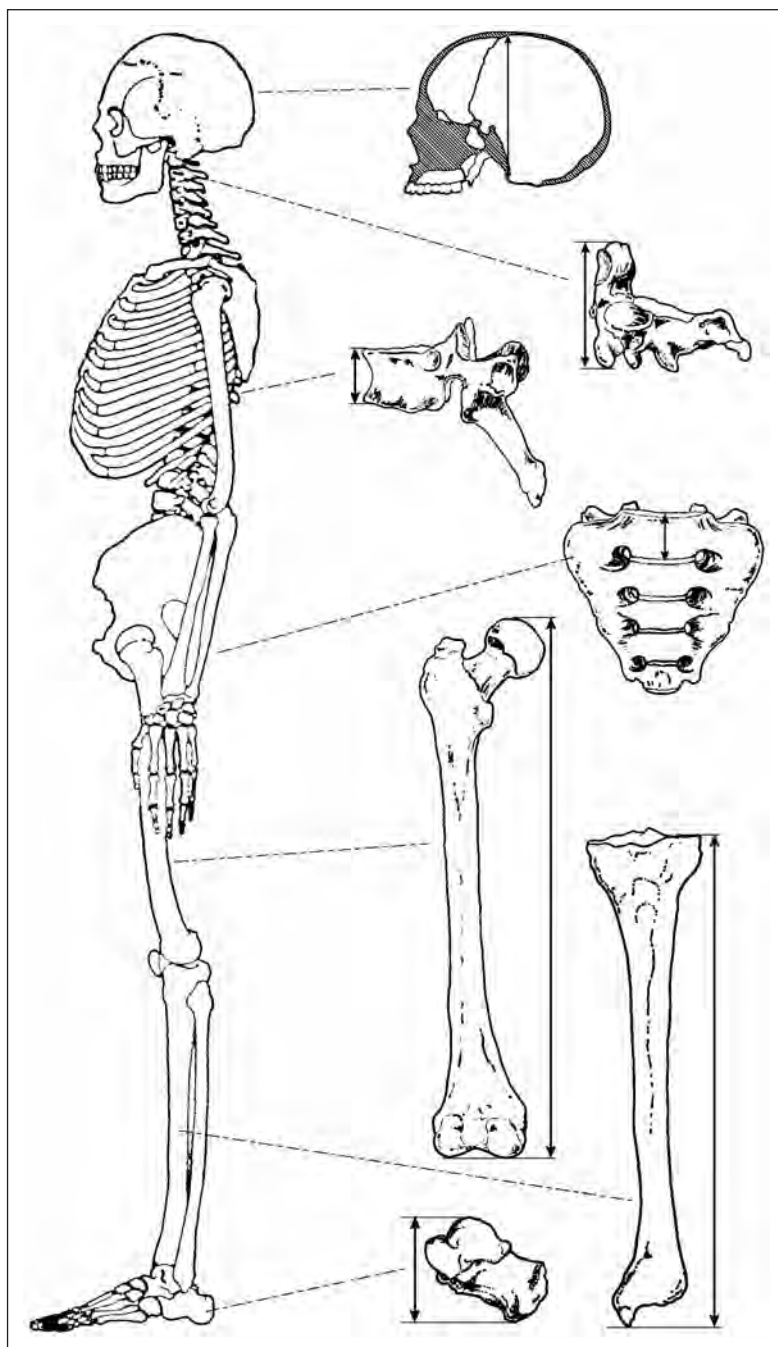


Figure 22.1 Measurements involved in estimating stature using the whole skeleton

Box 22.1 Estimating Stature Using the Whole Skeleton

Stature was estimated using the entire skeleton of remains identified as Farrier Vincent Charley, a 7th Cavalry trooper who died during the Battle of the Little Bighorn in June 1876. The skeleton was excavated and measured in the 1990s (see accompanying table). Making the estimation challenging, five of the vertebrae were either missing or had incomplete anterior bodies, and all vertebrae had been measured following an earlier technique; those vertebral measurements were estimated (indicated in parentheses in the table, after Raxter, Auerbach, & Ruff 2006; Raxter, Ruff, & Auerbach 2007; Auerbach 2011). Once the elements and estimations constituting skeletal stature were summed (skeletal total=164.06 cm; see Table 22.1), the total inserted into a regression formula not considering age-related reduction, yielding an estimated stature of 176.8 cm (69.6 in.).

Farrier Charley's reenlistment information, recorded three months before his death at the age of 27 years, indicates he was 5 ft 10 ¼ in. (178.4 cm) (Nichols 2000: 55). The skeletal estimation of 176.8 cm is 1.6 cm (0.6 in.) shorter than Charley's recorded stature, perhaps suggesting Charley was measured while wearing boots.

Whole-skeleton stature estimation for remains identified as Vincent Charley, 7th Cavalry Farrier; measurements in parentheses indicate estimations of some vertebral body heights

<i>Segment</i>	<i>Length (cm)</i>
Skull height (bregma-basion)	13.0
Cervical body heights (summed)	(11.36)
Thoracic body heights (summed)	(25.6)
Lumbar body heights (summed)	14.7
Sacral segment 1 height	3.1
Bicondylar femur length	48.2
Physiological tibia length	40.9
Talus & calcaneous height	7.2
<i>Total skeletal element heights</i>	<i>164.06</i>

Table 22.1 Soft-tissue additions for skeletal-element sum used in whole skeleton approach (from Fully & Pineau 1960: 145)

<i>Skeletal Sum</i>	<i>Soft Tissue Addition</i>
≤153.5 cm	10.0 cm
153.6–165.5 cm	10.5 cm
≥165.5 cm	11.5 cm

example, Fully 1956). All these measurements are summed, and, based on that total, a soft-tissue correction figure is added (Table 22.1). The additional soft-tissue figure differs depending on the total of skeletal element height measurements. Raxter and associates (2006, 2007) and Bidmos and Manger (2012) have revised the Fully and Pineau soft-tissue estimations.

Using the complete-skeleton technique to estimate stature has advantages and disadvantages. Advantageously, it can be employed regardless of the ancestry or sex of the individual. In addition,

whole-skeleton stature estimations should be more accurate than other techniques (Maijanen 2009) if anomalous numbers of vertebrae occur (Lundy 1988b; Raxter & Ruff 2010) or if the individual is unusually proportioned (for instance, long trunk and short limbs).

Disadvantages of the technique include requiring complete elements and a complete skeleton—unless the analyst is prepared to estimate heights of missing elements (see Auerbach 2011 for approaches to those estimations). In addition, taking the 29 measurements required to estimate stature of the normal skeleton is tedious and time consuming. An alternate approach avoids many of these limitations.

Regression of Limb Bones

Estimating stature using a limb bone-length measurement in regression formula was developed by Pearson (1899). It is sometimes called the “mathematical” method of estimating height and is widely used today. The method is simple. Measure the length of a limb bone, select the appropriate regression formula by sex, ancestry, and temporal period, insert the measurement into the formula, and calculate the estimated stature. The standard formula follows the format

$$\text{estimated stature} = a + bx \pm SE$$

where a is the line's Y axis intercept,
 b is the line's slope,
 x is the limb bone length(s), and
 SE is the standard error

Limb bone measurements are usually maximum lengths; the tibia measurement, however, has more complexity and is discussed in Box 22.2.

In addition to formulae for individual limb bones, regression formulae exist for multiple limb bones. In multiple regression applications two or more limb bone lengths are added, then multiplied by a coefficient, and a scalar (a in the preceding formula) is added. Whether univariate or multiple variate formulae are used, the formula with the smallest standard error is the most accurate and should be employed.

Formulae are available by sex for a number of populations. In the United States Trotter and Gleser's (1952, 1958; Trotter 1970) formulae are most often employed. They include large samples of U.S. Black and White males, and smaller samples of U.S. Mongoloid, Mexican, and Puerto Rican males, as well as U.S. Black and White females.

An innovative approach involving regression formulae is the stature estimation function in the software package FORDISC (Ousley & Jantz 2005). After entering a limb bone length in a screen and selecting the stature option, FORDISC calculates statures for black and white males based on Trotter and Gleser's (1952) World War II sample. FORDISC also estimates Forensic Stature for Black and White females and males, and Hispanic males (more about forensic stature shortly). And it calculates cadaver statures for 19th-century Black and White females and males based on the Terry Anatomical Collection.

Statistical Fundamentals

Regression formulae are based on statistical calculations and assumptions. Applications of regression formulae include using the single-best formula and estimating the confidence interval.

After one controls for sex, ancestry, and temporal cohort, the most accurate formula is the one with the smallest standard error. The formula with the smallest standard error usually involves an

Box 22.2 Estimating Stature Using Regression Method

Using measurements of the same skeleton for which stature was estimated in the previous example (Farrier Vincent Charley), stature is estimated with a regression formula and limb bone length. Trotter and Gleser's (1958: 84, Table 3) widely used stature estimation formula for white males for a single limb bone includes a formula for the left fibula, the limb bone with the smallest standard error and thus the most accurate stature estimator. The formula and calculations are

$$\text{stature} = 2.59 \times (\text{maximum left fibula length in cm}) + 75.37 \text{ with a standard error of } \pm 3.83$$

Inserting the measurement of the left fibula from the skeleton identified as Farrier Charley's, the equation is

$$\text{stature} = 2.59 (40.2) + 75.37 = 179.488 \text{ cm (70.66 in.)}$$

The resulting estimation (179.488 cm, 70.66 in.) is 1 cm (about ½ in.) greater than Farrier Charley's recorded reenlistment height of 5 ft 10¼ in. (Nichols 2000: 55). Especially when the estimation distribution is considered (95% confidence interval of ± 7.51 cm [± 2.96 in.], following Giles and Klepinger 1988), the estimation fits Charley's antemortem record well.

Yet another technique with a different regression formula can be applied. Inserting the left fibula length measurement in FORDISC's (Ousley & Jantz 2005) stature function for 19th-century white males, the resulting stature estimation is 71.1 in. (180.59 cm, with a 95% prediction interval of ± 7.11 cm [2.8 in.]). That result is similar to the one calculated using Trotter and Gleser's formula, as well as Farrier Charley's reenlistment stature.

element of the lower limb or combined elements including the lower limb bones. Unfortunately some practitioners are seduced into calculating several formulae, then averaging those estimations, thus reducing the accuracy of their estimation. This erroneous practice of averaging should be avoided. The formula with the smallest standard error alone should be employed.

Another frequent and erroneous practice is using the standard error to provide a confidence interval as if a confidence interval and a standard deviation were identical. It has been noted (Giles & Klepinger 1988) that the standard error is not the same as the standard deviation and therefore should not be employed as such. The prediction interval associated with a regression is a curvilinear, double parabolic distribution, not linear, as simply doubling the standard error implies. If an accurate confidence interval is required, then a confidence interval should be calculated and appropriately applied. See Giles and Klepinger (1988) for steps in calculating the confidence interval. From a practical perspective, however, the confidence interval increases little within three standard deviations of the mean bone length (Ousley 1995; Ousley & Jantz 2005).

There is an additional issue to be considered when one is presenting variation associated with a regression estimation. The use of confidence intervals assumes that the regression parameters are known and similar to those employed in establishing the regression formula. But the origins of many unidentified remains are obviously undetermined. An alternate assessment stature estimation variation is more appropriate: prediction intervals FORDISC software provides 90% and 95% prediction intervals for its stature estimations (Ousley & Jantz 2005). Because prediction intervals do not assume that the same parameters employed to establish the formulae are appropriate for the estimation, prediction intervals are necessarily larger than confidence intervals.

Corrections

Limb bone measurements are straightforward; in most standards they are the maximum lengths. There is an exception, however: Trotter's tibia measurements appear to be in error. Jantz, Hunt, and Meadows (1994, 1995) concluded that Trotter misreported tibiae measurements in most of her samples. The standard practice (and Trotter's description of how she measured tibia length) is from the lateral portion of the lateral condyle to the most distal end, *including* the medial malleolus. However, when Trotter's measurements of the Terry Collection tibiae were remeasured, they averaged 13 mm less than the remeasurements. Jantz, Hunt, and Meadows (1994, 1995) concluded that the difference occurred because Trotter's measurements *excluded* the medial malleolus. In addition to the Terry Collection specimens, Trotter and Gleser's WW II and Korean War tibiae measurements appear to be too short. As a consequence of these apparent errors the resulting stature estimations based on Trotter and Gleser's 1952 tibiae formulae are 2.5–3.0 cm too short, depending on the ancestry, sex, and formula involved. Jantz, Hunt, and Meadows (1994, 1995) make recommendations to compensate for this error.

Advantages and Disadvantages

Using regression formulae to estimate statures has advantages as well as disadvantages. The major advantages are that only one or at most several bones are required, measurements are simple, and calculations are easy and quick. However, accuracy of the regression formulae estimations relies on consistent proportionality of limb bone lengths to stature. Because body proportions may vary by sex, ancestry, and temporal period, accurate stature estimation requires correctly determining those parameters beforehand and having appropriate regression formulae for that sex, ancestry, and time period. Fortunately regression formulae are available for both sexes of many different populations and temporal periods. Individual proportional peculiarities, in contrast, are an issue that is difficult to overcome with these formulae. In addition, the estimated statures of very tall and very short people may be less accurate than estimations for individuals of average height. A final disadvantage is that a complete limb bone is required.

Two approaches overcome the requirement of complete limb bones: estimating limb bone length from fragmentary bones and using non-limb bones to estimate stature.

Fragmentary Limb Bones

One problem with both whole-skeleton and whole-limb-bone methods is that the requisite complete bones may be absent. This issue was anticipated by Seitz (1923) and later documented by other researchers, most notably Steele (1970). The solution to the problem is to estimate the length of a limb bone using the fragment present by applying a regression formula. The estimated limb bone length is then used as if the bone were complete in another regression formula (described previously). Because this approach relies on two estimations (limb bone length and stature), it is less accurate than the previous approaches and should be avoided if possible.

Elements Other Than Limb Bones

As an additional problem, even fragmentary limb bones may be absent. To overcome this obstacle, elements other than limb bones have been employed to estimate stature. Since the early 1980s regression formulae have been calculated for estimating stature from measurements of the cranium (Chiba & Terazawa 1998, Cui & Zhang 2013), sternum (Macaluso & Lucena 2014), vertebrae (Tibbetts 1981), sacrum (Karakas et al. 2011, Torimitsu et al. 2014a), clavicle, scapula,

innominate (Peng & Zhu 1983, Giroux & Wescott 2008), metacarpals (Meadows & Jantz 1992), hand phalanges (Zhu 1983), and foot bones (Byers, Akoshima, & Curran 1989; Holland 1995; De Groote & Humphrey 2011, Pablos et al. 2013). Although these techniques may prove useful in cases involving skeletons lacking limb bones or limb bone fragments, their applications are limited to a few ancestral groups, and their stature prediction intervals are greater than that typically associated with estimations from limb bones.

Additional Statistical Approaches

Some researchers have utilized both regression and whole-skeleton approaches to estimate stature. This combination of approaches has been applied, for example, to the spine. Segments of the spine were measured on corpses or cadavers, and those segments regressed on stature (Terazawa et al. 1985, 1990; Jason & Taylor 1995), or individual vertebral bodies were measured then summed, and then that sum was regressed on stature (Tibbetts 1981).

Another approach—the stature estimation method, requiring the fewest arithmetic steps—is using a ratio. The ratio between stature and an element length (for example, femur) is calculated to establish a coefficient (for instance, Feldesman, Kleckner, & Lundy 1990). To estimate stature, then, a limb length measurement is employed in the ratio. Although some authorities claim that the ratio approach is superior to the more conventional regression formulae (Feldesman, Kleckner, & Lundy 1990; Feldesman & Fountain 1996), others have objected. The femur/stature ratio overestimates statures, especially those of tall individuals. It has a greater prediction interval and therefore is less accurate than estimations associated with regression estimations (Meadows & Jantz 1995). So, the femur/stature ratio appears to be a poorer estimator of stature than the more widely used regression approach (Konigsberg et al. 1998).

At the other end of the statistical sophistication spectrum, Konigsberg and associates (1998) recommend inverse calibration from a ratio when stature estimation of an individual employs a base sample with similar parameters as the individual whose stature is being estimated.

Age-Related Stature Decrease

Regardless of the stature-estimation method employed, the age of the individual may affect the individual's living stature. As adults age their statures decrease from their young-adult maximum. Although research supports the existence of age-related stature decrease, questions remain concerning the age of onset, rate of loss, and whether sex influences the decrease.

Pioneering work indicated that stature decrease began around 30 years of age (Trotter & Gleser 1951), but more recent analyses (Galloway 1988; Giles 1991) found that in fact age-related stature decrease begins at about 45 years of age (Figure 22.2). The pioneering work (Trotter & Gleser 1951) also concluded that once stature decrease began, it proceeded in a linear manner at 0.6 mm per year. More recent work, however, found that the rate of loss was more than twice that fast (1.6 mm per year, Galloway 1988). And a longitudinal study determined that stature decrease occurred at a variable rate, not a constant linear decrease (Giles 1991).

The pioneering study found stature decrease to be homogeneous in both sexes (Trotter & Gleser 1951), and this conclusion was supported (Galloway 1988). However, a longitudinal study reported sex differences (Giles 1991; Klepinger & Giles 1998) showing that males lost stature more rapidly than females until about 75 years, when the trend reversed (see Figure 22.2). A recent reevaluation of stature decrease employing cadaver length suggests greater complexity of all of these issues than previously documented (Niskanen et al. 2013).

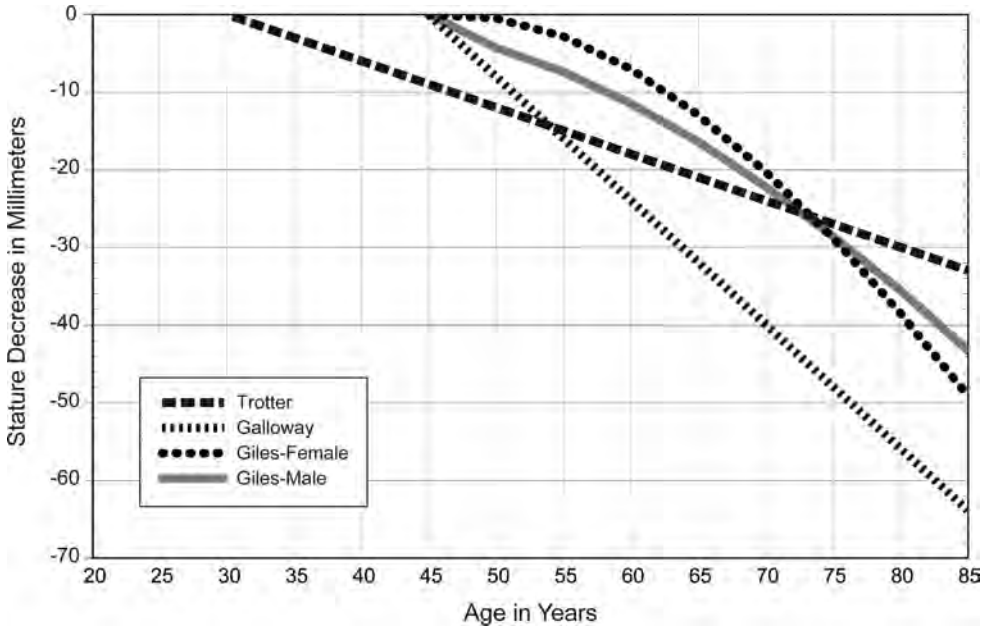


Figure 22.2 Age-related decrease in adult stature. “Trotter” is the decrease that Trotter and Gleser (1951) derived; “Galloway” the decrease Galloway (1988) calculated; “Giles-Fe” the decrease Giles (1991) found for females, and “Giles-Ma” the male decrease.

Antemortem Stature Records

Another variable that affects the reliability of comparisons between antemortem records and stature estimations is the accuracy of antemortem stature information. Accurate antemortem stature records are critical for comparing stature estimations. The problems associated with measuring antemortem stature, such as time of day, measuring technique, and inter-observer error, have frequently been addressed (for example, Giles & Hutchinson 1991). The subject of this section is a related matter; it considers the nature of antemortem records and how accurately they reflect actual height.

Distortions occur in self-reported heights. Employing the often-used driver’s license (DL) and comparing its recorded statures with the living person’s measured stature, Willey and Falsetti (1991) found a tendency for college students’ DLs to over-report their statures (averaging nearly 1 cm). Males’ DLs over-report their statures to a greater degree (average over-reporting 1.321 cm) than females (average over-reporting 0.574 cm).

The problems of self-reported statures were investigated using a large U.S. Army personnel sample, which was compared to U.S. Health and Nutrition Examination surveys. Examining self-reported statures of older individuals as well as those of shorter and taller groups, older individuals (≥ 45 years) tended to exaggerate stature, most likely compounded with age-related stature decrease (Giles & Hutchinson 1991). The investigators also found that taller individuals tended to estimate their statures more accurately than medium and shorter individuals (Giles & Hutchinson 1991: 771).

To include the degree of distortion associated with antemortem stature records, Ousley (1995) developed “forensic stature.” Forensic stature is the antemortem stature information available for a missing person, which in his sample usually came from DL, booking, or medical records. In an evaluation of forensic stature Wilson, Herrmann, and Jantz (2010) found

that forensic stature better reflects a person's reported stature than do the Trotter and Gleser formulae. Because forensic statures are less precise than Trotter and Gleser's formulae indicate, Ousley recommends using a broad estimation interval in casework. According to these studies, forensic anthropologists should present a broad stature estimation interval (for example, 90% or 95% prediction or confidence intervals).

Recent Developments

Established in 2008, the Scientific Working Group in Anthropology (SWGANTH 2015) established guidelines and promoted best practices in forensic anthropology (SWGANTH website). Thus it anticipated some of the National Academy of Sciences' (NAS 2009) recommendations for application of forensic sciences in the United States (NAS 2009). SWGANTH's document on stature estimation abbreviated this chapter published in an earlier edition (Willey 2009). With SWGANTH's dissolution in 2013, the National Institute of Standards and Technology, Forensic Standards Board, Subcommittee on Anthropology took over those responsibilities and is in the process of establishing standards for the discipline, including stature estimation.

Topics for Future Research

There have been many recent strides and innovative approaches to estimating stature from bones. The frequency of publication since the late 1990s indicates the importance of stature estimation in forensic anthropology, and, as the trend continues, much will be learned in future decades.

First and perhaps foremost, development and enhancement of current techniques must continue. Research in stature estimation has shown improved statistical sophistication, employed additional elements, documented age-related stature decrease, and employed imaging technologies (for example, Kieffer 2010), thus expanding many of the classic studies. In addition, populations of forensic interest have changed and additional research will be needed to estimate accurately their statures. As examples, subgroups from Central and South America (Garmendia et al. 2014), Eastern Europe (Petrovečki et al. 2007; Jantz, Kimmerle, & Baraybar 2008), Asia (Mahakkanukrauh et al. 2011; Sargin, Duyar, & Demirçin 2012; Gocha et al. 2013; Torimitsu et al. 2014b), and Africa (Didia, Nduka, & Okechukwu 2009; Ahmed 2013) have been studied with specific attention to stature estimation.

There are two additional areas ripe for stature estimation research. One area that has been gaining attention is estimating stature from soft tissue-covered remains. In some forensic contexts tissue-covered bodies dominate the remains, and accurate stature estimation may be possible without time-consuming maceration. Two approaches have been used. A few studies employ postmortem computed tomography (PMCT) (Karakas et al. 2011; Torimitsu et al. 2015).

Most of these studies, however, have approached this issue using anthropometric body dimensions and relating them to stature. To estimate stature they employed dimensions of the head and face (Pelin et al. 2010), vertebral column components (for example, Terazawa et al. 1985; Jason & Taylor 1995), limb segments (for instance, Nath, Garg, & Krishan 1991), hands (such as Abdel-Malek et al. 1990; Uhrová, Beňuš, & Masnicova 2013), and feet (for example, Giles & Vallandigham 1991; Kanchan et al. 2010; Krishan et al. 2012; Uhrová, Beňuš, & Masnicova 2013). In addition, a great number of anthropometric surveys for many different populations exist, and many stature-correlated dimensions may provide useful formulae. A warning is in order. Adams and Herrmann (2009) conclude that, although body segments prove useful for estimating stature,

they are less accurate than whole bones are. Adams and Herrmann suggest that soft tissues obscure anthropometric landmarks, making those measurements less accurate.

Besides fleshed body segments, impressions and prints made by hands and feet may be employed to estimate statures. Footprints have been used to estimate stature (for example, Atamturk & Duyar 2008; Krishan 2008; Fawzy & Kamal 2010; Kanchan et al. 2012; Reel et al. 2012; Hemy et al. 2013; Babladi et al. 2014; Moorthy et al. 2014) as have hand impressions and prints (Ahemad & Purkait 2011; Ishak, Hemy, & Franklin 2012). These works extend stature estimation beyond human remains to trace evidence, although caution is urged in these applications (Reel et al. 2012; Krishan & Kanchan 2013).

Another area receiving some attention involves growth-related stature estimations. Most current stature estimation techniques are for adults. However in some forensic contexts, infants, children, and adolescents (subadults) are recovered, and they, too, require identification.

Techniques available for estimating subadult stature use diaphyseal lengths (Imrie & Wyburn 1958; Telkka, Palkama, & Virtama 1962; Visser 1998; Ruff 2007; Smith 2007; Abrahamyan, Gazarian, & Braillon 2008; Cardoso 2009), upper extremity and hand lengths (Banik et al. 2012; Pandhare et al. 2013), fleshed lower leg (Zorab, Prime, & Harrison 1963, 1964), foot (Krishan, Kanchan, & Passi 2011), and metacarpal lengths (Himes, Yarbrough, & Martorell 1977; Kimura 1992). With few exceptions, most of these studies are based on cross-sectional data.

The few subadult stature estimation techniques that have been developed are applicable to a limited number of populations and employ few elements. Beyond the secular, ancestry, and sex effects that influence adult stature estimation, an additional subadult issue is growth allometry (including proportional changes among limbs and limbs-trunk ratios during growth). Subadult stature estimations should be made cautiously.

Conclusions

Stature estimation of remains is an important component of forensic identification. Two most often used approaches involve the whole skeleton and regression formulae employing limb bones. Both approaches provide relatively accurate estimations, although secular trends and the effects of age, sex, and ancestry must be considered in regression formulae. For less complete remains, less accurate techniques, including those that rely on fragmentary limb bones and non-limb bone elements, may prove useful. The future holds great promise for continued improvements of traditional approaches to stature estimation and wonderful potential for new ones.

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Antemortem Trauma

Eugénia Cunha and João Pinheiro

Antemortem traumatic injuries are those produced before death. The anthropological analysis of skeletal trauma has a major benefit for forensic anthropology since bones retain a record of traumatic events (Passalacqua & Rainwater 2015) that can allow positive identification and contribute to the determination of cause of death.

The evidence of bone repair is the basis for the antemortem diagnosis in anthropology and is thus a central issue of this article. Although cause of death may not directly relate to an antemortem lesion whose signs of bone repair mean that the injury was not lethal, sometimes the complications caused by that injury can result in the subsequent death of an individual. In other words, some antemortem trauma might be viewed, in general terms, as an indirect cause of death, although this qualification has other medico-legal implications. In fact, this type of antemortem trauma cannot be discarded as the cause of death. A classic example is the fracture of the neck of the femur in the elderly. Although rarely fatal, it may be followed by a subsequent complication such as bronchopneumonia or a pulmonary thromboembolism that results in death. From a forensic point of view the original fracture will be considered in most jurisdictions as the cause of death, complicated by one of the factors just mentioned (Pinheiro 2006).

Among the possible agents of trauma mechanical forces are those most commonly seen by the forensic anthropologist. Although antemortem lesions might be understood as synonymous with vital lesions, this equivalence is not totally accurate, because the concept “vital” includes not only the antemortem injuries but also the injuries that occurred immediately before death or that caused the death—the last two types considered by forensic anthropologists to be perimortem lesions. Yet in forensic pathology terminology the designation “vital” is more commonly associated with the last two situations than with antemortem trauma (Figure 23.1). Because the main objective for a forensic pathologist is to determine the cause of death there are only two moments: before and after death, or *vital* and *postmortem*. Lesions before death are vital injuries, because they are produced during life. Definitely they are also antemortem injuries, but pathologists reserve the term *antemortem* for healed fractures, old lesions, and scars. Any lesion that occurred some minutes after death is *postmortem* for pathologists but *perimortem* for forensic anthropologists, because the bone still reacts as a green bone. Consequently, for forensic anthropologists there are three moments: *ante-*, *peri-*, and *postmortem* (see Figure 23.1); that is, there is a conceptual difference between forensic anthropology and pathology in the determination of the vitality of a wound (Cattaneo et al. 2010).

The benefits of the forensic anthropologist's assessment of antemortem traumatic lesions are many; analysis of antemortem trauma can be particularly informative to the reconstruction of life episodes and thus work as excellent factors of individualization (Maples 1984; Komar 2003;

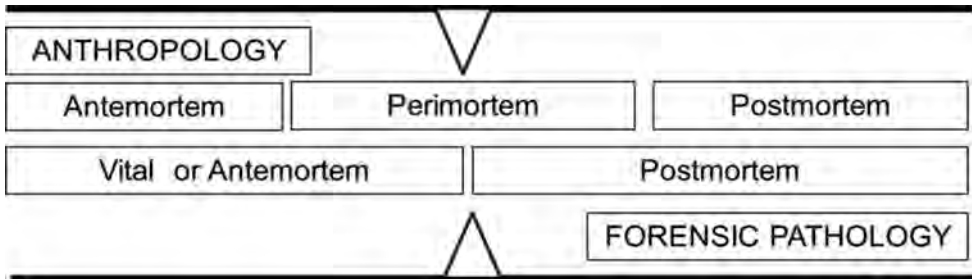


Figure 23.1 Antemortem, perimortem, and postmortem concepts in forensic anthropology vs. vital and postmortem in forensic pathology. The triangles represent the moment of death.

Steyn & İşcan 2000; Cattaneo et al. 2006; Cunha 2006; Cunha & Cattaneo 2006; Cunha & Pinheiro 2007; Scott et al. 2010; Cunha & Pinheiro 2013; İşcan & Steyn 2013; Passalacqua & Rainwater 2015). The more antemortem injuries a skeleton has the more distinctive it will be, thus increasing the chances of achieving a positive identification.

Another major value of forensic anthropology assessment relates to child abuse, an important forensic topic that has been extensively researched during the last decades. Diagnosis of child abuse may be made by assessing antemortem fractures, particularly those affecting the ribs in different phases of healing (Vigorita 1999; Saukko & Knight 2006; Kemp et al. 2008; Ross, Abel, & Radisch 2009; Steyn 2011; Christensen, Passalacqua, & Bartelink 2014). The forensic anthropologist's knowledge about the process of bone fracture and repair is essential to assess not only child abuse cases but also those involving the elderly (Symes et al. 2012). In addition, the assessment of skeletal traumatic injuries has been an important tool in elucidating whether human rights violations have occurred: bones often hold the key to the evaluation of the timing of the injuries (Rodríguez-Martin 2006; Kimmerle & Baraybar 2008; Báez-Molgado et al. 2013; Christensen, Passalacqua, & Bartelink 2014).

This chapter deals with antemortem trauma and examines differential diagnoses among pathological and true antemortem traumatic injuries. In addition, it discusses the mechanisms and chronology of bone remodeling and outlines a method for categorizing traumatic injuries. Some practical cases that illustrate the benefits and the medicolegal value of assessing antemortem traumatic injuries are also provided.

Bone Injury

Bone injury is, for most people, synonymous with fracture. However, there are a variety of other conditions that can result in injury to the bone tissue, such as tumors, infection, and genetic disorders, among others. Because antemortem trauma is the subject of this chapter, specific attention is given to fractures, although the other conditions are also discussed.

Pathogenesis of Fractures

“A fracture is a discontinuity of or crack in skeletal tissue, with or without injury to overlying soft tissues” (Aufderheide & Rodríguez-Martin 1998:20). Fractures may result from the application of repeated forces of low magnitude over a certain period of time—the so-called stress or fatigue fractures—or from a single impact of a force with the capacity to overcome the elasticity

and anisometric properties of the bone tissue—the “normal” fractures, as they are considered in the common sense.

Specific and unusual stress over a certain length of time, that is, some weeks, might result in a fatigue fracture (Ortner 2003). In these cases the fracture does not occur immediately after the application of stress but with the repetition of that stress over the bone. Gymnasts, athletes (long-distance runners, baseball pitchers), ballet dancers, and military infantry recruits increasingly display such fractures as a result of repetitive and continuous activities (Vigorita 1999; Ortner 2003). Such fractures may act as good factors of individualization and thus contribute to positive identification.

Spondylolysis, one of the best-known examples of a stress fracture, consists of a partial to complete separation between the vertebral body and the arch of the corresponding vertebra (Merbs 1989; Ortner 2003). Congenital predisposition to such a defect has been proposed for specific populations (for example, Barnes 1994).

Concerning “normal” fractures, that is, when the trauma is direct, the associated injury of soft tissue and eventual comminuted fracture is related to the loading rate. When the force is applied distant from the fracture site, strong muscle contractions across a joint with a fixed distal segment (such as joints at the elbow and the knee) may result in separated fracture fragments (Day et al. 2004). These forces will mainly act over the three principal planes of stress of a bone: compression, tension, and shear. Such forces may act independently or in association, determining different patterns of long-bone fractures (Day et al. 2004).

The vulnerability of bone to trauma is also related to its capacity to absorb energy, following the classic formula of kinetic energy as $\frac{1}{2}mv^2$, where m is mass and v the velocity of the impacting object. This formula explains the higher degree of comminution and displacement observed on impacts with high-velocity objects. The same law is applied to gunshot wounds, whereby high-velocity projectiles determine a higher destruction, comminution, and soft-tissue injury than do low velocity munitions (see Loe, Chapter 24 this volume).

Pathological Fractures

Normal fractures such as those just outlined occur in normal, healthy bone. However, some conditions might produce abnormal, pathological bone, which will break easily with minor trauma or even with the normal use of the bone. These are known as *pathological fractures*. In these cases, even when the trauma involved is of great magnitude they are still considered pathological fractures.

Distinguishing the basic disorders that favor these fractures is mandatory in the anthropological analysis. The pathological conditions more often involved are osteogenesis imperfecta; osteoporosis (related to many causes but where a decreased bone mass is responsible for increased risk of fracture); rickets; osteomalacia; scurvy; osteomyelitis (hematogenic, secondary to injuries, tuberculosis); rheumatoid arthritis; avascular posttraumatic necrosis; postirradiation necrosis, tumors/neoplasms (bone, cartilage, connective tissue, angiogenic and mielogenic, and metastatic) (Aufderheide & Rodriguez-Martin 1998; Salter 2000; Ortner 2003).

In the majority of these diseases ageing can be considered a paramount predisposing factor, since low bone mass is generally associated with age. Furthermore, it is well known that the specific setting of fractures within the skeleton depends on the age and the sex of the individual.

Types of Antemortem Trauma

There are several ways to classify trauma, depending on the way it is inflicted. Classification may be according to the mechanism/instrument employed (see Pinheiro 2006; Wedel & Galloway 2014) or whether it was intentional (Table 23.1). Yet, the large majority of trauma categorisation

Table 23.1 An attempt to classify antemortem trauma

<i>Type of Trauma</i>	<i>Examples</i>
Accidental trauma	Many types of fractures, dislocations
Intentional trauma	Gunshot, stab, hammer, or axe wounds
Cultural trauma	Chinese foot-binding
Therapeutic trauma	Surgical intervention

is mainly related to perimortem, which means that strict categorisation of antemortem trauma is difficult to achieve.

Accidental versus Intentional

Trauma can occur either intentionally or accidentally as a result of actions against another person or self-inflicted. Traumatic injuries can also result from cultural habits that can lead to bone deformation and surgical interventions or other therapies for pathological conditions (Figures 23.2 and 23.3). The categorisation of trauma according to presence or absence of intention is stated in Table 23.1. However, the examples given can never exclusively describe the type of trauma, since, for instance, a dislocation and a fracture or a gunshot wound can obviously occur both accidentally or intentionally.

Ortner (2003) emphasizes that distinguishing between an accidental fracture (for example, resulting from a fall) and a fracture resulting from intentional violence might be virtually impossible. Our experience corroborates Ortner's statement: when dealing with traumatic injuries, distinguishing between intentional and accidental trauma is, almost always, an unbearable task. Another classic example is vertebral fractures. Although some authors argue that compression fractures of the spine tend to occur as a result of an accidental fall, in most cases, in our opinion, again based on our practice, it is virtually impossible to find exclusion arguments to preclude one of the two hypotheses.

In some cases of skull trauma, however, several clues may be available: a localized vault fracture with a depressed fragment and little or no radiating fractures is normally due to a local impact and, depending on the region, possibly produced by an aggressive act involving an object; a wide pattern of complex fractures, sometimes in spider-net pattern and/or reaching the base of the cranium, is more common in falls, traffic, and other type of accidents. Because of the potential legal effect of a forensic anthropologist's findings, their interpretations must have an objective and well-supported argument in support of their conclusions (see Table 23.1). Furthermore, in a medico-legal context it is always dangerous to evaluate intentionality based solely on the objective analysis of the bones. Context is paramount, without it no legal case can be supported.

Cultural and Therapeutic Trauma

In contrast, the identification of cultural and therapeutic trauma is much easier. For the former, prior knowledge of the context—namely, ancestry—will be very helpful, since it is well known that certain traumatic injuries are particular to certain populations, such as feet deformation of Chinese females and cranial deformation as practiced by some communities in Chile (Aufderheide & Rodriguez-Martin 1998). In the interpretation of trauma resulting from therapeutic cases, the marks of surgical intervention (see Figures 23.2 and 23.3) and/or fracture

treatment will be fundamental. A further importance of assessing the presence or absence of surgical devices is noted by Ubelaker (2003: 38): a strongly misaligned femur, with limited evidence of treatment, will most probably be an archaeological case and therefore of no forensic significance.

How to Assess the Mechanism of Trauma

When the mechanism causing the lesions is accounted for and trauma associated with specific pathological conditions and fatigue fractures are discarded, it is possible to define another way to classify trauma (Table 23.2). Usually, each of these types of trauma displays specific attributes that are well discussed in the chapter dealing with perimortem trauma (see Loe, Chapter 24 this volume). The difference is that when those injuries are not lethal, they will show some kind of osteogenic response along the fractures lines and borders (see Figures 23.2 and 23.3), which can mimic some of the signs that are used to classify fractures. As in the interpretation of perimortem trauma, radiographs are mandatory to improve the interpretation of the fracture. Furthermore, it may also be possible to find evidence of some pieces of metal from the instrument that caused the damage to the bone. Scanning-electron microscopy and post-mortem computed tomography (PMTC) (Pechníková et al. 2012) may also provide helpful details to the mechanism diagnostic. Determining the type of weapon responsible for the injuries is essential for the reconstruction of the traumatic event, for the police, and, in general, for the



Figure 23.2 Example of an antemortem trauma (accidental and therapeutic): a craniotomy detected during the autopsy of a fresh cadaver victim of a traffic accident, with clear signs of healing (note the smooth aspect of the edges) indicating that the individual survived. Observe on the right top the detail of a skull fracture consolidated, irradiating from the posterior corner of the craniotomy, quite different from long bones pattern of repair (photograph courtesy of the authors).



Figure 23.3 Human skull found on a beach in 2006, most probably that of a female Caucasoid individual aged older than 45 years (forensic anthropology case). It displays exuberant antemortem lesions on the right portion of the skull affecting frontal, parietal, and temporal bones of that side, derived from a craniotomy, with the typical trepan holes (photograph courtesy of the authors).

criminal investigation. This determination is one of the primary objectives of each forensic examination on human bodies or remains, wherever it may occur, both in pathology or anthropological sets.

Mechanisms of trauma have traditionally been seen as resulting from the application of blunt, sharp, and perforating forces (Pinheiro 2006). In addition to these three classical trauma mechanisms, heat (thermal) and blast force are now added (Christensen, Passalacqua, & Bartelink 2014). However, as there are many areas of overlap between each of the aforementioned categories, trauma classification should be used merely as a loose guideline rather than strict criteria that must be met (Kroman & Symes 2013). Therefore, the biomechanical aspects of trauma should be the major focus. In any of these cases the natural elasticity of the osseous tissue is exceeded as a consequence of the application of direct or indirect forces.

Depending on the severity and the position of the force to the bone, fractures can be categorized as stated in Table 23.2. Although this is the same classification as that used to describe perimortem fractures, it is obvious that in antemortem injuries, knowledge of the mechanism involved in producing them might be less important and even imperceptible. However, in cases of human rights violation, when one is interpreting whether injuries occurred immediately before death, knowledge of the mechanism becomes much more important, particularly if the case under study will be subject to a trial.

A further aspect that should never be forgotten whenever bone lesions of any type are involved is the absence of pathognomonic reactions. No matter how diverse the traumatic injuries might be, there are no pathognomonic traumatic reactions: “In other words, different

Table 23.2 Classical classification of trauma according to the mechanisms of production (adapted from Aufderheide & Rodriguez-Martin 1998; Black 2005).

Type of Fractures	How It Is Caused
Tension or traction	Violent muscle contraction
Compression	Force applied in the axial direction
Twisting, rotation, or torsion	Like shearing but in the same plane as the diaphysis
Bending	Force is applied perpendicular to the long axis of the bone
Shearing	Two opposite forces perpendicular

causes can produce the same lesions and different lesions might have been caused by the same weapon/mechanism. This is indeed a complexity factor when dealing with the decodification of antemortem traumatic injuries” (Rodriguez-Martin 2006: 201).

Traumatic Injuries Distribution Location and Pattern

Analysis of the distribution of traumatic injuries on a body may provide information about the nature of the event that caused the injury. Trauma interpretation is also aided by the separation of cranial and postcranial lesions, mainly because of the different nature of bones involved and the frequency of occurrence. Furthermore, because of the different pattern of reaction among the postcranial lesions, it is worthwhile to separate appendicular from axial bones, since, for instance, a long bone will display a distinct reaction from a rib. The type of bone (cancellous versus compact bone) also partially explains the different reaction pattern. Further, consideration of the different functions of bones (that is, to protect organs, support weight, and so forth) provides a more detailed interpretation of the consequences of trauma to that region. It becomes obvious and paramount that some bone lesions, once very severe, are more likely to be lethal. Even if the severe bone lesion results in an individual’s death, it is not the bone injury itself but the injury to the vital organ nearby the bone that causes the death.

Traumatic wounds of the head are the most common in forensic anthropology. However, since severe injury to the skull often results in death, it is not common to find huge associated antemortem lesions, unless there was a certain period of survival. Yet, as noted by Ortner (2003: 135), “the extent of injuries to the skull that an individual can survive is often remarkable.” It is therefore paramount that the forensic anthropologist thoroughly examines the cranium for evidence of antemortem injury. The skull is a particularly valuable tool in forensic anthropology, since it is a “closed bony box” with an increased possibility of having marks or signs imprinted on it, if compared with thorax and abdomen, both with less bone and plenty of soft tissues. Healed incised wounds, small blunt traumatic injuries, with the typical bone depression, surrounded or not by infectious signs, are commonly found. The callus osseous in the skull has a different appearance, being smaller and less developed than that displayed on long bones (see Figure 23.3).

Gunshot wounds, if not lethal, will be observed as holes, maybe smaller than the initial lesions, bordered with smooth margins, occasionally with a thin layer of new bone closing the orifice. The size of the hole and the potential for closure as a result of healing are directly related to the type and the caliber of the ammunition. The anthropologist should look for discrete and often almost imperceptible signs of consolidated fractures radiating from the entrance wound. The classic appearance of internal beveling on the entry hole and external beveling on the

exit wound will eventually be unapparent, depending on the time of the injury. Furthermore, it might be difficult to distinguish between the entrance and the exit wounds. To accomplish this objective, it is essential to open the vault with a saw in order to observe the inner aspect of the skull, a procedure often forgotten in anthropological settings (Pinheiro & Cunha 2006). Barbian and Sledzik (2008) provided a useful study on the gross appearance of the initial osseous response following cranial gunshot wounds.

Healing can also be observed on fractures of other skull bones such as the nasal bones (Figure 23.4) and of the zygomatic arch. Much less common, yet still possible to find, is the irregular external surface of the outer table of the skull bones as a response to scalping (Ortner 2003). We argue that this situation should always be verified throughout a careful macro and microscopic examination of the affected areas when one is dealing with a suspicion of human rights violation.

Injuries to the thorax, ribs, and vertebrae are of extreme importance, in particular for identification purposes as well as for child abuse reports (in the case of the ribs), because often, with the exception of the vertebral injuries, they are not lethal. Subsequently, injuries will start to heal, the evidence of which will remain until the victim dies, later, of another cause. If eventually that body is subjected to an anthropological examination, the callus osseous will survive to tell the story of this individual.

This was the situation of a case involving an elderly female whose body we identified (Figure 23.5). The contiguous and severe antemortem traumatic fractures affecting several ribs



Figure 23.4 Noticeable and misaligned antemortem trauma on the nasal bones of an adult individual (unsolved forensic anthropology case performed 20 years ago). Although these fractures might had been clearly noticeable by the relatives, the individual was never identified—perhaps because of the lack of medical files and the limitations of missing persons data at the time (photograph courtesy of the author).

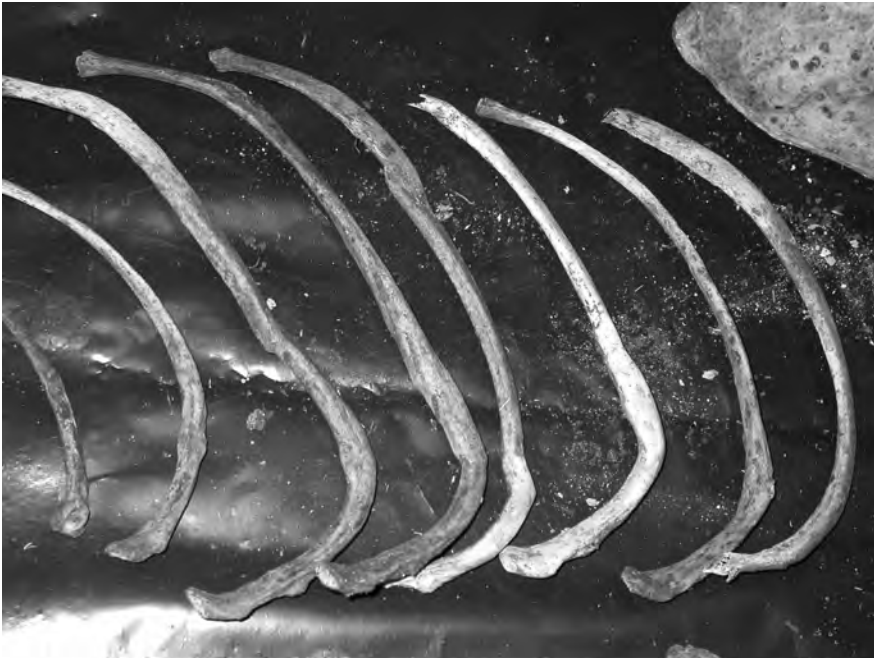


Figure 23.5 Contiguous and misaligned old fractures affecting several ribs of an old female that were a valid and extremely useful factor of individualization, later confirmed by her family (forensic anthropology case performed by the authors in 2005). The pattern of consecutive ribs fractured in two parts could correspond (when it determines a detached fragment of the rib cage) to the most dangerous surgical complication of rib fractures—the flail chest, potentially lethal. However, this was not the case. In the boxes, details of typical rib osseous callus (photograph courtesy of the author).

were later confirmed by her family, who stated that she suffered from a severe fall some years before death. These types of injuries have been helpful in the identification of old people, which are some of the most frequent cases involving a forensic anthropologist in Portugal and which can be seen as a consequence of the demographic profile alteration (Cunha & Pinheiro 2007).

Bone Reactions to Trauma

This section reviews the different reactions that bone can have when traumatized and the individual in question survives. Macroscopically, once a bone displays evidence of osteogenic reaction it can be described as antemortem trauma (SWGANTH 2011). According to the same guidelines (SWGANTH 2011), several reactions can be considered as signs of antemortem trauma: (1) evidence of healing or healed fractures; (2) development of a pseudarthrosis; (3) evidence of infection such as woven bone formation, and (4) surgically implanted devices.

To analyze perimortem trauma one must pay attention to the: (1) fracture type; (2) chronology of the trauma; (3) individuals' biological profile, and (4) importance of the injury to identification and/or cause and manner of death.

Normal Consolidation

In comparison with other tissues bone has a unique form of repair: a fracture is not repaired by the body replacing necrotic bone with fibrous tissue or a scar but by bone tissue itself (Salter 2000). Fracture healing is a complex event that involves the coordination of a variety of different processes (Schindeler et al. 2008). “Bone remodeling is a complex process where many physical phenomena take place and many scales are involved” (Nali et al. 2001). Repair used to be divided in two main processes, the primary and the secondary consolidation (Hoppenfeld & Vasantha 2000; Salter 2000). Now the trend is to consider more phases: six (by Vigorita 1999); four (Schindeler et al. 2008) and İşcan and Steyn (2013); or even three (Christensen, Passalacqua, & Bartelink 2014):

- 1st phase—initial inflammatory response: corresponds to the appearance of new bone in the fracture area;
- 2nd Phase—soft callus stage: corresponds to subperiosteal new bone formation. Normally it can occur 7–10 days after the injury in young children and 10–14 days in older ones (in İşcan & Steyn 2013);
- 3rd phase—hard callus phase: corresponds to when periosteal bone starts to change into lamellar bone. In X-rays the solid union is perceptible; and
- 4th phase—remodeling stage: when there is gradual restoration of the original bone shape and correction of the deformities (after 3 months).

One of the most complete sequences of bone repair, with the benefit of providing the correspondent chronologies of the events, is the one provided by Maat (2008). In practical terms, there is rarely such a clear delineation of events; on the contrary, there is a significant overlap between the different stages during fracture repair (Schindeler et al. 2008).

Callus usually forms in about two weeks. The process results from the osteoclastic reabsorption followed by the osteoblastic formation of new bone. There is no radiographic evidence of a bone callus when this form of consolidation occurs, because the repair is done directly through the compressed ends of the bone (Hoppenfeld & Vasantha 2000).

The secondary consolidation, the most common type, will show mineralization and replacement of the bone by a cartilaginous matrix that has correspondence in a radiological callus. The higher the mobility of the fracture, the larger the callus. This consolidation is favored by external fixation, casts, and intramedullary nails. The reparative phase will last several months; the haematoma will be invaded by fibroblasts and chondroblasts, which synthesize connective tissue and cartilage that constitute the matrix to the soft callus (Hoppenfeld & Vasantha 2000). The callus will then mineralize, resulting in a hard callus, which stabilizes the fracture. The remodeling phase happens over a much longer period of time (months to years) and consists of the replacement of the immature reticular bone by lamellar mature bone, owing to osteoblastic and osteoclastic activity.

The role of the periosteum is crucial in bone repair (Hoppenfeld & Vasantha 2000; Salter 2000). Its integrity, responsible for the vascularization and the degree of injury of the soft tissues surrounding the fracture, is essential for a rapid fracture repair; that is why a comminuted fracture takes longer to consolidate. The periosteum is thicker in the bone parts surrounded by muscles (for example, femoral diaphysis) than in subcutaneous bones (for instance, the antero-medial aspect of the tibia or the intra-articular portions of bone). The periosteum is also stronger, larger, and more osteogenic during childhood (Salter 2000). As a consequence, age is an important factor in bone response; children consolidate quicker than older people. For example,

rib fractures in children can consolidate in two weeks, a classic sign for the battered child syndrome (Saukko & Knight 2004).

Abnormal Consolidation and Secondary Reactions of Bone

Many factors can affect the healing process, such as injury severity, anatomical location, the quality of medical treatment, age, and nutritional status. The growth of callus depends on the mechanical condition of fracture fixation (elastic fixation and instability or rigid immobilization), the type of treatment (nonoperative, closed or open surgical procedure, intramedullary nailing, external fixation, plate, and so on) and the specific characteristics of the local vascularization (Merloz 2011). Thus, apart from a delay in consolidation (average of six months), two other main problems with anthropological consequences might arise when a fracture does not have a normal evolution: vicious consolidation (the repair is done at the right time but in a bad position) and the absence of union and the formation of a soft fibrous union of bones, called *pseudoarthrosis*, indicating lack of immobility and wrong or absent treatment (Rodríguez-Martin 2006). It is worthwhile recalling that the medical term *callus* means regenerated bone that fills the defect between the two bony fragments (Merloz 2011).

Pseudoarthrosis, so-called because a synovial-like cavity develops between the un-united fractured fragments (Vigorita 1999), occurs when the ends of the affected bone are surrounded by connective tissue and callus but do not consolidate. It is the most common complication when a fracture does not consolidate; misalignment can also occur. When the overlying muscles are affected and respond with the production of bone directly in the muscle tissue, accompanied by hematoma, *myositis ossificans traumatica* can result. Such a result involves the formation of irregular calcified bone masses, in most instances related with calcified crushed muscles (DiMaio & Francis 2001). Rhode, Goodhue, and Stephan (2012) published an interesting case of trauma-related remodeling, in which a clavicle developed into a pseudo-arthritis over a 12-month period before the individual's death.

Other reactions of abnormal bone are osteomyelitis in open fractures, posttraumatic osteoporosis, refracture, and avascular necrosis. The last reaction, also known as aseptic necrosis, would be better called osteonecrosis (Day et al. 2004) because this term is closer to the histopathological process observed and does not relate to any specific etiology. Osteonecrosis means the death of a segment of bone from a lack of circulation, not from disease. The condition is not avascular, since the vessels are present, although compromised in their function by mechanical disruptions (fractures), occlusion of arterial vessels, pressure on the arterial wall, and occlusion of the venous outflow. The most frequent osteonecrosis associated with trauma are femoral neck fractures; dislocation of femoral head; displaced fracture of scaphoid; displaced fracture of talar neck; and four-part fracture of the femoral head (Day et al. 2004).

Posttraumatic osteoarthritis and arthritis in the nearby bone joints should also be considered, particularly in relation to their effect on different postures or gait after a fracture. Since open fractures have a much greater risk of infection, when open intra-articular fractures occur they may result in septic arthritis. In extreme cases situations such as gangrene, pus-forming followed by septicemia, and/or sequestrum may also occur.

All these reactions are part of fracture complications and are of paramount importance clinically and well discussed in every orthopaedic textbook. Anthropologists should never forget that behind a bone reaction many, often vital, consequences for the individual might have happened (Pinheiro 2005). Depending on the bone fractured these may include haemorrhage, neurological injuries, vascular lesions, muscle sections, and visceral (thoracic or abdominal)

wounds. It is vital to consider the body as a whole and bear in mind that bone is, in many instances, the last body system to respond to an “aggression.”

Anthropological Analysis of Antemortem Trauma: Step by Step

In anthropological cases the basic factors of the biological profile are not enough for positive identification, obliging the expert to look for the so-called factors of individualization. Antemortem fractures are among the most valid features to enable individualization (Cattaneo et al. 2006; Cunha 2006; Cunha & Pinheiro 2013). However, the interpretation of these injuries is not always straightforward. Many interrogations can be addressed in any case of trauma analysis, where discrimination of ante-, peri-, and postmortem alterations has to be done, which is, indeed, the great challenge in every forensic anthropology examination. To attempt to determine whether the traumatic event occurred before death, it is necessary to address these questions:

- 1 Is the defect a postmortem artefact or a true alteration?
- 2 If accepted as a true alteration, did the defect occur ante- or perimortem?
- 3 If the trauma is antemortem, is the aetiology morphological or pathological?
- 4 Within the pathological alterations, is the aetiology traumatic?
- 5 When the aetiology is traumatic, is it possible to comment on when the fracture occurred—that is, a long time before death or immediately before?

1 Is the defect a postmortem artefact or a true alteration?

The first step to perform is to discard all the taphonomical alterations (see Nawrocki, Chapter 25 this volume) that can mimic and/or be confounded by true lesions. Animal bites, roots effects, and microfauna action are examples of taphonomical alterations that can lead to erroneous interpretations. They can both hide and mimic not only peri- and postmortem wounds but also antemortem traumatic injuries. Several examples can be found in literature (Cunha & Pinheiro 2007; İşcan & Steyn 2013; Christensen, Passalacqua, & Bartelink 2014).

When there is no evidence of osteogenic reaction, the pattern of injury is crucial—namely, the discrimination among green-bone response, determining a perimortem wound and a dry-bone one, characteristic of a postmortem injury. Despite the existence of some clues extensively discussed in the literature (for example, Sauer 1998), the determination remains difficult, often based on one’s experience, and it is sometimes virtually impossible to distinguish between perimortem and postmortem fractures (see Loe, Chapter 24, and Nawrocki, Chapter 25 this volume). Yet the possibility to detect hemorrhagic signs in dry bone is an important step forward to this discrimination (Cattaneo et al. 2010).

2 If accepted as a true alteration, did the defect occur ante- or perimortem?

Once postmortem alterations have been identified, one must then distinguish between peri- and antemortem trauma. Antemortem lesions will be recognized when a callus or any type of bone reaction, such as porotic appearance of the periosteum, new bone formation, smooth surfaces, and/or misalignment, can be identified. Signs of bone remodeling can be used to discriminate between peri- and antemortem trauma, in particular when the period of time elapsed since the traumatic injury was longer than two weeks. Bear in mind that these are macroscopic signs that arrive later than the microscopic ones.

3 *If the trauma is antemortem, is the aetiology morphological or pathological?*

When examining antemortem alterations one must take into consideration that some morphological alterations or anatomical variations can be confounded with lesions; in other words, morphological variants can occasionally mimic trauma. Some of the most well-known morphological alterations to mimic antemortem trauma are os acromiale, the sternal perforation, no vastus in the patella, and the septal aperture on the lower epiphysis of the humerus. Nonfusion of the end of the acromial process might be confused with an ancient cutting wound, whereas the anatomical variants on the lower epiphysis of the humerus and on the corpus of the sternum (Figure 23.6) can lead to misdiagnosis of perforating wounds—namely, when they have rounded and smooth edges, alterations could be erroneously mistaken for a thoracic firearm injury by inexperienced practitioners. Further complications can derive from the existence of two 1st or 12th ribs or double/bifid ribs (Moore & Dalley 2004; Kimmerle & Baraybar 2008), which can cause problems in analyzing the rib cage, a known difficult task in anthropological examinations. Occasionally these variations are associated with vertebral malformation (Moore & Dalley 2004), which will increase the complexity of the interpretation of the supposed injuries. All these arguments justify the reason to have a solid background in anatomical variation. Ruling out normal skeletal variation is not always an easy task.

4 *Within the pathological alterations, is the aetiology traumatic?*

It is then necessary to determine whether the lesion has a traumatic aetiology and therefore to rule out skeletal pathology as a cause. In most cases this differential diagnosis is not difficult to

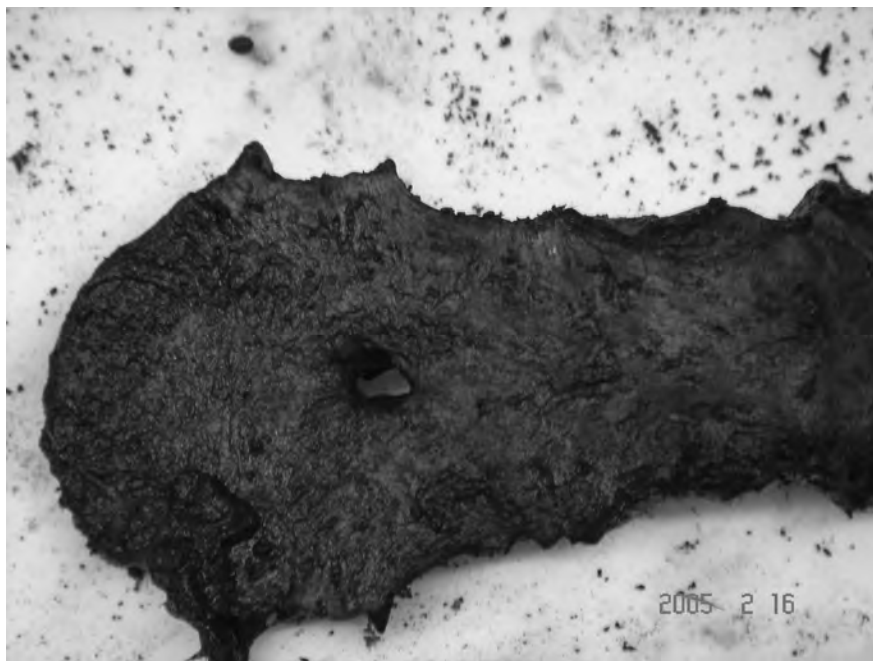


Figure 23.6 A morphological variation—perforation of the adult human sternum (photograph courtesy of the author)

achieve; in others it is quite complex—the aspect of a vicious callus can be confounded with a tumour or other type of bone illness. Congenital defects such as the ones affecting vertebrae can also enhance these difficulties; even spina bifida can be misdiagnosed as a traumatic injury (Figure 23.7). This condition involves the failure of the normal fusion of the midline in the posterior neural arches and is frequently found affecting the sacrum or the lumbosacral region of the spine. However, in the case illustrated here (an unsolved forensic case dating back to the 1980s) (Figure 23.7), the adult individual shows three thoracic vertebrae with incomplete fusion of the posterior arches. The margins are so smooth that confusion with a remodeled trauma might be possible. Yet an injury on that location most probably might have produced serious effects on locomotion/gait. When information about the circumstances of death is not available to confirm a possible accident or traumatic event, or when the medical files are insufficient, the task of determining traumatic aetiology will be even harder. Good guidelines for the best practice to the differential diagnosis of skeletal trauma are provided by Kimmerle and Baraybar (2008).

In the production of the final case report, the practitioner should separate observation from inference, to keep description distinct from speculation and to state clearly whether bone lesions



Figure 23.7 Failure of the fusion of the posterior neural arch on a thoracic vertebra of an adult male individual (forensic anthropology case dating back to the 1980s). The smooth aspect of the margins might be confounded with the ones of antemortem trauma (photograph courtesy of the author).

are detected. In the case of absence the inference should never be that the victim did not suffer from any aggression and/or disease. Many violent episodes do not leave any trace on the skeleton (Cunha 2006). The terminology used to describe the fractures is of paramount importance, as well noted by Komar and Buikstra (2007).

5 When the aetiology is traumatic, is it possible to comment on when the fracture occurred—that is, a long time before death or immediately before?

The final stage of assessing antemortem trauma is attempting to determine the chronology of injuries. This determination involves the identification of antemortem injuries that occurred so close to death that the healing process was not yet recorded, or are poorly recorded on the skeleton—the so-called perimortem trauma (Sauer 1998: 323; see Loe, Chapter 24 this volume). Obviously, these injuries are much more difficult to detect than those with clear signs of remodeling/response. The very early stages of healing, such as the ones of porous nature detected by means of microscopy, can be the key clues. The histopathological study of bone fractures—besides giving good insights to verify whether the fracture was vital or not—can also provide information on its time of production (Cattaneo et al. 2010). This benefit will be particularly important in some criminal circumstances where they might be the only evidence of torture immediately before death. It is worthwhile emphasizing the difficulty in distinguishing between perimortem and antemortem trauma occurring immediately (some hours or a few days) before death. Yet it is important to consider whether the traumatic injuries occurred immediately after death. Although the dried-bone response to trauma is known to be quite distinctive from that of fresh-bone fractures (Sauer 1998), since the different patterns are dependent on the quantity and the quality of both the moisture and organic part of the bone, the length of time required for moisture and organic loss is obviously paramount. In turn, because this time depends on the environment where decomposition takes place (for example, heat accelerates collagen deterioration), the time period becomes a multifactorial phenomenon. Fitzgerald's report (1975: 325, cited by Sauer 1998), well documents this statement: at room temperature, bone loses measurable elasticity, which lasts about five hours after death. Furthermore, Maples (1986 in Sauer 1998) suggests that the typical attributes of green bone response may persist for several weeks after death, which has direct implications on the concepts of ante-, peri-, and postmortem. In mass graves where several corpses are interred together the micro-taphonomical environment leads to a longer duration of the elastic properties of bone.

As previously stated, vitality does not have exactly the same meaning for forensic pathologists and anthropologists owing to the conceptual difference regarding this concept (Cattaneo et al. 2010) (see Figure 23. 1). For the former, and consequently for a trial, it is absolutely essential to determine whether a lesion was vital (produced during life) or postmortem. For anthropologists it is relative (as described earlier), given a green-bone response, which can last for hours, days, or more after death. This decision leads to obvious and important legal consequences. In a case of a serial killer's victim found in a river and autopsied by the authors, an undoubtedly perimortem fracture of the 4th rib was diagnosed. However, we could not confirm to the police whether it had resulted from aggression to the victim while alive or had occurred after death, during the disposal of the body into the river.

Interpreting Evidence of Bone Remodeling and Its Relation to Chronology

The amount and type of trauma displayed in the skeleton are dependent on a series of factors that are well systematized by Black (2005), which we have also tried to systematize referring to

their consequences (Table 23.3) that might be particularly helpful in estimating the chronology of the event.

It is well known that evidence for remodeling associated with a skeletal lesion indicates that the injury occurred antemortem however, the question remains as to how much time before. Sauer (1998) says that when macroscopic remodeling occurs, the injury happened at least one week before. But, as outlined by Black (2005), antemortem trauma, as is any other pathological condition, is not a static event. It is therefore quite complex to infer, on the basis of the alterations on the dry bone, whether the lesions were in their early stages, active or non-active, or healed or unhealed, particularly in a forensic context. This situation means that the same pathology can express itself in the skeleton in various ways.

The osteogenic response depends on several factors, such as the type of fracture (severity, location, type of bone, apposition of the ends, stability) and the age, sex, and nutritional and health status of the individual (Hoppenfeld & Vasantha 2000; Salter 2000; Ortner 2003; Galloway, Zephro, & Wedel 2014). Obviously, there are too many variables to permit any kind of reliable prediction. Ortner (2003) cites the general guidelines given by Paton: "cortical bone in adults heals in about three months, cancellous bone takes about six weeks, and children repair fracture about twice as quickly as adults" (1992 in Ortner 2003: 128). Thus, a general rule is that the length of time needed to heal increases with age. Some key features/signs can be very helpful; the formation of layers of woven bone is a sign of rapid bone formation.

Although empiric data on times of reaction are difficult to acquire, some research in this field has been undertaken. Using skeletons with traumatic injuries that showed evidence of having been autopsied (the autopsy reports were found at the Archives of the National Institute of Legal Medicine in Portugal), from the Lisbon Identified Skeletal Collection, Macedo (2006) undertook research to try to confront the forensic anthropological expertise performed today with the data displayed at the autopsy report at the time of death, about 50 years ago. Because information was available for some individuals indicating whether they stayed at the hospital before death, Macedo had a unique opportunity to document reaction times/chronology for bone remodeling and traumatic events. As expected, physical condition at the time of death, as well as age of death, influenced the bone response. In the majority of the cases the anthropological findings about traumatic injuries concurred with the cause of death stated on the autopsy reports.

The first signs of reactions are visible only microscopically, the inflammatory cells by 48 hours and the haematoma even earlier (<12h) (Vigorita 1999). The initial bone reaction is

Table 23.3 Factors affecting the amount and type of trauma displayed in the skeleton and its general relation with chronology

<i>Factors</i>	<i>Eventual Meaning/Effect</i>
Nature and severity of trauma	The more severe the lesion is, the more evident it might be
Time since trauma	The larger the time interval, the higher the chances of resorption of fractures lines and the more evident callus formation will appear*
Amount, degree, and type of healing	The less healing, the lower the post-mortem interval**
Existence/inexistence of infection	The greater the infection, the more exuberant the lesion might be*
The presence/absence of signs of treatment	Absence of treatment: not a forensic case?

*If no treatment had occurred

**Until the end of consolidation, after which the callus will stabilize

known to start, more consistently, after one week with osteoclastic reabsorbing of necrotic bone tissue, at a structural level (Hoppenfeld & Vasantha 2000; Rodriguez-Martin 2006). New bone formation is usually said to begin by the same first week and has been described as happening in rabbits by 24 hours and in osteoporotic human bones by 48 hours (Vigorita 1999). However, the skill is to recognize the physical evidence of this reaction in anthropological sets—namely, when bones are completely dry. In those cases the margins of the lesions where one expects to verify the first signs of healing show a smooth and rounded reaction observable under a dissecting microscope.

Microscopically, the first signs of osteogenic response can be identified. At about the same time as the beginning of the aforementioned osteoclastic reabsorbing (one to two weeks after the traumatic event occurred), the first radiological signs will appear (Salter 2000). Sometimes the formation of new bone is the confirmation of a fracture only suspected on the initial X-ray. In cases when X-rays depict a white opacity for dense tissues (bone, cartilage, haematoma), some type of bone reaction might already be seen morphologically by the naked eye, depending logically on some factors discussed below. Subsequently, we can establish that the first signs of bone repair might be seen by the first to second weeks.

As previously stated, the time of repair depends on the specific bone: for a radial distal fracture, six–eight weeks are usually enough, although for a diaphyseal tibia fracture, three months will be necessary (Table 23.4), because there is minimal soft-tissue support for this bone. Metaphyseal fractures generate small callus, because there is less periosteum and good cooption of the bone tops. The same happens with intra-articular fractures—a small callus—caused by the small amount of periosteum and the presence of synovial fluid. The type of treatment will also influence the time of consolidation, depending on the proximity or separation they will proportionate.

A new perspective to age bone calluses is given by the Capella and colleagues (2013), who propose the application of cone-beam CT. They proved that this technique is a user-friendly and skillful one that gives good results to assess the age of a bone callus.

For orthopaedic specialists a fracture is consolidated when they no longer observe on X-ray the fracture line, the bone callus is present, and the patient has no pain, good mobility, and the capacity to support weight. For anthropologists these things are not helpful. Nonetheless, some orthopaedic specialists' concepts about consolidation and time of repair may be useful to the forensic anthropologist.

Taking all these factors into consideration, one can generalize that a normal fracture in a healthy, medium-sized individual with a normal development and with no complications will consolidate between four weeks and three months (Hoppenfeld & Vasantha 2000; Salter 2000). Taking this as rule of thumb, we felt the need during our practice in forensic anthropology for a guide to assist in the normal time previewed for specific consolidation of a bone. In an attempt to fill this gap we have provided a list of the normal time of consolidation for the majority of the human skeleton (see Table 23.4). This list should be used merely as a tool in helping to determine the chronology of a certain injury and never considered as a strict law of time of bone repair.

Need for Documentation on Trauma

Depending on the type and the severity of the lesion, trauma can significantly affect the individual's lifestyle. Specific peculiarities such as gait, handedness, mobility/immobility, and/or particular posture of the head are easily remembered by the victim's relatives and friends, becoming, therefore, key clues to identification. A misaligned fracture of the femur will most probably result in an abnormal gait that will be a fundamental osteobiographical sign of identification.

Table 23.4 Normal periods for postcranial adult bones consolidation (weeks) (Hoppenfeld & Vasantha 2000)

Clavicle 6–12

Upper limb

Humerus: proximal end 6–8

Diaphysis and distal end 8–12

Olecranon 10–12

Radius head 6–8

Forearm 8–12

Wrist (Colles) 6–8

Scaphoid 4–20

Metacarpals 4–6

Phalanges 3–6*

Lower limb

Femur: neck, subtrochanter, supracondylar, diaphysis 12–16

Inter-trochanter 12–15

Patella 8–12

Tibia: plate, diaphysis 10–12

Horizontal base 6–8

Ankle extra-articular 6–10

Intra-articular 8–12

Talus 6–10

Calcaneus 8–12

Middle foot 6–10**

Anterior foot (Metatarsal and toes) 4–8**

Vertebral column

Cervical column 6–12

C1 8–16

C2 8–12

Dens 12–16

Thoraco-lumbar column 8–16

*Clinical consolidation; radiological consolidation will take 10–12 weeks

**Depending on bones

The context of the detected traumatic injuries is also important. Whether the lesions are accompanied by osteoarthritis lesions, enthesopathies (reactive bone on sites for bone tendons, ligaments, and articular capsule attachments [Ortner 2003: 561]), or other reactions is crucial to the final interpretation.

In the majority of cases antemortem traumatic bone injuries are useful only for identification when antemortem records are available for comparison. The quality of these records is thus fundamental. The need for documentation of injuries is well discussed by Payne-James (2005). The author calls attention to the limitations of the documentation of injuries provided by medical practitioners: “In many cases documentation is appropriate for the therapeutic management of the injured person, but is rarely of the quality required subsequently to assist in issues such as causation or timing of an injury” (Payne-James 2005: 80). Furthermore, he emphasizes the importance for all forensic practitioners to be aware of the definitions of terms such as *injury*, *assault*, and *wound* in the jurisdiction in which they work, since they might have specific

applications. The lack of good and precise descriptions of injuries and incompleteness of medical files constitutes a common problem in the medico-legal activity wherever it is practiced.

An objective description of the lesions should permit another expert to do his or her own diagnostic assessment; in other words, it is essential that the description of the lesions is separate from the interpretation of the lesions in order to facilitate, where requested, a second opinion. Moreover, if a complete medical file is available which can be compared to the data recorded on the skeleton, the chances of achieving a positive identification will be significantly increased. Such was the situation in a case of an elderly woman whose good medical records permitted the confirmation of the venous exuberant bone pathology of the lower leg bones, found at the autopsy by Pinheiro and associates (2004), and subsequently her positive identification. Some factors that may be relevant for the necessary reconciliation between ante- and postmortem data are given by Payne-James (2005): time of injury or injuries; the existence or absence of injury treatment; whether there was preexisting illness; whether the individual practiced regular physical activity; occupation; regular medication; and handedness. The availability of these data is potentially extremely useful to forensic investigations.

Value of Antemortem Trauma for Forensic Anthropology

The value of antemortem trauma for forensic anthropology is mainly identification, the diagnosis of battered-child syndrome, a means to document human rights violation, and a possible contribution to the determination of the cause of death (Sauer & Simson 1984).

Identification

As previously mentioned, when identification is the main concern, healed traumatic injuries are among the most helpful factors of individualization (Maples 1984; Komar 2003; Steyn & İşcan 2000; Cattaneo et al. 2006; Cunha 2006; Cunha & Cattaneo 2006; Cunha & Pinheiro 2007). Furthermore, the way injuries were treated is very valuable to identification, in particular when marks of surgical interventions are detected. Various types of prostheses and other devices, such as implants, can be found during the postmortem. Such devices can be traced back to their manufacturer and are often issued with a unique serial or production lot number (Bennett & Benedix 1999; Simpson et al. 2007). For example, a case examined in 2006 by one of the authors involved an adult skull that exhibited exuberant signs of a therapeutic craniotomy (see Figure 23.3). The individual survived for many months after operation, as indicated by the well-rounded edges of the holes. In this case the type of suture allowed the supposition that the craniotomy was performed some decades ago. It is likely the skull was stolen from a cemetery and thrown out on the beach (remaining soil in the skull may have been able to prove this). Therefore, most probably it was not truly a forensic case (Rogers 2005). Note that in Portugal the time limit for forensic significance is 15 years.

The two examples of craniotomies provided in Figures 23.2 and 23.3 are, in a way, the opposite of each other. In the forensic anthropology case (see Figure 23.3), where only the skull was present and in the absence of any medical files and/or further data, it was the type of craniotomy displayed—namely, the type of suture—that led to the supposition that we were dealing with a particularly ancient case. In the other case (see Figure 23.2), the autopsy provided the cause of death (traumatic injuries of the chest and pneumothorax) and excluded the cranial lesion as the cause of death. Yet the poor medical documentation in this case—namely, the lack of medical data on the surgery—prevented any further conclusions. Furthermore, if this skull had been found much later, completely dry and isolated as the other one, the data to infer on this

basis would have been limited. However, some weeks after the autopsy, the husband confirmed that the deceased was involved in a serious traffic accident with a motorcycle, whose handlebar had penetrated into the skull when the victim was 4 years old.

Child Maltreatment

The pattern of bony injuries in child maltreatment fatalities, with an emphasis on the prevalence of antemortem fractures and the presence of associated perimortem fractures, is the subject of Ross and collaborators (2009) in a paper that highlights the usefulness of antemortem trauma to investigate child maltreatment cases. They state that, after soft tissues, fractures are the second most common presentation of physical abuse—of the ribs, followed by long bones metaphyses, the most commonly affected. Yet, Kemp and associates (2008) recall that no fracture, on its own, can distinguish an abusive from a non-abusive cause. Therefore, the site, the type, the developmental stage of the fracture, and the child can help to determine the likelihood of abuse (Kemp et al. 2008). Actually, and as pointed by Steyn (2011), not many case reports of suspected child abuse are assessed only on the basis of skeletal remains; clear-cut evidence is very difficult to obtain from juvenile remains.

In a child younger than 1 year—when rib fractures are not explained by major trauma—skull fractures result from short falls or metaphyseal long-bone fractures, and femoral fractures are observed—regardless of the cause of death ascertained one must suspect child abuse (Vigorita 1999; Saukko & Knight 2006; Love, Derrick, & Wiersema 2011). This diagnosis is also suspected or reinforced when other fractures of different chronologies are found. Antemortem trauma can thus play an extraordinary role in the detection of a typical forensic syndrome not only in children but also in the elderly.

Skeletal Evidence of Torture

The forensic analysis of skeletal remains of illegal immigrants or individuals who die under arrest is a relatively new area of intervention for forensic anthropologists (for example, Rodríguez-Martin 2006; Kimmerle & Baraybar 2008).

Antemortem traumatic injuries can be used as a means to document the violation of human rights. Rodríguez-Martin (2006) argues that the forensic anthropologist's skills in palaeopathology—specifically, the interpretation of antemortem traumatic injuries—can significantly contribute to the resolution of many cases of human rights violation. Therefore, antemortem trauma can be considered a very powerful tool in the investigation of violence. For this reason it is vital to have a detailed knowledge of the types of bone reaction and the mechanism of healing in order to document what happened. Rodríguez-Martin (2006) gives a detailed description of bone response to trauma, accompanied by the lesions related to the several methods of punishment or torture. He highlights the need to examine bones of the hands and feet for evidence of fractures that may suggest torture methods such as *falaka* or *falanga* (repeated beats on the sole or the palm). Báez-Molgado and collaborators (2013) present a case that gives insights into the relevance of detailed trauma assessment of skeletal remains in cases where neglect and human rights violations are suspected.

The identification of slightly healed defense fractures (for instance, fracture on the forearm bones, or Parry fracture) will be a chief element to the reconstruction of the events surrounding the dead, when one is dealing not only with human rights violations but also in cases of attempted and/or true homicides. In fresh bodies, however, parallel cuts on wrists are almost always synonymous with attempted suicide—but it is very improbable that these cuts,

classified usually as superficial, may go as deep as the bone. Thus, injuries with the same location might have, according to the type and depth, different meanings in forensic anthropology and pathology.

The detection of an amputation in an individual who subsequently survives also constitutes a key element regarding whether criminal consequences are involved. As pointed out by Rodríguez-Martin (2006), intentional amputation is a well-known method of torture, although the difficulty is to discriminate between intentional and accidental amputations. Affected typical areas are the upper-limb bones. The osteogenic response (bone-tissue formation) indicates whether the individual survived the traumatic event. The criteria to follow for a chronological diagnosis of amputation are given by Aufderheide and Rodríguez-Martin (1998). Several illustrative cases of skeletal trauma as a result of torture are provided by Kimmerle and Baraybar (2008).

When Antemortem Trauma Indirectly Contributes to Cause of Death

Finally, antemortem trauma has the potential to contribute to the knowledge of events before death. As previously discussed, if the bone displays signs of remodelling, the injuries underneath it did not cause the death. However, the complications derived from the traumatic injuries can cause the subsequent death. Thus correct interpretation of the lesions displayed within a skeleton, not only traumatic but also others, such as infectious ones, can provide clues to the understanding of the cause of death (Pinheiro 2006). For example, an open fracture of the femur may not result in immediate death but may lead to later serious complications—namely, a severe infection that ultimately results in death. Nonetheless, as stated before, this type of analysis must always be cautious, totally avoiding any type of over-interpretation.

Conclusion

The analysis of antemortem trauma is an important part of the forensic anthropologist's overall assessment. Signs of physiological response, healed wounds, callus formation, smooth edges, and thickly rounded surfaces are some of the classical macroscopic features to verify that the injury was antemortem. Yet the early signs of response can be detected only microscopically.

Trauma that occurred antemortem may be useful for identification purposes. In addition, antemortem trauma may also be useful in diagnosing battered-child syndrome, documenting human rights violation, and contributing to the determination of the cause of death (Sauer & Simson 1984).

The examples of antemortem trauma discussed in this chapter illustrate the differences between having expertise in dry bone compared to fresh bone. Differences in expertise promote the need for effective cooperation between the forensic anthropologist and the forensic pathologist (Cunha & Cattaneo 2006; Pinheiro & Cunha 2006; Cunha & Pinheiro 2007, 2013). This chapter, written by a forensic anthropologist and a forensic pathologist who have worked together for many years, provides a clear example of the value of a multidisciplinary approach. For a complete interpretation of the lesions displayed on dry bone, one should acquire experience with fresh bone and keep in mind the several phases through which the bone will go, as well as the limitations and dangers of deriving assumptions on cause of death on the basis of dry bone. This is indeed an area that requires more research.

Reading pathology from bare bones has its limitations that must be taken into account, especially when they involve antemortem trauma. Even when a bony injury is identified, one cannot speculate about the consequences for the victim, that is, cause of death (Pinheiro 2005). Nonetheless, although a skeleton is always less informative than a fresh cadaver, in most instances,

the skeleton is the ultimate body system to respond to an aggression. Once the bones are affected, the signs of the traumatic injuries remain on the bones long after death, significantly contributing to the osteobiographies of their owners. These are valuable elements for forensic anthropology in the various situations involved, from a routine case to mass disasters and crimes against humanity.

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Perimortem Trauma

Louise Loe

Perimortem trauma refers to any injury or wound to the body, occurring around the time of death, that may affect the bone and/or soft tissues (Roberts 1991: 226). In a forensic pathology examination the identification of any such lesions may indicate the cause and manner of death, suggest how the body was treated during the perimortem interval, and provide insight into its disposal (Wedel & Galloway 2014). Such lesions can also influence the decomposition of a body and so are factors in estimating the postmortem interval (for example, Smith 2014). Perimortem skeletal trauma may be identified as fractures or breaks in the continuity of a bone that may pierce, divide, crush, or penetrate the bone. Careful study of these changes may assist interpretations made by the forensic pathologist and/or anthropologist; it can serve to corroborate soft-tissue evidence that may be used in court and, at the same time, may highlight discrepancies in a case that may not be indicated by soft-tissue change alone (Galloway 1999).

This chapter synthesises current theoretical and practical issues associated with perimortem trauma analysis of skeletal remains recovered from forensic contexts. Initially, I review the biomechanics of bone; then I evaluate the criteria that may be employed to distinguish perimortem from antemortem and postmortem trauma. Projectile, sharp, and blunt traumas are reviewed, with particular emphasis on fracture patterns and the information that may be potentially gained from fracture pattern analysis. I discuss the circumstances of fracture patterns, including those factors that may mimic perimortem trauma (see Nawrocki, Chapter 25 this volume). This discussion is followed by consideration of some of the limitations of, and relevant methodologies for, perimortem trauma analysis in a forensic setting.

Principles of Perimortem Trauma

To interpret perimortem trauma one must have an understanding of the biomechanics of bone fracture, including the extrinsic and intrinsic variables that influence fracture patterns.

Biomechanics of Bone Fracture

Research into the biomechanics of bone fracture dates back to the 19th century and has involved experiments using autopsy specimens, living animals, and human and nonhuman skeletal remains, primarily to explore fracture dynamics in the skull (see Passalacqua & Fenton 2012 for a more detailed review). An important study is that of Gurdjian, Webster, and Lissner (1950), who applied a strain-sensitive lacquer to skulls (the “stresscoat” technique) to explore

fracture mechanisms and who introduced several key principles that are still employed today. There are numerous publications on the biomechanics of bone fracture (for instance, Frankel & Nordin 1980; Mascie-Taylor & Bogin 1995; Berryman, Lanfear, & Shirley 2012; Symes et al. 2012; Schmitt et al. 2014). Publications written from an anthropological rather than engineering perspective are most relevant to forensic anthropology and pathology because they concern responses in living bodies, rather than to inert bone sections.

Bone is anisotropic; that is, it has the ability to respond differently, depending on the direction of the loading force. It is governed by the interaction of collagen fibres that afford it tensile strength and hydroxyapatite crystals that afford it compressive strength (Frankel & Nordin 1980). A fracture will occur in bone only if sufficient force allows it to travel through the interface of collagen fibres, from crystal to crystal (Berryman & Haun 1996).

In response to extreme load, bone responds in an elastic then plastic manner before failing (Mascie-Taylor & Bogin 1995). This response means that bone can recover its shape and dimensions after loading (elastic phase). However, when elastic qualities reach their maximum capacity, the outer fibres begin to yield, and increased loading beyond this point results in deformation (plastic phase), even after the loading has ceased (Frankel & Nordin 1980). Bone fracture occurs when the ultimate strength of a particular region of bone is exceeded (Hipp & Hayes 2003). At the microscopic level the trabeculae are the first structures to break, followed by the interface between compact bone and trabecular bone and ending with fracture of the outer compact bone (Zhi-Jin & Jia-Zhen 1991) (Figure 24.1).

Fractures may result at the point of impact (direct force), or they may occur at a different site to the point of impact (indirect force). They are traditionally described in response to four main types of force: tension, compression, bending, and torsion. These forces typically result in transverse, oblique, butterfly, and spiral fracture patterns, respectively (Crawford 1983). These patterns are not mutually exclusive, and the majority of fractures seen in a clinical setting are a complex combination of several loading forces and fracture patterns (Hipp & Hayes 2003).

Fracture Propagation, Extent, and Morphology

Fracture propagation, extent, and morphology are determined by a complex interaction of extrinsic and intrinsic variables (Harkess, Ramsey, & Ahmadi 1984). Extrinsic variables relate to the physics of the applied force, such as its magnitude and direction (Tomezak & Buikstra 1999). Intrinsic variables relate to the properties of the bone, including its morphology, elasticity, and structural buttressing (Berryman & Haun 1996). For example, “Le Fort” fractures are seen in the facial skeleton in relation to the structural buttressing of the orbits, maxilla, and nasal bone (Rogers 1992; Berryman & Symes 1995a) (Figure 24.2).

Another example concerns the decrease in rib restraint and the changes in disc size and shape at the thoracolumbar junction, which mean that the spine is more susceptible to fracture (Tomezak & Buikstra 1999). Furthermore, bones with a large surface area resist forces more successfully than do those that have a small surface area, because there is greater area in which to dissipate the force.

Adult bones fail sooner than those of children, because the former are brittle and the latter, elastic (Currey & Butler 1975). Brown and associates (2005) examined blunt trauma and demonstrated that skeletal involvement also varies for obese and non-obese individuals, mortality being a more likely outcome among the former. Bones may also be predisposed to fracture because of pathology that may require surprisingly little force (Fenton, deJong, & Haut 2003).

Finally, fractures propagate along the lines of least resistance. Therefore, they usually extend toward foramina, regions of weakness where blood vessels merge (Zhi-Jin & Jia-Zhen 1991).

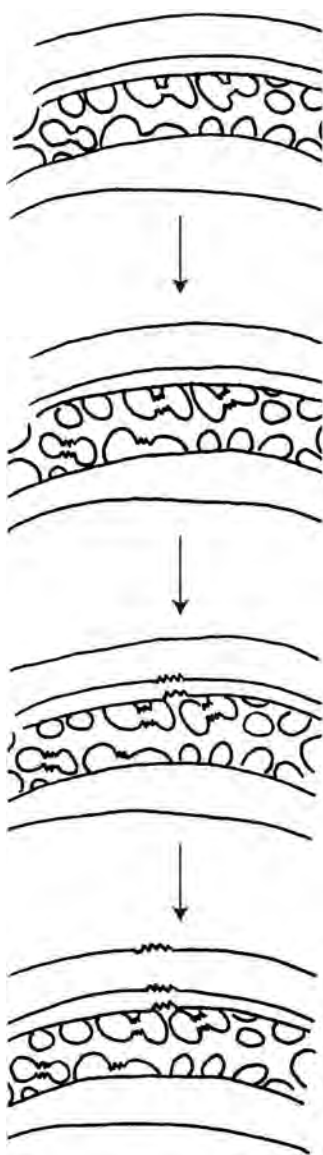


Figure 24.1 Diagram representing the order of microfracture of the skull as described by Zhi-jin and Jia-Zhen (1991: 8)

The concentration of foramina on the base of the cranium means that this is a common site for fractures to occur (Gurdjian, Webster, & Lissner 1950). Often, but not always, they are interrupted by the suture lines and the epiphyses (Kanz & Grossschmidt 2005: 210; Jordana, Colat-Parros, & Benezech 2013).

Cranial Fracture Patterns

Several texts describe the mechanisms of fracture in the cranial vault (Gurdjian, Webster, & Lissner 1950; Smith, Berryman, & Lahren 1987; Berryman & Haun 1996; Hart 2005; Symes et al. 2012). According to Gurdjian (1975), fractures initiate away from the point of impact and

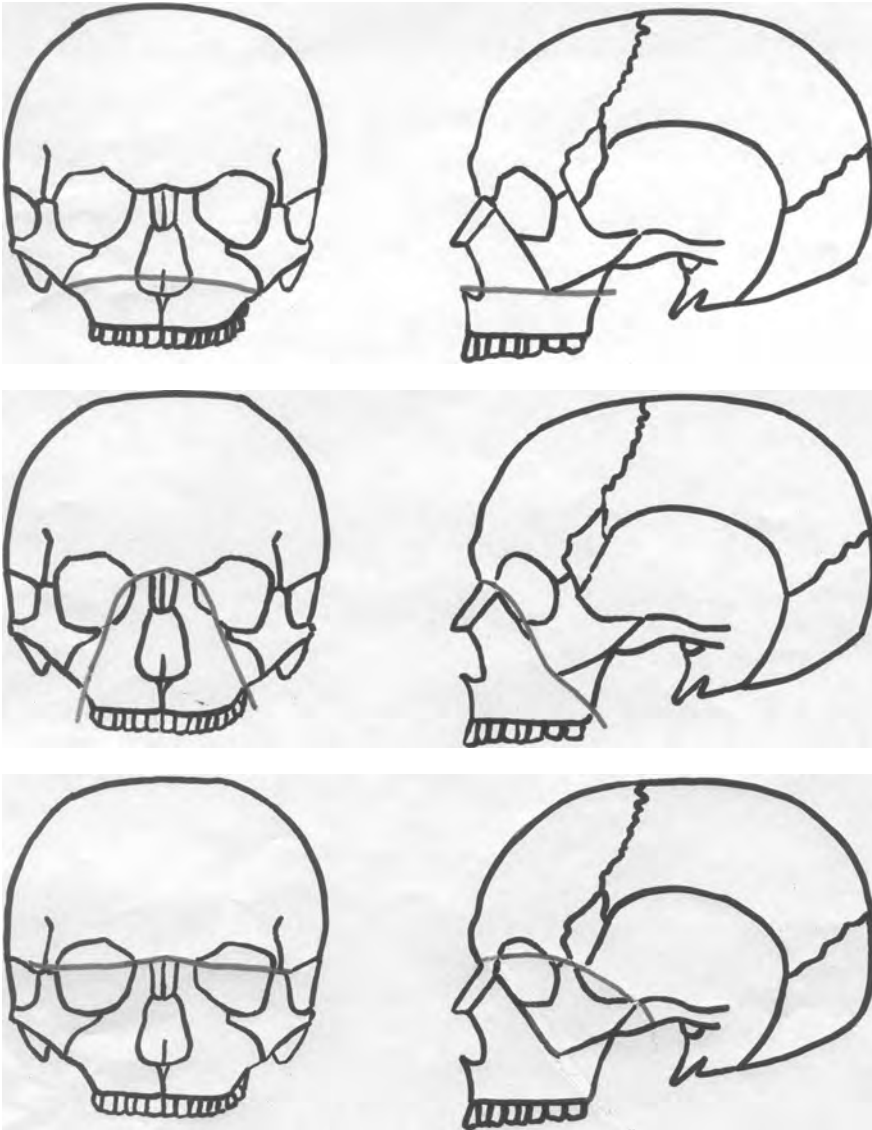


Figure 24.2 Le Fort fractures of the facial skeleton (modified from Byers [2005: 325] and Galloway [1999: 74])

travel back toward it, but more recent experiments show that fractures initiate at the point of impact and propagate away from it (Kroman, Kress, & Porta 2011). Bone is weaker under tension and shear than it is under compression and therefore break on the tension side (the endocranium) first (Berryman, Lanfear, & Shirley 2012; Symes et al. 2012). If the energy of the insult is of sufficient force, secondary and tertiary fractures may develop in the area surrounding the impact site. Secondary fractures (or radiating fractures or fissures) are linear; tertiary fractures are curvilinear and form perpendicular to these. Secondary and tertiary fractures vary depending on the direction of the force and the type of weapon. For example, wide, split fissures are

associated with an oblique force and multiple fissures are associated with broad blunt weapons (Gurdjian, Webster, & Lissner 1950; Berryman & Haun 1996). Concentric fractures may form in the absence of linear fractures, and, depending on the energy of the insult, more than one may be present in concentric bands (Hart 2005).

Pattern and shape of injury relates to the velocity of the blow; the higher the velocity the more distinct the pattern and the less likely there will be associated deformations (Gurdjian, Webster, & Lissner 1950). For example, large depressed lesions with satellite patterns are caused by slow loading blunt instruments, whereas neat holes are determined by high-velocity bullets. However, discrete patterns are not always associated with high-velocity weapons; shattering will occur when the velocity of a missile is considerable.

The number of linear fractures is determined by the amount of energy of the force, with fewer being associated with less force (*ibid.*). Further, linear fractures occur in locations that are weakest in relation to the initial impact area. Thus, an impact in a certain location will have a predictive influence over the location of the linear fracture. For example, a blow to the posterior parietal region has three related areas that are most likely to come under stress, these being (in order of susceptibility) the temporal bone, the superior parietal region, and the parietal mastoid region. Linear fractures can involve all three if the energy of the force is severe, or just the most susceptible if it is adequate. Further patterns are described by Lovell (1997: 155) and are useful for exploring the point of impact and mechanism of the injury.

The relationship between radiating fractures may be examined to determine the sequence of injuries where more than one occurs. This approach is based on the principle that secondary fractures terminate in primary ones (“Pupples law of sequence”; see Symes et al. 2012: 362) and on observations of fracture patterns in broken glass (Madea & Staak 1988).

Also associated with fracture production is bevelling, or cratering, which refers to the removal of a cone of bone. If the cone is removed as a result of a right-angled strike, the bevel has a symmetrical appearance (Kanz & Grossschmidt 2005). It arises as the fracture propagates and encounters shear forces causing angulation in its direction and it may be present ecto- or endocranially (Berryman & Haun 1996).

General Characteristics of Perimortem Trauma

The identification of perimortem trauma rests on the principle that bone that has an intact organic matrix (“green bone”) will respond differently to bone that has partial organic matrix (“dry bone”). Criteria relating to perimortem fracture identification primarily focus on the cranium and the long bones.

Typical characteristics of green-bone fractures include fracture margins that are sharp and smooth, radiating fracture lines and fracture lines that are straight; irregular fracture margins (or splintering); fragments that tend to stay attached to one another (or hinging); peeling or lifting of fracture margins; bending; margins that are usually discoloured or the same colour as the surrounding bone; and trabeculae that are stained from the haematoma may also indicate perimortem trauma (Brothwell 1981; Berryman & Haun 1996; Kanz & Grossschmidt 2005). Knusel and Outram (2006: 255) describe “spalling,” or the removal of chips of cortical bone in association with a perimortem parry fracture. Additionally, maggots and larvae in trabeculae, exposed as a result of fractures occurring during the perimortem or early postmortem periods, and other taphonomic signatures on surrounding bone surfaces may be present (Galloway 1999; Raul, Ludes, & Willinger 2008). Dry-bone fractures result in smaller and more regular fragments, have margins that are rough and uneven, and (often) have discontinuous fracture lines (Sauer 1998; Kanz & Grossschmidt 2005).

Fracture margin texture, fracture angle (created by the fracture surface and the cortical surface), and fracture outline (in relation to the longitudinal axis) distinguish green fractures from dry fractures in long bones (Villa & Mahieu 1991). Fractures with smooth textures, an obtuse or acute fracture angle, and a curved outline are associated with green bone, whereas those that have jagged textures, have a right angle, and are transverse in outline are associated with dry-bone fractures (Villa & Mahieu 1991: 34–35) (see Figures 24.3a and b).

Knusel and Outram (2006) further divide dry-bone fractures into those that show a mineralised response (“mineralised fractures”) and those that show failure when bone has retained some of its organic properties (“dry fractures”)—that is, is not mineralised, but it is not “green” either. Stepped fracture outlines and a rough, corrugated surface texture are features of this type of fracture (Knusel & Outram 2006: 262). In a forensic context the identification of dry fractures may facilitate the assessment of secondary burial in cases where, for example, remains have been exhumed and reburied to conceal a crime.

At the microscopic level Shipman (1981: 371–72) distinguishes between two types of change associated with fracturing: (1) when the fracture plane lies between two adjacent collagen bundles exposing a smooth laminar surface and (2) when the fracture plane lies perpendicular to the dominant bundle direction, exposing a roughened and stepped surface as the result of sudden rupture. The first type refers to horizontal tension failure (dry-bone fracture), and the second refers to spiral tension failure (green-bone fracture). Houck’s (1998) experimental study contrasts the microscopic appearance of knife cut marks made to fresh bone that was subsequently air dried, with further knife cut marks made to bone after it was dry. In the wet bone the line of the periosteum is located apart from the line of cut, whereas in the dried bone the location of the line of both is the same (Houck 1998: 420).

(a)



(b)



Figure 24.3 (a) Perimortem helical fracture involving the mid-shaft of a left humerus from a Bronze Age deposit at Charterhouse Warren Farm swallet, Somerset England (courtesy of Wells Museum). (b) Postmortem fracture involving the mid-shaft of a right humerus from one of the Medieval or post-Medieval burials from Oxford Castle (courtesy of Oxford Archaeology).

Biologically, there is considerable overlap between the perimortem period and the antemortem and postmortem periods. For example, injuries can occur well before death but show no signs of healing, even though they are classified as perimortem. Under controlled laboratory conditions maintained at room temperature, the elastic properties of bone decrease after approximately five hours following death (Kanz & Grossschmidt 2005). However, in some contexts the moisture content of bone may be retained several weeks after death (Maples 1999). The stages of change may vary between different bones in the same body undergoing differential decomposition and heat induced change (Symes, Berryman, & Smith 1998; Wieberg & Westcott 2008). Thus, a bone may bear the characteristics of a fresh break, but it may not necessarily relate to the death event, as defined in a forensic pathology context (Passalacqua & Fenton 2012: 401–42). It is therefore essential that forensic anthropologists employ the term *perimortem* with extreme care, providing qualification in every case. A further complication is that some fracture patterns, for example, “butterfly” fractures, are not exclusive to perimortem trauma and may be identified in dry-bone fractures as well (Ubelaker & Adams 1994).

There is enormous variation in the amount of lapsed time before macroscopic signs of healing, seen as new bone formation, can be detected on bone. This healing process takes at least a week or as long as three weeks, depending on extrinsic and intrinsic variables such as the nature and the extent of the injury, the health status of the individual, and genetic variations (Buikstra & Ubelaker 1994; Sauer 1998: 332). For these reasons, observations relating to the type, severity, and location of the injury, the victim’s age, the likelihood of secondary infection, and the forensic pathologist’s opinion regarding survivability in relation to these factors should also be considered when one is attempting to distinguish antemortem from perimortem lesions (Wedel & Galloway 2014).

Healing may be detected histologically less than 48 hours following an injury, whereas radiologically, it cannot be identified until between 10 and 12 days have lapsed (de Boer et al. 2015). Also useful is the application of high-powered microscopy, which enables healing to be detected as areas of osteoclastic activity (bone resorption) after about one week following the insult. This is followed by osteoblastic activity, or new bone deposition (Boylston 2000; de Boer et al. 2015).

Classification

Perimortem trauma is usually described in terms of the injury that caused it and is thus divided into projectile, sharp-force, and blunt-force injuries.

Projectile Trauma

Projectile trauma broadly refers to the characteristic changes that result from objects that travel through the air with enough velocity to alter bone (Byers 2010). Such projectiles include those from a range of devices, in particular, firearms, crossbows and other bows, muskets, catapults, and spear/javelin-type weapons (for example, White 1988; Bowman, MacLaughlin, & Scheuer 1992; Downs et al. 1994; Liston & Baker 1996; Novak 2000; Roberts 2003; Byers 2005). In spite of the rise in terrorist bombings over recent years, few studies have looked at projectile injuries caused by missile fragments, despite the fact that they cause more deaths than do the actual blast effects (Knight 1996).

Devices

One cannot analyse projectile injuries without knowledge of the devices themselves. Firearms and ammunition are the most complex and sophisticated of these, and they receive the most attention in the literature. This literature broadly relates to single and multiple projectiles,

internal and external bullet construction, and the size of the firearm (handguns and rifles). A comprehensive review of these key issues is provided by DiMaio (1999), Walter (2000), Dodd (2005), and Mahoney (2005). Adam (1989), Chamberlain and Gander (1974), and Quertermous and Quertermous (1994a, b) discuss details of manufactured gun models used today.

Mechanics of Projectile Injury

The velocity (the rate at which an object changes position) with which a projectile contacts the body characterizes the resultant wound. Thus, a high-velocity projectile that travels at least 610 m/sec has a more explosive effect on its target than does a low-velocity projectile travelling at 305 m/sec or less (Gellman, Wiss, & Moldawer 2003). However, the nature of the target is also a variable. For example, bullets must travel at greater velocity to penetrate thicker bones (DiMaio 1999). The amount of kinetic energy (the energy of an object as a result of motion) required by a projectile to cause damage to humans is not great: a projectile fired at bone by, for example, a catapult or a gas canister with as little as 66 foot-pounds of kinetic energy (5.58×1020 electron volts) can be deadly (Byers 2005: 311).

Tissue damage occurs when the kinetic energy of the projectile is either entirely or partly absorbed. A projectile, therefore, may not necessarily result in trauma if it fails to transfer its kinetic energy. Thus, blunt-force trauma patterns may result if bullets lose most of their kinetic energy before impact (Symes et al. 2012). The more kinetic energy that is transferred, the greater the tissue damage (Knight 1996). If missile mass is doubled, kinetic energy is also doubled. However, if velocity is doubled, the kinetic energy is quadrupled. Therefore, both mass and velocity are important determinants of tissue damage, but velocity has more influence (Gellman, Wiss, & Moldawer 2003).

Missiles may pass—retaining their kinetic energy—completely through soft tissues and leave a missile track. Some missiles are designed to slow or stop inside the body so as to ensure that as much kinetic energy is transferred as possible and that maximum damage is caused. Thus a bullet may pass straight through the body (a “through and through” injury); it may deviate from the original trajectory, split into distinct parts in the body, and produce more than one exit wound; or it (particularly pellets) may remain in the body. Bullets may also be deflected off hard tissue, causing fragments of bone to be dispelled in many directions, leaving multiple secondary exit wounds (Knight 1996: 243).

The dynamics of projectiles as they travel through the air also influence the amount of kinetic energy. For example, the trajectory of a projectile may take on various forms, depending on the projectile’s weight, design, and distance from the target. Projectiles may tumble end over end and enter on their side; wag (or wobble—the bullet rotates around its centre) and yaw (the nose of the bullet rotates away from the axial trajectory) from side to side on their line of flight; and process (yaw in a circular pattern about the centre of gravity in the form of a decreasing spiral) and nutate (rotate in a small circle forming a rosette pattern, as would a spinning top) with complex spiral or circular movements about the axis; or the base may rotate around the axis, the tip remaining on a straight path (Owen-Smith 1981: 18).

Mechanism of Injury

Missiles may penetrate bone, depending on a variety of factors. As outlined earlier, variables include velocity, kinetic energy, bullet construction, and bullet weight. Other factors are the angle of interaction between the bullet and the bone (in turn, influenced by the trajectory of the bullet) and the type of bone (for example, long or flat).

Laceration and crushing, shock waves, and cavitation (a cavity that is formed in the wake of the bullet and causes the bullet track to be stretched outward) are the primary mechanisms of

injury in shotgun trauma and are described by Knight (1996) and Owen-Smith (1981). Firm tissue (for instance, muscle) may be lacerated and crushed as the bullet forces a track, or a permanent cavity, through it; this occurs when a low-velocity bullet penetrates the body. Studies of gelatin blocks show that, despite similar missile velocities, the profile of the permanent cavity varies considerably depending on the dynamics of the bullet and whether, for example, the bullet fragments (Fackler, Bellamy, & Malinowski 1988). High velocity bullets generate spherical shock waves ahead of them, causing injuries in locations other than those immediately in the bullet track. High-velocity bullets also produce temporary fusiform cavities that form around the bullet track in the wake of the bullet and may damage surrounding structures (Owen-Smith 1981). Secondary missiles are another mechanism and include fragments of fractured bone or fragments of bullet that may be expelled in a number of different directions, causing injury to surrounding soft tissues (Gellman, Wiss, & Moldawer 2003).

When a gun is fired, a number of by-products, such as carbon, gasses, grains of powder, and abrasion from heat and friction, result in soft-tissue wounds. Examples include soot soiling, powder tattooing, and a grease ring. Soft-tissue wounds vary, depending on the type of missile fired (for example, hand gun or shot gun), intermediary artefacts (for example, clothing), and whether the firearm is in contact or at close, intermediate, or long range. Detailed accounts of the different by-products of a firearm are provided by Knight (1996: 247–61) and DiMaio (1999).

Firearm Wounds in Bone

Firearm wounds in bone are primarily described in the literature in relation to the cranium and concern entrance and exit wounds, radiating fractures, and concentric heaving fractures. Entrance wounds have sharp, internally bevelled margins and are round or conical in plan, depending on the angle of the impact, the stability of the bullet, and the morphology of the bone. Thus wounds most commonly occur on the parietal or occipital bones, on the frontal bone less so. Exit wounds tend to be larger than entrance wounds and have a bevelled margin externally. On penetration of the outer table, the projectile forces a cone-shaped path through the bone, creating a wider girth on the inner table compared to the outer table. On exiting the cranium, the same process occurs, but this time in reverse, so that the wound on the outer table is wider than it is on the inner table.

Bone fractures can be caused by bullets without characteristic entrance and exit wounds (Berryman, Lanfear, & Shirley 2012). Further, entrance and exit wounds are difficult to identify on the thin bones of juvenile crania, in particular, the temporal bone. Such wounds may also not be visible on any victim, juvenile or adult, if surgical debridement has been performed, bones are inadequately recovered from site, or taphonomic alteration (especially animal scavenging) obscures the wound margins. Interpreting bone fractures is particularly difficult if remains are highly fragmentary (either as a result of postmortem damage or in the case of comminutions), such as in contact gunshot wounds (Fenton et al. 2005). Thus maximum recovery from site and subsequent reconstruction are essential. Entrance and exit wounds may indicate weapon class and, sometimes, small- and large-calibre weapons, but they should not be employed to estimate precise bullet calibre, because current methods have not achieved an acceptable level of accuracy to be employed in legal contexts (Berryman & Symes 1995b; Ross 1996; Berryman, Lanfear, & Shirley 2012).

It is now a widely accepted (but still imperfectly understood) phenomenon that a bevelled margin may be produced on the surface opposite to the direction of the bullet. This situation is believed to occur if a bullet enters perpendicularly or tangentially to the surface of the bone. Where this occurs the reverse bevel is usually smaller than the bevel it opposes (Coe 1982). Bones may also present two entrance wounds and one exit wound if a bullet is deflected back into the body when it hits an intermediary target on exiting.

The shape of a firearm wound in bone can vary, depending not just on whether it is an entry or an exit wound but also on impact velocity, trajectory of the projectile, tissue density, type of bullet, and whether or not the bullet deforms. Different firearm wound shapes in relation to these variables are summarised by Byers (2005: 300–02).

Smith and colleagues (1987) summarise the sequence of fracture development in gunshot trauma. Radiating fractures first initiate around the impact site, and concentric heaving fractures are produced as intracranial pressure causes outbending of the plates of bone. Radiating fractures may also accompany exit wounds. However, these are not to be confused with entrance–wound radiating fractures, which travel faster than the speed of a bullet and, therefore, advance to the other side of the vault before the bullet. Radiating fractures associated with an exit wound may terminate in a radiating fracture associated with an entrance wound and can be useful for determining the direction of a bullet when the entrance and exit wounds are themselves missing (Smith, Berryman, & Lahren 1987).

Postcranial Projectile Trauma

Reference to projectile trauma to the postcranial skeleton is negligible in the forensic literature, and presently most knowledge derives from medical texts. Unlike cranial fractures, postcranial fractures resulting from direct impact tend to leave fewer prescribed patterns other than considerable comminution, bone loss, and perhaps nicks and depressions from metal fragments. Bone fractures resulting from indirect shock waves tend to show a linear pattern with little displacement (Ryan 1997).

Eismont and Lattuga (2003) review gunshot injuries to the spine. They report that associated secondary fractures involving the vertebral body are common in gunshot injuries to the posterior arch or pedicles. However, secondary changes to posterior elements are unlikely when the vertebral body is the primary site of injury presumably because, owing to its cancellous structure, it transmits less energy to surrounding structures (Ryan 1997: 989). The same conclusion was reached by Heulke and Darling (1964), who observed that fragmentation was greater in diaphyses than in epiphyses. Based on experiments that yielded similar results, Ragsdale and Sohn's study (1988) describes how diaphyses fragment into larger pieces and act as secondary projectiles.

As in the cranium a tangential entrance wound in tubular bones can also result in a keyhole lesion (Berryman & Gunther 2000), although interpretation would benefit from additional experimentation. Bevelling has been described on flat bones, such as ribs and the pelvis, and may be used to explore directionality (Spitz 1980; Besant–Matthews 2000), although this bevelling is somewhat harder to observe than in the cranium (Galloway & Zephro 2005).

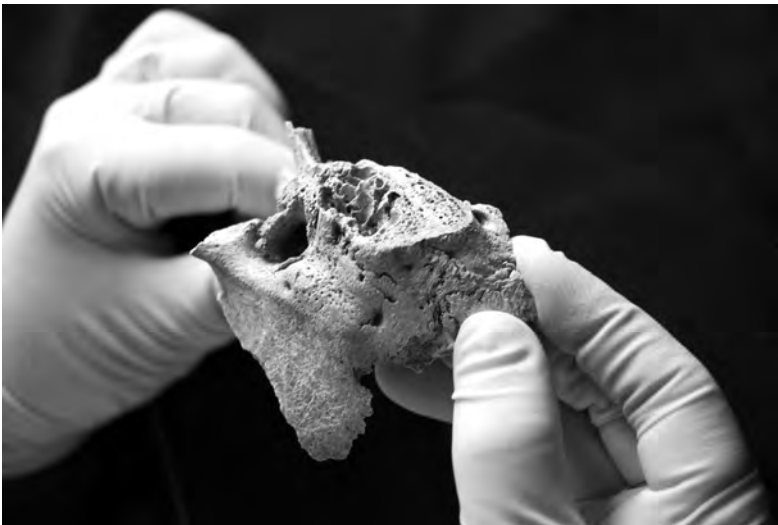
Sharp-Force Trauma

Injuries that cut and divide tissue are classified as sharp trauma and are caused by instruments with acute edged blades (“edge bevel”; see Symes et al. 2010) that produce cut/incision, stab, or cleft/notch wounds. These wounds are caused by a compression force that is both dynamic and acutely focused and may result in lesions that penetrate through to the endocranial or medullary surface of bone, skip or glance off bone, or slice, chop, or scrape bone, depending on the angle and the impact of the instrument (Figure 24.4). Sharp lesions may be accompanied by blunt force fractures if delivered with excessive force, and such cases have been termed *blunt-force trauma with a sharp object* (Symes et al. 2012: 365).

Diagnostic features of each type of wound (cut, stab, or cleft) relate to its shape, length, and width and the morphological appearance of the wall of the lesion and associated secondary lesions. Primary characteristics broadly relate to the fact that cuts are longer than they are wide



(a)



(b)

Figure 24.4 Blade trauma in 10th- or 11th-century executed victims from Ridgeway Hill mass grave, Dorset, England; (a) second cervical vertebra; (b) right mastoid process; *(continued)*

and have parallel margins, one hinged and one polished. Stab wounds may be identified as punctures that are shorter than they are wide, and cleft wounds are linear and broad. Secondary characteristics include fractures that radiate from the point of impact, hinge fractures, and separation of bone fragments from the main lesion (bone wastage, or chipping). Hinge fractures and bone wastage will vary in extent, depending on the instrument. Note that with reference to puncture wounds made with knives of a certain size, the length of the wound corresponds to the width of the blade (Williams et al. 1998).

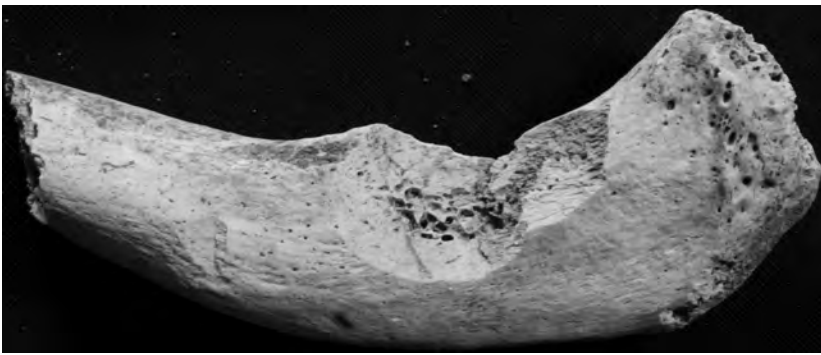
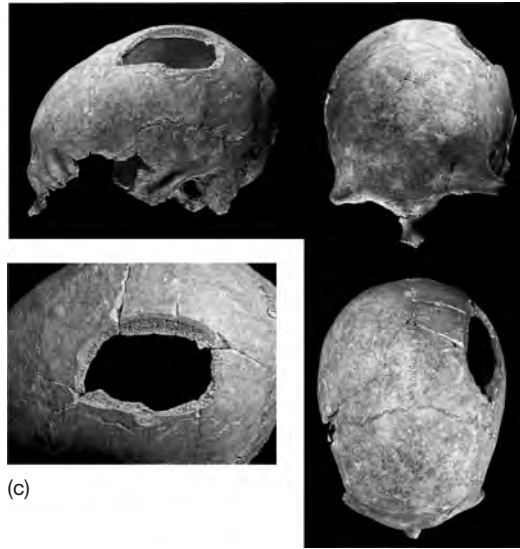


Figure 24.4 (continued) (c) right clavicle—resulting from decapitation—and (d) cranial vault with scooped defect (courtesy Oxford Archaeology)

Literature is limited in terms of information on individual tool-mark characteristics, with most focusing on class characteristics (for example, Shipman 1981; Blumenschine, Maren, & Capaldo 1996; Houck 1998; Greenfield 2000). Tool marks are difficult and often impossible to identify (Reichs 1998). Studies on individual characteristics have examined various implements, for example saws (Symes, Berryman, & Smith 1998); machetes, cleavers, and axes (Humphrey & Hutchinson 2001); hatchets (Alunni-Perret et al. 2005) and serrated versus nonserrated blades (Thompson & Inglis 2009).

Microstriations and Directionality

Microstriations are faint lines that run along the longitudinal axis of the walls of a cut and reflect imperfections in the instrument as it is drawn across the bone (Figure 24.5). Their appearance

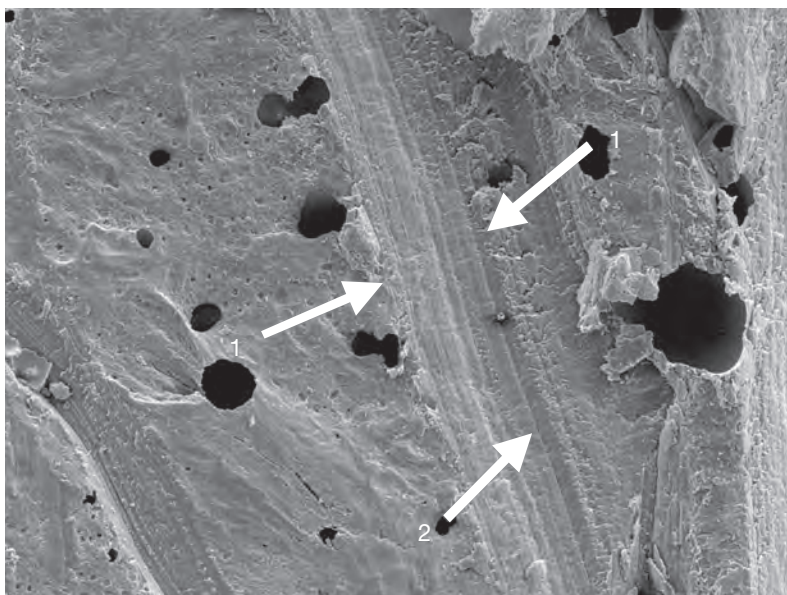


Figure 24.5 Scanning electron micrograph (x80) showing an experimental cut mark (arrow 1) with internal microstriations (arrow 2). The cut was made on animal bone using a flint tool (photograph courtesy of Dr. M Smith).

may vary, depending on the instrument used. This observation has largely been developed in the zooarchaeological and archaeological literature, which contrasts the appearance of cut marks made by stone tools with those made by bladed tools (for instance, Greenfield 2000). Although the study of stone tools is not of great relevance to the forensic anthropologist, the associated literature makes a valuable contribution to present understandings of class characteristics, including general configuration, contour, and profile.

Another significant contribution is to the interpretation of directionality of cut marks. At the macroscopic level, angle and direction of an instrument may be indicated by the profile of the lesion and its location (Novak 2000). However, these may be expanded, through high-powered microscopic analysis, to include information on whether the cut was being made from left to right or from right to left. In their experimental study that applied SEM analysis to cut marks made on bovine bone, Bromage and Boyde (1984) determined three criteria of directionality: morphological changes, including bone smears, oblique faulting, and oblique chipping, which may be observed on the floor and walls of the cut. Although these features were not the focus of their study, Bromage and Boyde (1984) observed that they were also useful for indicating handedness. Other factors, including the relative position of the victim and the assailant and variation in cutting edge, remain to be fully explored at this level (Bromage & Boyde 1984; Houck 1998).

Blunt-Force Trauma

Trauma resulting from contact with a blunt instrument or a fall may be identified on dry bone as focal or penetrating injuries that have discrete patterns, which sometimes bear characteristic hallmarks of a particular type of weapon (for example, a pole axe, a hammer), or as areas of crushing with few distinctive features. Severity, extent, and appearance of blunt-force trauma are

mediated by a number of factors, including the nature of the impact, the area struck, the angle of the force, and the amount and duration of the force.

Most blunt trauma is described in the literature in terms of insults from weapons (for example, Boylston 2000; Novak 2000). Tomezak and Buikstra (1999) have reviewed fracture patterns sustained as a result of falls (vertical deceleration injuries) and vehicular-pedestrian accidents (horizontal deceleration injuries). Fracture patterns for each are explored, including consideration of the different variables that may determine their outcome (for instance, body mass, speed and size of automobile acceleration, body position, height of fall, humidity, and air drag of clothes).

Fractures That Result from Local Deformations

Fracture production arising from blunt trauma is usually described in four stages: (1) inbending at the site of impact producing a compressive force on the outer table and tensile force on the inner table, peripheral outbending and initial fracture production on the inner table; (2) formation of radiating fractures; (3) inbending of plates of bone; and (4) concentric fracture formation in areas of tension produced on the outer table (Berryman & Symes 1995a; Berryman & Haun 1996).

The area directly below and around the impact site may rebound if the impact is not of a sufficient velocity or energy (Gurdjian, Webster, & Lissner 1950). Such rebounding may result in linear fractures that extend toward the impact area and in the opposite direction (a result of the impact area coming under tension as it immediately rebounds from compression). Otherwise, a depressed fracture will result. This fracture will vary, depending on the brittleness and the elasticity of the bone when the impact occurs (Berryman & Symes 1995a: 340):

- 1 A plug of bone is forced inward (brittle bone);
- 2 There is inbending, and the fracture advances from the inner to the outer table (elastic bone);
- 3 The outer table and diploe are crushed, but no fracture occurs on the inner table (brittle diploe); and
- 4 There is inbending of the inner table with shattering of the inner table and diploe (brittle iploe).

The fracture is dependent on the magnitude¹ of the blow, the instrument used, and the area struck. The main types of impact pattern are summarized by Boylston (2000: 363) after King (1992):

- 1 Linear fracture with radiating fissure fractures;
- 2 Depressed fracture;
- 3 Depressed fracture a la signature;
- 4 Depressed fracture produced by a sharp edged weapon;
- 5 Depressed pond fracture (also comminuted);
- 6 Depressed satellite fracture; and
- 7 Comminuted fracture.

These injuries are further classified as depressed, expressed diastatic and gutter fractures. A depressed fracture results from bone fragments being pushed inward and is either comminuted (broken into many different fragments) or has a pond or satellite appearance. When bone fragments protrude outward from the cranium, they are described as expressed fractures. Fractures that involve the parting of sutures (common in children) are classified as diastatic, whereas those

that arise as a result of an instrument grazing bone are referred to as gutter. Another classification system is described by Galloway (1999) and includes patterns relating to the cranium, axial skeleton, and upper and lower extremities. These are broadly categorised as complete fractures and incomplete fractures.

Other postcranial blunt trauma patterns include incomplete and buckle rib fractures and are described by Love and Symes (2004). In their study, incomplete fractures were observed in children and adults aged between 21 and 76 years with no significant bias toward a particular age group. This observation is contrary to the belief that such fractures are more common in children. Buckle fractures resulting from compressive force had not been described before.

Fractures That Result from Indirect Violence

Le Fort fractures and ring fractures are examples of those that occur away from the area of impact. Ring fractures partially or completely encircle the foramen magnum, depending on the force. They arise when the skull is driven down onto the vertebral column, usually as the result of a fall from a height. In severe cases they may continue into the petrous portion of the temporal bone and terminate at the foramen of the middle fossa (Byers 2005: 324).

Blunt Trauma versus Gunshot Trauma

Berryman and Haun (1996) suggest that if skull fragments are impossible to reconstruct, they are more likely to have arisen as a result of a slow loading force (that is, blunt trauma) than a fast loading force (for example, projectile trauma). Reconstructing fragments is difficult because, under a slow loading force applied over a large area, bone will fracture when it is in its plastic phase of deformation. A rapid loading force applied to a small area will result in a brittle response causing an explosive pattern of fracture with minimal or no plastic deformation (Berryman & Symes 1995a). Caveats to this rule include the fact that sediment pressure may act as a slow loading force and therefore cause similar plastic deformation in remains that are still wet. Furthermore, these responses are mediated by numerous extrinsic and intrinsic variables, including the age of the individual (for instance, children's bones are more plastic than adult bones), the duration of the blow, and the density and the morphology of the bone, among other factors.

Although concentric fractures are observed in both blunt and projectile trauma, the ways these are produced are very different. In blunt trauma, the bevel is usually located internally, whereas in gunshot trauma, the bevel is usually external. However, reverse bevelling may occur in projectile trauma, and bevel direction may not always be apparent in blunt trauma, depending on buttressing of the vault, from the impact site and the spherical shape of the skull (Berryman & Symes 1995a; Berryman & Haun 1996). These factors were tested by Hart (2005), who, using 211 forensic specimens, demonstrated a strong statistical relationship between mechanism of trauma and direction of concentric fracture, particularly in areas of the skull that are not buttressed. Under these circumstances concentric fractures develop under tension on the inner table and advance to the outer table producing an external bevel as shear forces are encountered, unlike the concentric fractures seen in blunt trauma.

The production of a triangular wedge-shaped piece of bone is also known to blunt and projectile trauma involving long bones, but, like concentric fractures, the biomechanics are different in each. Thus, although similar, only those caused by blunt force trauma may be classified as butterfly fractures (see Berryman, Lanfear, & Shirley 2012: 377–78).

Analytical Applications

The application of scanning electron microscopy (SEM) to analyse perimortem skeletal trauma occupies an ambivalent status in terms of its perceived usefulness (Bunn 1981; Shipman 1981; Blumenshine, Maren, & Capaldo 1996; Loe & Cox 2005). Symes and associates (2012) consider that it results in the loss of detail and advocate the use of a light stereo-microscope instead. However, Rickman and Smith's (2014) SEM analysis of gunshot trauma assisted with identification of directionality, ruling out other mechanisms (for example, blunt force trauma) and, possibly, bullet construction identification. Other work employing SEM analysis has highlighted the difficulty in identifying different implements from cut marks in bone (Bartelink, Wiersema, & Demaree 2001) because, as with macroscopic analysis, cut-mark width tends to overlap for different knife types (Houck 1998). However, Alunni-Perret and associates (2005) reported on the benefits of applying SEM analysis to distinguish hacking trauma from knife trauma, or pure sharp trauma from sharp-blunt trauma.

More recent analytical applications include computerised tomography to determine the timing of an embedded weapon injury (Flohr et al. 2015) and reconstructed three-dimensional multidetector computed tomography (3D MDCT) imagery to differentiate perimortem and postmortem cranial lesions (Fleming-Farrell et al. 2013). In addition, Bello and Soligo (2008) and Bello (2011) have employed optical surface measurement systems in cut mark analysis. This method produces detailed three-dimensional models of bone surfaces and is particularly useful where SEM analysis is not possible (for instance, Schulting et al. 2015). Other applications concern ballistics, such as finite element analysis and primer derived gunshot residue analysis, and are discussed by Berryman and colleagues (2012).

Perimortem Trauma Patterns in the Skeleton: Causes

Much of the literature on the circumstances of trauma is anecdotal. Gellman and colleagues (2003) note in passing that gunshot trauma to the foot is more common under accidental circumstances, when a gun is being loaded or cleaned. Fractures that affect the hands and forearms are associated with defence injuries (Roberts 1996) and those involving the facial skeleton, an attack (Walker 1997). Injuries that predominantly affect one side of the skeleton more than the other may indicate handedness of the assailant, and fractures that occur on the back of the skull may be caused by an attack from behind (Walker 1997). Certain fractures are associated with falls (for example, a Colles fracture of the wrist). The head and the neck are the most common areas to receive insults during an attack (Knight 1996), whereas fractures to the sternum, scapula, and ribs may be associated with direct blows (Roberts 1996). Trauma patterns arising from armed conflict are presented by Kimmerle and Baraybar (2008), and criteria for distinguishing suicide from homicide in gunshot wounds are considered by Stefan (2014).

More recent anthropological literature focuses on the identification of victims of child abuse, as evidenced in skeletal remains (for example, Cattaneo et al. 2006; Lewis 2007; Love, Derrick, & Wiersema 2011; Ross & Juarez 2014). Diagnostic features include peri- and postmortem lesions (in particular multiple non-accidental trauma) and evidence for nutritional deprivation (Cattaneo et al. 2006; Ross & Juarez 2014). Fractures involving the ribs are regarded as a strong indicator of child abuse (Kerley 1978; Cattaneo et al. 2006: 5) and tend to be bilateral (Walker, Cook, & Lambert 1997), with those involving the posterior portion of the rib being highly indicative of the victim having been squeezed around the torso (Lewis & Rutty 2003: 206; Lewis 2007). Cranial involvement can result in simple linear, wide, depressed, complex, diastatic, growing, and/or multiple fractures that cross the sutures (Abel 2011). Other sites that

may be involved, such as the facial skeleton, metaphyses, epiphyses, and diaphyses, are discussed by Walker and colleagues (1997) and Bilo and associates (2010), who present detailed lesion descriptions by body region.

Patterns of skeletal involvement that are common to contexts of human rights violations, including those associated with different methods of punishment and torture are considered by Rodríguez-Martín (2006) and Kimmerle and Baraybar (2008). For example, this includes open fractures involving metatarsals and hand phalanges associated with repeated beatings and multiple fractures at different stages of healing. Fractures involving the hyoid (and ossified neck cartilages) are associated with manual and ligature strangulation, suffocation, a direct blow to the neck, and hanging (Pollanen, Bulger, & Chiasson 1995). In addition, a fracture involving the odontoid process of the second cervical vertebra (axis) is typical of hanging (that is, “Hangman’s fracture”). However, absence of a fracture involving these structures cannot be regarded as reliable evidence that trauma has not occurred (Ubelaker 1992). Even when fractures do occur, they are often difficult to distinguish from postmortem fractures in the absence of soft-tissue haemorrhaging.

Cut marks may be present on bone as the result of dismemberment, decapitation, cannibalism, defleshing, and deliberate disarticulation. These may be differentiated from one another based on their frequency, location, and orientation, as well as the type of cut mark and associated injuries (for example, Olsen & Shipman 1994; Reichs 1998). Dismemberment patterns may inform about the motives, state of mind, and knowledge of the perpetrators, as well as link victims from different murder scenes to the same perpetrator if lesions share similarities in their distribution, appearance, and location. In addition, Seidel and Fulginiti (2014) consider dismemberment patterns and suggest that weapon choice may be significantly influenced by the sex of the perpetrator.

Superficial cut marks that are randomly located are associated with defleshing. If these marks occur on the skull and tend to follow the crown, they are indicative of scalping, whereas if they are multidirectional and involve the face and base of cranium, they are indicative of defleshing (Olsen & Shipman 1994; Mays & Steele 1996). Decapitation is indicated by the presence of cut marks on the cervical vertebrae, clavicles, basioccipital, and mandible. However, microscopic analysis may be required to determine whether the decapitation occurred at, or after, death (that is, skull removal).

Certain perimortem sharp-force trauma patterns are associated with the surgical removal of a piece of bone from the cranium (trepanation). This procedure may be performed by scraping, grooving, bawing-and-cutting, or creating rectangular intersectioning incisions (Lisowski 1967). Several examples have been identified in the archaeological record (Arnot, Finger, & Smith 2003); problems with this study include the fact that it is usually impossible to distinguish unsuccessful trepanation (that is, performed before death) from exploratory surgery (performed shortly after death) and identify the motives behind such intervention, unless there is an associated trauma (Roberts & McKinley 2003).

Other circumstances that may be reflected in perimortem trauma patterns relate to falls in which the height of a fall influences the orientation of the body when it lands and thus the parts of the skeleton affected (Tomezak & Buikstra 1999). When considered together, the “hat brim line” rule,² side lateralisation of fractures, and the number of lacerations have been found to be useful for distinguishing blunt trauma from falls from blunt force homicidal blows (Kremer & Sauvageau 2009).

The identification of projectile, sharp, and/or blunt-force trauma arising from explosive munitions is another area where forensic anthropologists are increasingly involved. The impact of explosions on the human skeleton may include multiple, extensive, comminuted fractures, an absence of fractures associated with a point of impact, decapitation, amputation, penetrating

wounds, embedded fragments of bone and/or metal and/or debris, blunt-force injuries, and acceleration and deceleration injuries and burns. Forensic anthropology criteria for diagnosing such lesions have only recently appeared in the literature (for example, Kimmerle & Baraybar 2008), previous work having relied on clinical sources (for example, Knight 1996; Ritenour & Baskin 2008; Turegano-Fuentes et al. 2008; Kosashvili et al. 2009). In addition, experimental work has been undertaken using pig carcasses to identify patterns unique to primary and secondary blast trauma (Christensen et al. 2012; Christensen & Smith 2013). Analyses of trauma arising from explosives in the skeletonised remains of WWI soldiers from Pheasant Wood, Fromelles (Figure 24.6) (Loe, Barker, & Wright 2014; Barker, Loe, & Flavel Forthcoming; see also Cox, Loe, & Jones, Chapter 39 this volume), which emphasize the importance of an integrated approach, are another contribution.

In addition to trauma patterns, weathering and evidence for scavenging provide evidence about the nature of an assemblage exhibiting perimortem trauma. Remains that are weathered and scavenged suggest exposure following death; this situation is more likely to be encountered in the remains of victims of a massacre than of other events, such as accidental trauma (Hurlbut 2000).

Although patterns of perimortem trauma may indicate the circumstances that gave rise to them, one must remember that very rarely can such interpretations be extended to suggest the cause (for example, heart disease, cancer, haemorrhage) and manner (for instance, suicide, accident, homicide, natural or accidental) of death. Although it is not the legal obligation of forensic anthropologists to determine the cause of death, they have a very important role in assisting the forensic pathologist or medical examiner in establishing the manner (Byers 2005). Interpretations of trauma are particularly important given the fact that trauma accounts for most suspicious deaths, and skeletal trauma may provide the only information about the cause and manner of death if the body has decomposed (Roberts 1996; Byers 2005). The relationship between skeletal lesions and cause and manner of death is a very ephemeral one; a stab wound may have caused death, but it may also have been delivered following death by other means (Byers 2005: 276–77).

Pseudotrauma

Factors that may mimic perimortem trauma can be broadly classified as those relating to pathology and medical procedures, skeletal morphology, burning, or animal and environmental activity. Postmortem modification is particularly difficult to distinguish, current macroscopic criteria not always being adequate, particularly when flat bones and trabecular rich bones are involved (Cappella et al. 2014).

Numerous skeletal pathologies may be mistaken for child abuse, such as birth trauma and accidental and self-afflicted trauma (Lewis & Ruttly 2003) and spontaneous fractures, secondary to osteopaenia (a lower than normal bone-mineral density) (Torwalt et al. 2002). In addition, blood vessel markings and naturally occurring apertures (for example, the sternal aperture) may be mistaken for cut marks and bullet wounds, respectively (see Cunha & Pinheiro, Chapter 23, this volume), but should be relatively easy to identify based on their smooth, biological, and often less well-defined margins, as well as familiarity with skeletal anatomy.

Sufficient exposure to fire may hinder identification of perimortem trauma, in particular, gunshot and blunt trauma (Herrmann & Bennett 1999; Pope & Smith 2004). In such cases, reconstruction and microscopic examination are essential, so that characteristic patterns (for example, longitudinal, curved transverse and straight transverse fractures, patina and delamination) of heat-induced trauma may be distinguished from genuine injuries (Thompson 2005).

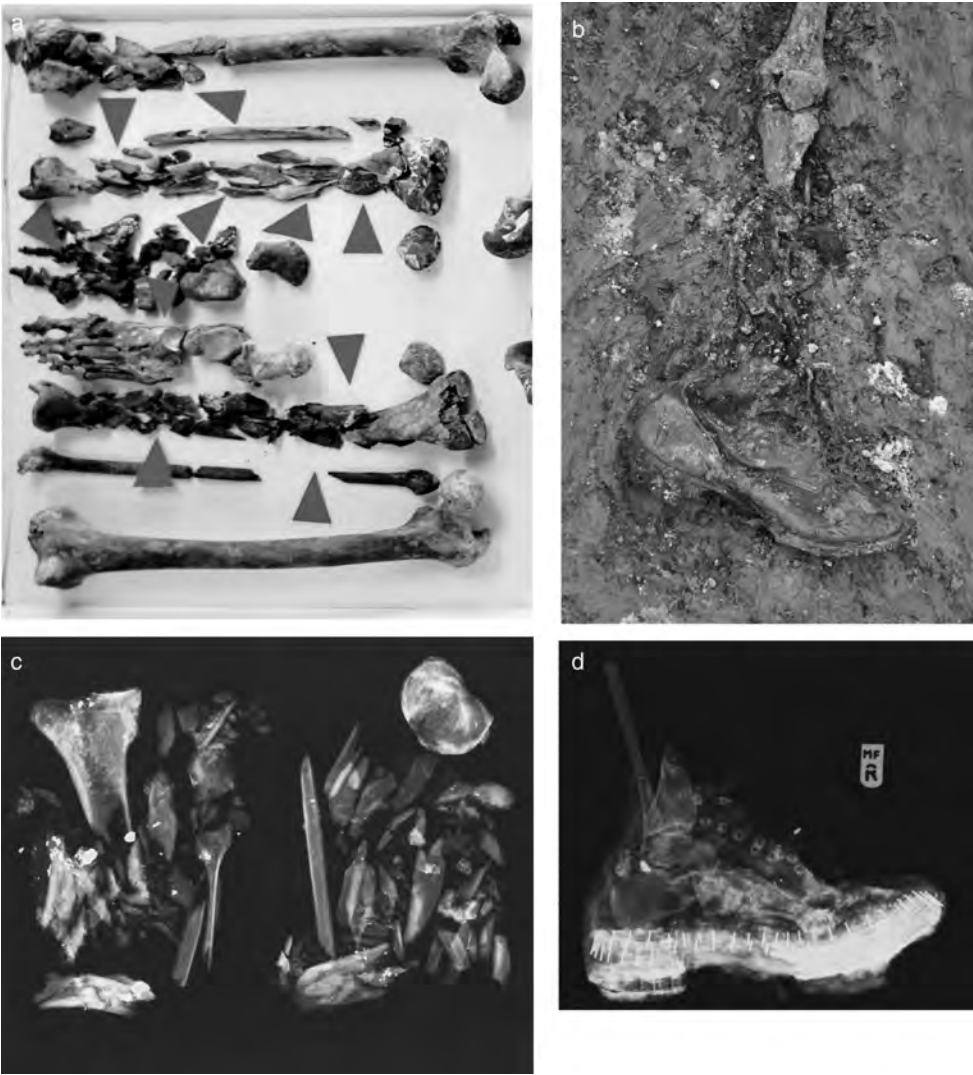


Figure 24.6 Blast type trauma from explosive munitions causing bilateral partial limb amputation in a WWI casualty from Pheasant Wood, Fromelles, N. France: (a) extensive comminuted fractures (arrows); (b) burial context; (c) radiological appearance showing radiopacities, consistent with degraded metal (exploded shell casing); (d) unlike most casualties from Pheasant Wood, the soldier's boot had not been removed, probably because of the trauma (courtesy of Oxford Archaeology).

Carnivore or rodent tooth marks may be confused with cut marks, and several papers describe criteria for distinguishing these (Blumenschine 1988; Haglund, Reay, & Swindler 1988; Milner & Smith 1989; Blumenschine, Maren, & Capaldo 1996; Laudet & Fosse 2001). In addition, carnivore scavenging activity (Villa & Mahieu 1991) can be difficult to distinguish from fractures caused by human activity, and, to this end, knowledge of scavenging patterns, such as those reviewed by Bonnicksen (1979), is essential. The importance of being able to differentiate taphonomic changes from cut marks was highlighted by Puskas and Rumney (2003) on

bilateral fractures of the coronoid processes in relation to intra-oral gunshot trauma and canid scavenging. Besides scavenging, trampling and fluvial activity may also result in fresh breaks to bone (Shipman & Rose 1983; Behrensmeyer, Gordon, & Yanagi 1986; Brooks & Brooks 1997).

Striations may occur on bone that has come into contact with sharp stones or substrate through being trampled or transported in water and may be mistaken for cut marks. These marks tend to be multidirectional, faint, intersect with one another, lack meaningful anatomical locations, and be of uneven thickness and depth (Shipman & Rose 1983; Cook 1986: 282–83; Blumenschine & Slevaggio 1988: 765; Olsen & Shipman 1988: 543).

Some limitations of the data illustrate the extent to which the present understanding of the biomechanics of perimortem trauma is inadequate, particularly in relation to the postcranial skeleton. For example, Love and Symes (2004) found that, contrary to experimental and observational biomechanic studies, ribs failed first under compressive rather than tensile force. Further, chronological age was not found to influence the presence or absence of incomplete fractures, suggesting that plasticity versus brittleness may not have such an influence over fracture mechanics as has been assumed.

At the root of these problems is the uniformitarian assumption that all bones will respond to trauma and/or modification in a universal manner (Young 1989; Reichs 1998). Further, the problem of “equifinality,” which means that some trauma-related features reflect nothing more than the interaction between bone and an instrument, results in enormous cross-over between criteria for distinguishing different events (Cook 1986: 284; Oliver 1989: 91). Thus marks made on bone may relate to the same mechanical movements but quite different events (for example, a human drawing a sharp stone across bone or a sharp stone being drawn across bone in the context of trampling).

Complete recovery of bone fragments is a challenge, because they may be lost in maggot masses, be transported away by insects, or surrounded by soft tissue in varying stages of decomposition (Galloway 1999). In addition, the characteristics of a perimortem injury may be modified (and hence obscured or erased) by factors such as weathering, soil abrasion, and animal scavenging, a process referred to by Shipman and Rose (1983: 60) as “taphonomic overprinting.”

Regarding sharp-force trauma, the anthropologist is unlikely to observe the true frequency of this trauma in any given case, owing to the fact that many injuries, such as those to the chest area, will perforate the soft tissues without marking the bone. Further, the appearance of bone lesions will vary depending on the thickness of the soft tissue covering it. Thus, cuts to fingers are often small and extremely fine, owing to the fact that the overlying tissues absorb the energy of the cutting instrument (Alunni-Perret et al. 2005).

Last, sediment pressure may not only cause plastic deformation to bone but also cause fracture, particularly among bones with thin cortices relative to their large diameters (for example, femora and tibiae) (Trinkhaus 1985: 206–07). Where this situation involves relatively green bone, the characteristic features are essentially perimortem. Relatively fresh long bones will naturally break along the long axis of the bone, because of the orientation of the collagen fibre bundles and Haversian systems. These longitudinal fractures, or split line cracks, are discussed by Johnson (1985) and Bonnicksen (1979). This pattern is not necessarily, therefore, the result of human activity.

Limitations such as those mentioned require a cautious approach to analysis. To this end several texts deal with methodologies from the recovery of human remains to court testimony. They include Wedel and Galloway (2014) on blunt-force trauma; Loe and Cox (2005) and Reichs (1998) on tool-mark analysis (see also Symes et al. 2010); DiMaio on gunshot wounds (1999); Kimmerle and Baraybar (2008) on armed conflict and human rights abuse; and The Scientific Working Group for Forensic Anthropology (SWGANTH 2011) and Barker and colleagues (2008) on best practice guidelines.

Important points include the fact that analysis should be based on methods and principles that are scientifically valid (SWGANTH 2011); classification should be assigned according to the predominant characteristics of the wound, not the mechanism or weapon that may have been responsible, and interpretations that attempt to explain the circumstances in which injuries arose should be avoided (Wedel & Galloway 2014). The anthropologist's goal should be to identify the forces and comment on possible causes. Other key points include the fact that the anthropologist should be involved from the moment human remains are discovered, and a multidisciplinary approach (for example, Cattaneo et al. 2006 on diagnosing child abuse) is essential.

Conclusions

The analysis of perimortem trauma analysis is a rapidly expanding field. It is also one of the most challenging areas of forensic anthropology—perhaps more so today than ever before. Being able to confirm that injuries are not ante- or postmortem lesions and in turn distinguishing genuine perimortem injuries from normal anatomical variation, pathology, and taphonomic changes are the main issues. These are compounded by the ever-increasing sophistication of weapons and by attempts made by perpetrators to cover up their crimes, factors that require experience and knowledge of skeletal anatomy to identify. Although some areas of the discipline, such as macroscopic estimation of age and sex, are being replaced by more advanced techniques (for example, DNA analysis), perimortem trauma analysis, once ignored in forensic textbooks (for example, El-Najjar & McWilliams 1978; Stewart 1979), is receiving increasing medicolegal emphasis (Symes et al. 2012) in which more precise interpretations (for instance, directionality and number of assaults) of lesions are expected (Berryman, Lanfear, & Shirley 2012: 390–91). This situation has been influenced by mounting atrocities against humanity worldwide and the increasing requirement for anthropologists to contribute to investigations of fleshed remains (Passalacqua & Fenton 2012; Symes et al. 2012), bringing accountability and scientific rigor in analysis and interpretation into sharp focus.

It is within this context that there have been a number of significant developments in recent years. For example, best practice guidelines have been produced; the number and type of experimental studies have increased and new techniques have been applied. There has also been greater focus on a holistic approach in which histology, pathology, forensic anthropology, engineering, ballistics, taphonomy, and physics are more integrated. In addition, epidemiological analyses of victims of recent human rights violations and conflicts, with a focus on human bone, have been published (for example, Kimmerle & Baraybar 2008). Future work should aim to continue to develop objective and reliable criteria, increase present understanding of fracture biomechanics and their modification by taphonomic agents, and explore epidemiological trends, especially among little studied groups, such as victims of elderly abuse and victims of explosive trauma.

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Notes

- 1 *Magnitude* is defined by Symes and associates (2012: 345) as “the area (and possibly weight, and possibly speed) of the force being applied; the property of relative size or extent.”

- 2 The “hat brim line” (HBL) is the area between two parallel lines on the Frankfurt horizontal plane, the superior of which passes through the glabella and the inferior, through the centre of the external auditory meatus (Kremer & Sauvageau 2009). Thus it incorporates the orbits, nasal bone, and most of the temporal and occipital bones. Although the subject of some debate, trauma due to falls is more common in the areas of the level of the HBL, whereas trauma above the HBL is more commonly the result of blows (Kremer & Sauvageau 2009).

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Forensic Taphonomy

Stephen P. Nawrocki

Taphonomy is defined as the study of the phenomena that affect the remains of biological organisms at the time of and after death. The field was originally developed in the 1930s by palaeontologists attempting to explain the distribution of plant and animal fossils in the geological record (Efremov 1940). By the 1970s taphonomy was being applied to the study of prehistoric human remains, and more recently to human remains recovered in historic and forensic contexts (Stewart 1979; Behrensmeyer & Hill 1980; Brain 1981; Shipman 1981; Bonnicksen & Sorg 1989; Micozzi 1991; White 1992; Lyman 1994; Nawrocki 1995; Haglund & Sorg 1997, 2002; Galloway 1999; Pokines & Symes 2014). The application of taphonomy in medico-legal settings is somewhat different from its use in ancient contexts, with problems and concerns that are particular to processing recently deceased humans as a part of potentially criminal casework.

This chapter discusses the effects of the processes and forces that influence the preservation of human skeletal remains at modern death scenes. Of key importance is the concept that decomposing remains are part of a complex *ecosystem* (Nawrocki & Latham 2013; Sorg et al. 2014), and so any analysis must reference that ecosystem to interpret the final condition of the remains. Furthermore, a holistic approach that blends biology, geology, and environmental science increases the depth and reliability of any reconstruction of the peri- and postmortem histories of the remains.

The Scope of Taphonomy

The scope of taphonomy is broad, encompassing both perimortem and postmortem processes, as well as soft and hard tissues. As such, taphonomy as practiced in the forensic context frequently involves a number of different forensic experts. For example, the changes that occur to the body in the immediate postmortem period (intraocular fluid pressure, algor mortis, rigor mortis, livor mortis, skin slippage, autolysis, and putrefaction) are generally recorded by the forensic pathologist during an autopsy. The insects that colonize a decaying body are analyzed by the forensic entomologist. Later postmortem changes to the soft tissues (mummification, adipocere formation, and skeletonization), as well as changes to the bones themselves, are generally studied by the forensic anthropologist. Perimortem trauma may be analyzed either by the pathologist and/or the anthropologist, depending on the circumstances. The common thread linking these diverse and seemingly disparate areas is the focus on the processes and forces that alter the body from its living, vital condition and the resulting modifications of the tissues that must be interpreted by the forensic expert in the laboratory.

In general, taphonomic processes result in the loss of biological information available to the analyst. For example, algor mortis, or the process of cooling after death, makes it difficult and eventually impossible for the scientist to determine the original body temperature of the animal. A carnivore that gnaws the end of a long bone is removing morphological details that otherwise might be measured or observed. A tractor may plow over a skeleton, dispersing the individual bones and making them difficult to recover. In some circumstances, taphonomic processes may actually help to preserve information by slowing down decomposition, such as when a body is buried or frozen, or when it mummifies. In addition, taphonomic processes leave their imprints on the remains, helping the analyst to reconstruct the broader ecological system of which the remains had once been a part. For example, the gnawing on the bones indicates, at least, that large scavengers had once been present in that particular ecosystem despite their absence when the remains were recovered. However, in most situations encountered by the forensic analyst working in a medico-legal context, the net effect of taphonomic processes is the loss of biologically meaningful information that otherwise would have been used to establish the identity of the decedent or the cause of death. It is useful then to view the remains as having passed through a number of ecological filters or screens, each of which has removed some proportion of the data that was once available.

Nawrocki (1995) identified three broad classes or categories of taphonomic processes and variables. *Environmental factors* are aspects of the environment that affect the remains. Temperature, ultraviolet radiation from the sun, and rainfall would all be classified as *abiotic* (nonliving) environmental factors. Carnivores, rodents, and plant roots can be classified as *biotic* (living) environmental factors. *Individual factors* are those intrinsic traits that the decedent brings to the decomposition process, such as body weight, age at death, and sex. *Behavioral or cultural factors* are the actions of humans that affect the remains, such as burial, embalming, and autopsy. Behavioral factors can be introduced by an assailant, by authorized funerary or medico-legal officials, and, in the case of suicide, by the decedent him- or herself (Congram 2014).

The taphonomic literature lists dozens if not hundreds of specific taphonomic factors that must be taken into account when one is analyzing human remains. However, experience suggests that three factors in particular tend to have the greatest effect on remains in a forensic setting: water, temperature, and exposure. The absence, presence, and quantity of water at the recovery scene can affect the remains at both the macroscopic and microscopic levels. Flowing water scatters remains and other evidence. The presence of excess water fosters the formation of adipocere (“grave wax”), an alkaline substance that eventually degrades bone surfaces. Too little water fosters mummification, preserving soft tissues and inhibiting necrophagous insect activity. Periodic wetting and drying encourage fracture formation as the bone expands and contracts. At the molecular level, water breaks down the protein-mineral bonds in the bone, increasing its fragility.

Temperature significantly affects biological and chemical reactions. As temperatures increase, insects and bacteria become more active, eating, growing, and reproducing more quickly. As temperatures dip to freezing, ice crystals form in soft tissues, bone, and soils, destroying cell structure, fostering the propagation of microfractures, and disrupting natural soil layering. However, biological processes slow as temperatures drop, and thus the decomposition process can grind to a near halt.

Remains exposed on the ground surface decompose and erode more quickly than do those that are buried. Burial tends to shelter the remains from animals, water, and climatic extremes (such as freezing). In addition, buried remains and evidence are not as susceptible to scattering and thus are more likely to be recovered and available for analysis. However, burial makes remains more difficult to locate at the outset, and so more time may pass before recovery, allowing subsurface factors (such as erosion of bone from soil acids) more opportunity to occur.

Taphonomy and the Crime Scene

The outdoor forensic scene is a dynamic microecosystem in which the three major categories of taphonomic factors interact in significant ways. Figure 25.1 presents a simple schematic of these interactions. On the one hand, the assailant affects the remains by introducing trauma, initiating burial, and positioning the body within the grave. In return, the victim's characteristics affect how the assailant processes the body; if the decedent is large or very heavy, the assailant may not be able to dispose of the body in a remote area or as quickly or as deeply as a small and light decedent. This two-way interaction is labeled pathway "A" in Figure 25.1. Pathway "B" illustrates the interaction between the assailant and the environment. The assailant alters the natural soil stratigraphy when excavating the grave, tramples vegetation, and leaves compacted footprints. In return, the environment influences where the assailant chooses to place the body, with plants (for example, poison ivy) and/or animals/insects (for example, mosquitoes) potentially affecting the assailant. Pathway "C" illustrates the interaction between the environment and the remains. The environment (soil, plants, animals, and climate) affects the way and rate that the remains (soft and hard tissues) decompose. In return, the decomposing remains give off fluids that change soil pH, moisture content, and nutrient availability.

In a forensic context two broad subfields of taphonomy have emerged in the past decade. The more traditional application is *biotaphonomy*, which examines modifications to the remains themselves. The scope of biotaphonomy centers on the remains in Figure 25.1. A more recent addition is *geotaphonomy*, which is concerned with the effects of the assailant and the decomposing remains on the surrounding geological and sedimentological environment (Hochrein 1997a, b, 2002). The scope of geotaphonomy is therefore centered on the environment in Figure 25.1. Issues of interest in geotaphonomy include the differential aeration, compaction, and mixing of

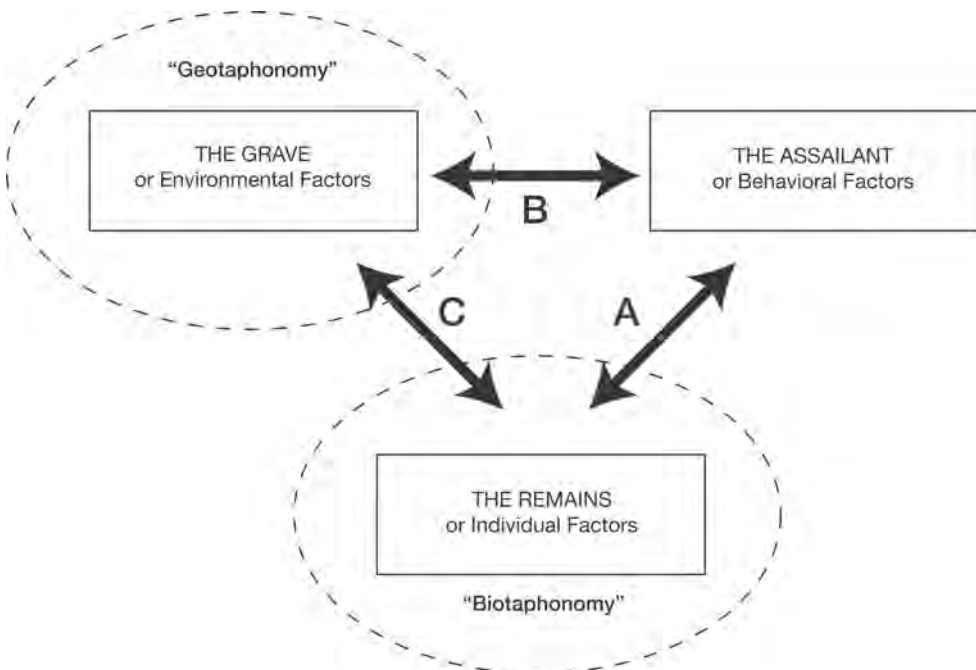


Figure 25.1 Interaction model of taphonomic factors encountered at forensic scenes (courtesy of the author)

the soil within a graveshaft, staining and chemical alteration of the soil by decomposition fluids, the production and identification of toolmarks, footprints, and handprints in the soil, and the disruption (acceleration or retardation) of plant growth in the vicinity of the body. The immediate practical applications of geotaphonomy lie in the ability to locate buried remains, to identify graves that have had the remains removed from them, and to help reveal the actions of the assailant. Clearly, careful geotaphonomic analysis requires detailed observation at the crime scene, and most geotaphonomists would identify themselves primarily as field archeologists rather than osteologists. Biotaphonomy has traditionally fallen within the confines of the osteology laboratory, although most practitioners have also come to realize that a detailed understanding of the context of the recovery scene is crucial to an accurate biotaphonomic reconstruction. It is much more difficult to envision the range and diversity of forces and factors that could have affected a skeleton if one has not examined the specific microenvironment of the recovery scene first hand.

The Circumstances of Death

By applying both biotaphonomic and geotaphonomic approaches, and by taking into account the environment of the recovery scene, the taphonomist may hope to reconstruct what may be broadly described as the “circumstances of death,” including:

- 1 time or season of death (postmortem interval);
- 2 original location of death;
- 3 final resting spot of the decedent prior to being subjected to environmental forces that may have dispersed the remains;
- 4 relevant perimortem and postmortem behaviors of the assailant and the victim, such as interpersonal violence, ritual preparation of the body, and concealment or burial of the remains; and
- 5 actual physical trauma inflicted on the remains near the time of death.

Unfortunately, it can be difficult to discern exactly when a traumatic injury to a bone actually occurred (see Loe, Chapter 24 this volume). Fracture characteristics are dependent not only on the forces and objects that produce them but also on the physical state of the bone at the moment of impact. Living bone contains significant moisture, fats, and collagen protein, all of which affect how fractures propagate. Dry, dead bone reacts differently in the absence of these intrinsic soft tissues. Fractures in living bone tend to be smooth edged and spiraling, whereas fractures in dry bone tend to be jagged, friable, and transversely oriented (Symes et al. 2012). However, bone does not immediately acquire its postmortem characteristics, and it may take quite some time for a skeleton to begin reacting as if it really were dead. In other words a gunshot wound acquired at the moment of death can look the same as one inflicted minutes, hours, and even days afterward, if not longer. The “perimortem” period, therefore, is quite broad and defined not by the physiological death event or the passage of a fixed unit measure of time, but rather by the highly variable process of decomposition (Ubelaker 2015). Working under these limitations anthropologists must be extremely cautious when interpreting trauma. Ethically it can be argued that the anthropologist should not make pronouncements regarding the cause or manner of death, because the data rarely allow one to reconstruct the exact timing of the injury. Instead the anthropologist should simply describe instances of perimortem injury and allow the appropriate medico-legal officials to make their interpretations of the trauma within the broader context of the investigation.

Failure to reconstruct the circumstances of death properly can derail a death investigation. For example, natural processes frequently move a skull away from the body after decomposition of the neck tissues has occurred. Police at the scene or prosecutors interpreting the scene photographs may erroneously infer that the head was “severed” from the body by an assailant. Such an inference would clearly guide the medico-legal system’s classification and pursuit of the case; “decapitation” would tend to implicate another individual in the death, turning what would otherwise be a suicide or drug overdose into a homicide.

In addition to elucidating the circumstances of death, the forensic taphonomist may be asked to assess competing explanations of the evidence by

- 1 clarifying instances of postmortem “pseudotrauma” (such as animal gnawing) that could be misinterpreted as perimortem trauma;
- 2 verifying or excluding the statements of witnesses or potential suspects regarding the perimortem treatment and postmortem history of the remains; and
- 3 verifying or excluding the recovery account provided by civilians when the source of the remains is in question.

For example, during the course of a serial homicide investigation in central Indiana in the 1990s (Nawrocki et al. 1998; Nawrocki & Baker 2001; Baker Bontrager & Nawrocki 2005), the wife of the suspect revealed that a few years earlier, her teenage son had discovered a human skeleton in the woods behind their house. Her initial impression was that it was an historic pioneer burial that had eroded from an embankment. When she later asked her husband about the skeleton, he explained that it had been an anatomical specimen once owned by his father, a physician, and that he had recently placed it in the woods, thinking that it would disintegrate. The next day the husband collected and disposed of this skeleton (one of his victims), and the matter was at least temporarily resolved to his family’s satisfaction. If the wife had called the police immediately and the skeleton had been collected and sent out for analysis, would the forensic scientist in charge have been able to verify or reject the husband’s claim? The analysis could have shown that the skeletal remains were in fact of medico-legal significance. Commercially prepared anatomical specimens tend to display a specific pattern of modifications, including chemical bleaching, drilling, grinding, and repairs. Those that have been used for teaching anatomy may show “handling wear” and polishing, and those that have been hanging in display cabinets for years will display accumulated grime and dust in predictable locations. The remains of recently deceased homicide victims, in contrast, are expected to display a very different set of characteristics, depending on the postmortem interval and the nature of the recovery location. The taphonomist sorts through the traits displayed by the remains and would reject the suspect’s claim if too many features were found to be inconsistent with the proposed story.

The Taphonomic Profile

An anthropologist assists in the identification of the decedent by constructing a *biological profile*. This profile is a summary of the decedent’s biological characteristics, including ancestry, (see Sauer, Wankmiller, & Hefner this volume), sex (see Rowbotham this volume), age at death (see Rogers this volume; also Crowder et al. this volume), and body size (see Willey this volume). Each of these biological characteristics is associated with a particular suite of morphological traits that form a unique *biological signature* that has been validated by previous research on known specimens. For example, “males” tend to have larger bones and joint surfaces, bigger brows, more prominent crests of muscle attachment, and relatively short pubic bones, and when

present this suite of traits constitutes a signature of masculinity. In essence, the biological profile is a set of hypotheses that are tested when the decedent is eventually identified. The specific hypotheses (for example, “sex = male”) are generated by recognizing the presence of signature traits in the decedent’s remains.

The taphonomist works in a similar fashion. The first step in determining the circumstances of death is the construction of the *taphonomic profile* (Nawrocki et al. 1997; Schultz et al. 2003). The analyst looks for *taphonomic signatures*, or suites of traits that are known to indicate a unique set of perimortem or postmortem forces that once acted on the remains (Pokines 2014). The taphonomic profile is therefore a set of hypotheses regarding the perimortem and postmortem history of the remains, generated by recognizing signature traits expressed in the condition of the bones and soft tissues and taking into account the features of the recovery site. These hypotheses specifically address the sources, sequencing, and timing of any modifications to the remains and soil. The profile can also include a reconstruction of the ecosystem(s) in which the perimortem and postmortem histories occurred if no information on the original recovery site is available. Such scenarios might occur when bones are handed in to the local authorities anonymously or when they have been curated (stored) for many years in private collections. As with the biological profile, the hypotheses are generated from comparisons of the remains to specimens with known postmortem histories. These hypotheses can be tested when the decedent is identified and the actual circumstances of death become known via witness or suspect testimony, or when they are verified with other, independent scientific evidence.

To illustrate the process of taphonomic analysis in general and the creation of taphonomic profiles in particular, the following sections examine two different ecosystems and the pattern of basic postmortem modifications that are likely to be encountered in each one. The discussions use examples drawn primarily from the northeastern and midwestern United States, although with some thought the scenarios can be adjusted to fit specific conditions encountered in other parts of the world. Although certain modifications (such as carnivore damage) can occur in many ecosystems, the overall pattern encountered in each environment is unlikely to be duplicated exactly in the others. It is the overall constellation or suite of traits rather than the presence or absence of any particular trait that defines the signatures that are used to construct a taphonomic profile.

Location of Remains

To appreciate the potential impact the environment has on human skeletal remains, two different environmental settings, forested landscapes and agricultural fields, are discussed.

Forested Environments

By definition, wooded areas tend to provide cover that conceals illicit activities and prohibits easy identification or location of evidence owing to reduced sight lines. Therefore bodies that are deposited in woodland settings are generally found by accident by hunters and hikers long after skeletonization and dispersal of the bones has commenced. Recoveries usually occur during the cooler months when the foliage is at a low point and the ground surface can be seen. Forests are very active in a biotic sense, with extensive animal, plant, and bacterial activity ranging from the soil all the way up through the canopy. This activity can change dramatically from season to season and even over short distances, with local variations in elevation, moisture, and plant cover. Thus human remains found in woods can display a wide range of overlapping and time-sequential postmortem modifications, making them a challenge to interpret.

The forest floor accumulates leaf litter and plant debris that decompose slowly to form the topsoil. Bones on the surface can be partially or completely covered by this debris, which when wet stains the bones dark brown or even black as tannins leach onto their surfaces. Fungus, mold, and algae can produce exotic colors (oranges, reds, greens, and blues). Sunlight penetrates intermittently and seasonally, gently bleaching exposed portions of the bones. Minerals in the topsoil stain the bones on their dependent (downward) surfaces. The end result is a patchwork of different shades and shapes on all surfaces (Figure 25.2).

Roots from trees, shrubs, and vines are frequently found growing across and through bones and clothing (see Figure 25.2). Because plant roots secrete acids, where they contact the bone they can leave small, sinuous, rounded channels that should not be mistaken for cut marks. These channels are often lighter in color than the surrounding bone surfaces, because they remove cortex that has already been stained by minerals in the soil, leaving behind white, unstained bone below. In other circumstances root masses may leave dark, sinuous stains rather than etchings (Figure 25.3).

In most parts of North America medium- to large-bodied mammalian predators and scavengers can be found in woodland settings. They may include opossums, foxes, domesticated and feral dogs, coyotes, bobcats, mountain lions, and bears. Some of these animals (especially the canids) are known to scavenge and disperse human remains well after death, even past the point where the external soft tissues have completely decomposed (Haglund, Reay, & Swindler 1988, 1989). The throat and face, genital region, and internal organs of the central body cavity are



Figure 25.2 Human coxa on an active forest floor. Note the patchwork of light and dark areas caused by leaves, sun bleaching, algae, and soil. Roots have grown across and into the bone (courtesy of the author)



Figure 25.3 Root staining on a human cranium (courtesy of the author)

avored soon after death. Ribs are frequently broken or gnawed at their sternal ends to open the thoracic cavity. Hands are especially vulnerable and are one of the first portions of the body to be disarticulated and removed, as are toes, if not protected by shoes. Later in the decomposition process scavenging shifts to the remaining dried scraps of tissue surrounding the joints and to the more sheltered bone marrow. Marrow contains fats and proteins that can be accessed by chewing the ends off of long bones or by gnawing down the spongy flat bones (ribs, sternum, pelvis, vertebral bodies). Because it is protected, marrow can survive much longer than the external soft tissues, resulting in periodic episodes of carnivore scavenging that continue throughout the postmortem period.

Since odiferous remains are still likely to contain trapped fats, moisture, and collagen, carnivore fractures should, at least theoretically, be more similar to perimortem fractures rather than to dry, postmortem fractures. However, the unique morphology of carnivore teeth and jaws compared to typical death weaponry (guns, knives, blunt objects) allows the taphonomist to distinguish carnivore damage from true death-related trauma (assuming, of course, that the predator was not the cause of death to begin with!). Carnivore damage can be identified by both the overall pattern or distribution of damage to the skeleton and the specific modifications made by the teeth. Ragged crushing of edges, crests, and ends is the norm, generally accompanied by conical or triangular punctures, broad gnawing channels, and deep scratches or striations (Figure 25.4). Bone that has actually been swallowed and passed through the animal's digestive system will have smoothed edges and an acid-etched appearance (Figure 25.5). Scat located in the vicinity of the body should be collected and examined for missing bones and fragments.



Figure 25.4 Typical carnivore damage to human hand phalanges. Note the crushed edges, deep gouges, punctures, and tooth scratches (courtesy of the author).

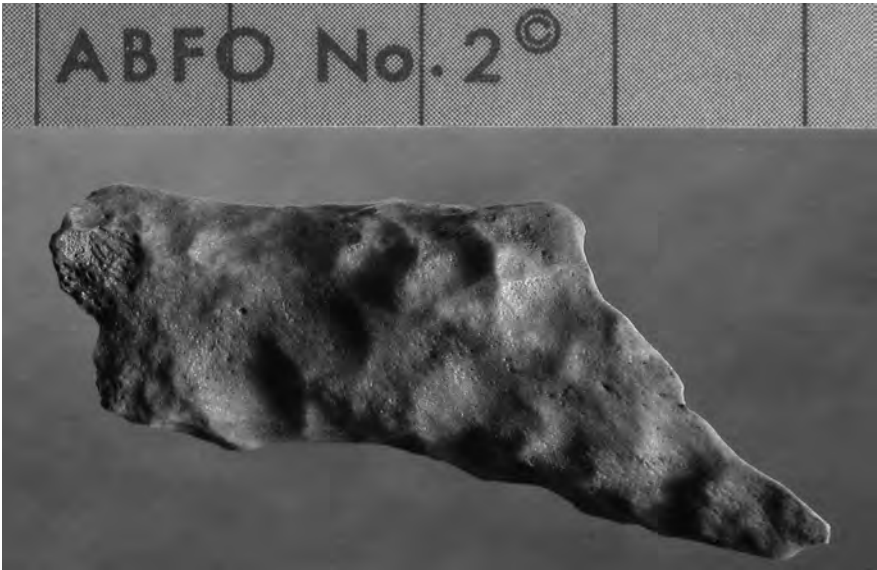


Figure 25.5 Fragment of animal cortical bone that has been digested by a domestic dog. Note pitting and smoothed edges resulting from exposure to stomach acids (courtesy of the author).



Figure 25.6 Rodent gnawing. Note the fan-shaped series of fine, parallel striations (courtesy of the author).

As bones lose their organic content (for example, fats and collagen), other mammals may alter the remains. Small rodents begin to seek out and gnaw bone surfaces in order to obtain minerals (for instance, calcium and phosphate) during lean times and also to sharpen and shorten their continuously growing incisors. Rodent gnawing can take the appearances of small “fans” or triangles of fine, parallel striations (Figure 25.6). Usually edges and projections are removed first, meaning that biologically diagnostic features of the bone (brows, muscle attachment points) may be lost, giving a false impression of gracility and thus femaleness. In the Midwestern United States we rarely encounter outdoor rodent gnawing during the first year of the postmortem period, presumably because the bones are not yet dry enough. Sometimes rodent gnawing can be found superimposed over carnivore gnawing or other modifications that occurred earlier in the perimortem or postmortem sequence (Figure 25.7).

The biotically active forest floor results in quick destruction of the decomposition fluid stain in the soil and rapid breakdown of hair and natural fibers (as in cotton and wool clothing—for example, Card et al. 2015). Plastics and human-made fibers (nylon, polyester) survive longer, particularly since they tend to be partially shielded from ultraviolet radiation by the overhanging tree and shrub canopies and by accumulated leaf litter. Dispersal of the remains in the forest depends primarily on the land contour and terrain features, drainage characteristics, and access by carnivores. Investigators are well advised to learn to recognize and follow game trails. Rodent burrows and bird nests should be examined carefully. Secondary, superficial burial of individual bones and smaller pieces of evidence that were originally deposited on the surface can occur as a result of multiple seasons of leaf litter buildup as well as by freeze-thaw cycles in the topsoil. Moist soil, when frozen, can develop deep fissures into which small elements can fall from the surface. During a rain or snowmelt soil will be washed into the fissures, re-leveling the ground surface. This process (known as *cryoturbation*) can result in significant loss of evidence in just a few years, and the archeologist should therefore modify search and recovery strategies at the scene to find these concealed elements.

In summary, the taphonomic profile for remains found in forested settings reflects the complex interplay of biotic and abiotic factors across seasons and between varying pockets within the ecosystem. Mottled and complex bone staining patterns are to be expected, as is plant,

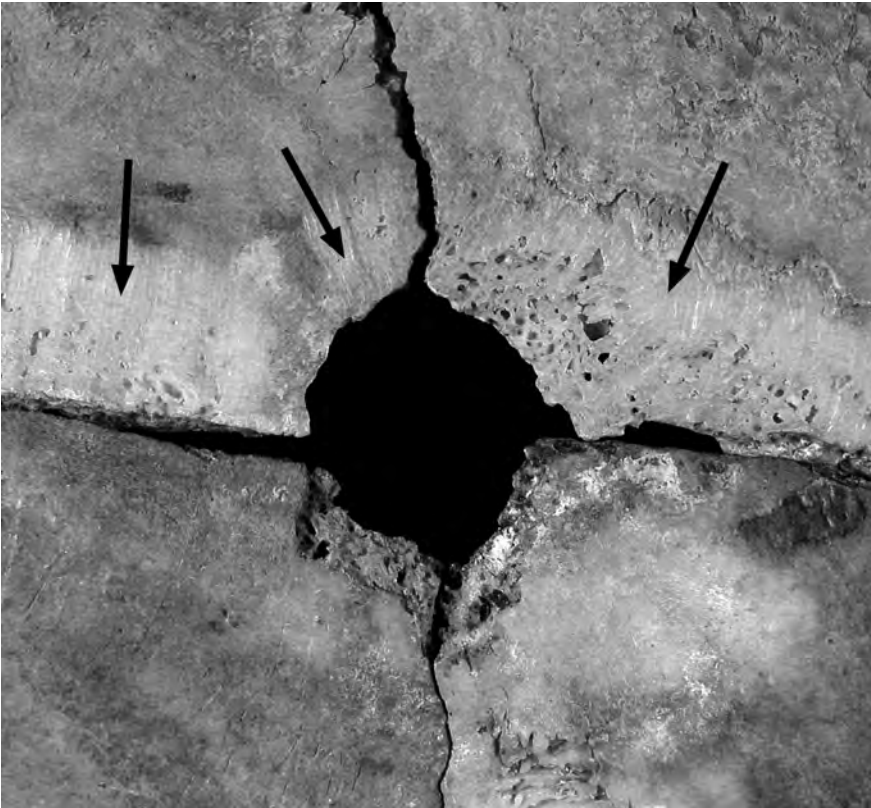


Figure 25.7 Rodent gnawing along the radiating fractures of a gunshot entrance wound. The beveling caused by the gnawing (arrows) gives the erroneous impression that the wound is an exit (courtesy of the author).

carnivore, and rodent modification. Dispersal of remains will be dependent on the slope of the terrain and carnivore activity, although because of the presence of trees and brush, one would expect less transport than would normally be encountered in other ecological settings.

Remains in Agricultural Fields

In contrast to the biotically active, highly variable, and sheltered ecosystem of the forest, agricultural fields tend to be less biotically diverse, more spatially homogeneous, less sheltered, and more culturally modified. Farmers tend to work their fields at predictable times throughout the year, and human remains are found most frequently during cultivation (spring) and harvesting (fall).

Most large farm fields in the North America are strictly controlled with chemicals and fertilizers, producing efficient monocultures but reducing botanical diversity within. Broad-leaf killers and the shade produced by taller crops inhibit competitive plant growth between rows, leaving patches of the ground surface exposed for much of the year. Bones present on the surface will tend to show much less plant root invasion when compared to forested

environments, although if the ground is sufficiently moist, algae will grow and stain the bones and soil green. The highly irregular patchwork pattern of colors and dark shapes produced by leaves and twigs on a forest floor is generally not seen in fields. However, because cultivation may partially bury bones, larger elements may display uneven or diffuse brownish-red staining from irons in the soil.

Grasses, weeds, and shrubs tend to accumulate at the boundaries of fields, providing a suitable nesting and foraging habitat for small rodents and their hunters. However, we tend to see much less rodent gnawing on remains found in fields, probably because loose, dry bones become buried by successive seasons of cultivation before they can be modified. The presence of carnivore damage is highly variable. If a coyote den or hunting trail is in the vicinity, or if farm dogs live nearby, then the remains may quickly attract these scavengers. However, the open exposure of cultivated fields may tend to discourage wild canids while attracting other types of scavengers. Soaring vultures, some of which locate dead carcasses with their highly developed sense of smell, have only recently been recognized as important taphonomic agents at forensic scenes (Pokines & Baker 2014). In Belize, black vultures (*Coragyps atratus*) were able to remove all skin, muscle, and internal organs from a 20-pound piglet in under an hour; the bones of the trunk were fully disarticulated and scattered across the surrounding terrain (Halling, Nawrocki, & Gibbs 2009). Avian scavengers may not be able to inflict the same degree of damage to the bones as terrestrial carnivores, but they do tend to produce a signature suite of traits, including dropped feathers at the scene, characteristic whitish scat, and bony alterations such as linear scratches and triangular punctures in thin bones (Figure 25.8).

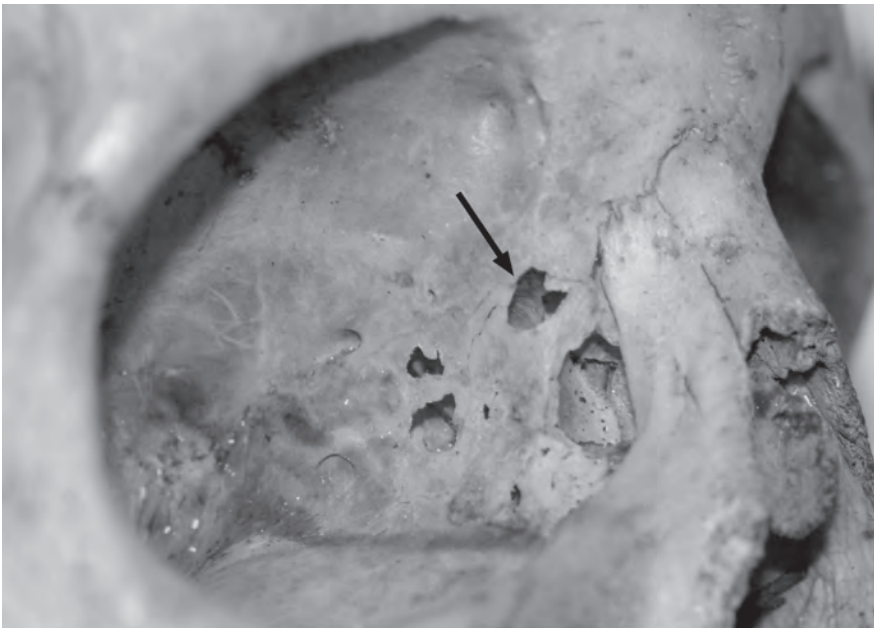


Figure 25.8 Damage to the orbital cavity due to vulture scavenging. The triangular shape of the largest puncture (arrow) matches the outline of the tip of the bird's beak (courtesy of the author).

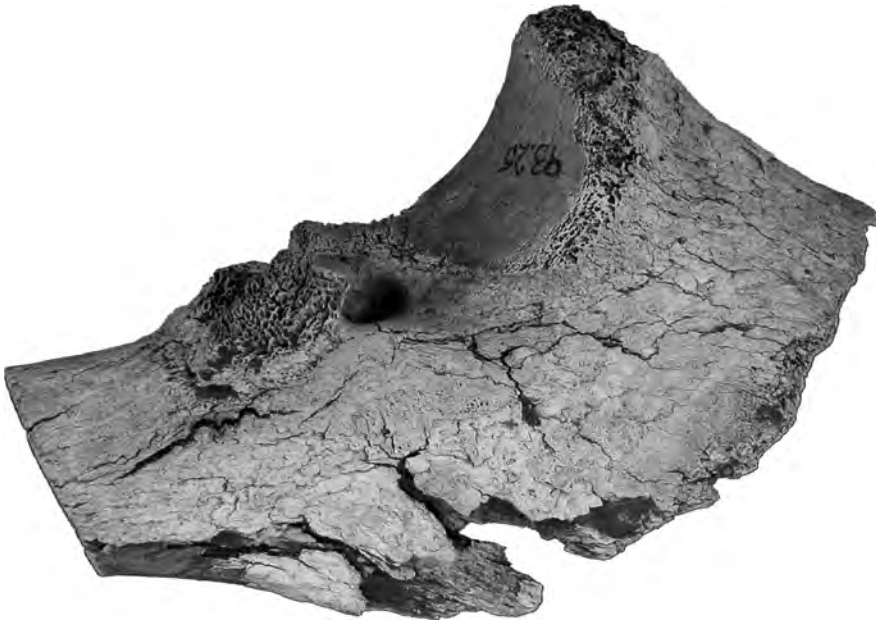


Figure 25.9 Proximal ulna of a cow illustrating extensive sun-bleaching and exposure-related fracturing (courtesy of the author)

Bones in a field are generally exposed to high levels of ultraviolet radiation and become extensively sun-bleached. As water evaporates or freezes on the surface of the bone, small microfractures accumulate and converge to form larger networks of flaking and erosion, ultimately resulting in extensive damage (Figure 25.9). If these fractures form on a curved surface, a star-shaped pattern may occur that can be misinterpreted as perimortem blunt force trauma (Figure 25.10). After a few years of constant exposure, the bone may crumble from the accumulated erosion. Human made fibers in clothing and plastics break down more quickly in fields because of higher exposure to ultraviolet radiation. Colors of personal belongings may fade rapidly.

Cultivation and harvesting practices that employ heavy machinery have two major effects on remains and evidence deposited in fields: extreme dispersal and damage. Plows, planters, and disk-ing equipment drawn by tractors have numerous projecting elements that can easily capture and transport bodies, portions of bodies, and bones. Skulls in particular are readily impaled and can be dragged hundreds of yards before breaking or being pulled off. The degree of dispersal depends on a number of factors that are difficult to quantify. Loose clothing may catch easily. As the body decomposes, its vertical profile diminishes. Therefore, fresh remains may be more easily trapped than decomposed remains. However, fresh remains are generally heavier than isolated elements and may fall from the machinery more quickly. A “lo-till” tillage method, which leaves the previous year’s crop residue on the surface rather than plowing it under in the spring, disturbs the soil much less than a “full-till” method. The type and configuration of the machinery, the tillage method employed, and the speed of the tractor will all affect dispersal rates.

In the end one would expect significantly more dispersal of remains in cultivated fields than in forested environments, necessitating more human power and time during the recovery.

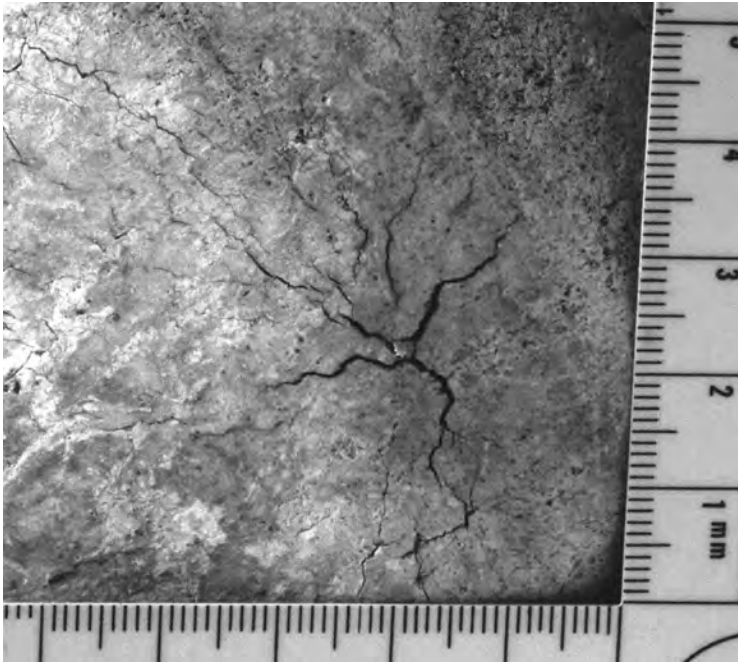


Figure 25.10 A star-shaped or “stellate” arrangement of postmortem fractures on the curving surface of a human parietal bone, resulting from sun-bleaching and freeze-thaw cycles. The keys to correct diagnosis are the rather wavy fracture lines and the presence of fractures that do not converge at the center of the defect (courtesy of the author).

Search strategies should take into account the type of crop, the cultivation patterns used by the farmer, and the presumed original point of deposition of the body. Remains tend to disperse along the primary direction of plowing rather than perpendicular to it. Since farmers usually replicate their plowing patterns from year to year, it should not be difficult for the investigator to predict the most likely direction of movement of remains even if the postmortem interval is more than one or two growing seasons. However, bones that are picked up by the rotating barrel of a combine can be shot out laterally, perpendicular to the direction of plowing. Therefore it is important to interview the farmer to learn what types of equipment have been used in recent years and whether there were any deviations from normal cultivation practices.

Locating the original position of the body can be extremely difficult in agricultural fields. If the individual decomposed since the last tillage, the investigator may be able to locate the decomposition stain. Otherwise, one will have to reconstruct the epicenter by carefully plotting the distribution of bones and evidence on a map. If the remains were struck soon after being deposited, the entire body could have been transported and the mapped epicenter may be far off of the original deposition point. If, however, the remains had decomposed significantly before being hit, a pocket or concentration of small bones, loose teeth, and hair fragments (if they can be found), may indicate the location of deposition.

Farming equipment can inflict significant trauma to the remains, including blunt force fractures, crushing, gouging, scratching, puncturing, and cutting (Figure 25.11). Depending on



Figure 25.11 Sharp force trauma to a lumbar vertebra caused by disking equipment (arrow). The margins of this incised wound show slight erosion due to continued surface exposure (courtesy of the author).

when it occurs, farming damage can be very difficult to distinguish from perimortem trauma related to the cause of death. Incised wounds caused by disking equipment on fresh bones can look exactly like knife wounds. However, the distribution of the wounds on the skeleton will not necessarily conform to what would be expected for a typical attack by an assailant. In addition, if the disking unit hit the remains after they had become at least partially disarticulated, the cuts may not make anatomical sense, crossing a joint on one side but not on the facing surface, or crossing areas that would normally be inaccessible to an assailant (such as the vertebral bodies).

In summary, the taphonomic profile of remains found in an agricultural setting differs in important ways from that of remains found in a wooded setting. Bone staining patterns are likely to be simpler compared to forests, and plant modifications are less likely. Animal activity is more variable and less easy to predict, although rodent gnawing tends to be less common. Dispersal of remains is likely to be greater by orders of magnitude compared to forests, and the chance of quick burial of evidence is higher, depending on the cultivation methods being used and the timing of deposition of the body around cyclical farming activities. However, the regularity of plowing at least makes it possible to come up with good predictions about the direction of dispersal. The investigator should expect significant trauma introduced by farming equipment, and it will be a challenge for the forensic anthropologists to differentiate this trauma from that inflicted at the time of death.

Conclusion

Forensic taphonomy is a broad and somewhat nebulously defined field that integrates methods and data from a number of disciplines, including anthropology, paleontology, geology, biology, entomology, chemistry, and pathology. By constructing a taphonomic profile for a set of remains,

the analyst tries to answer important questions concerning the circumstances of death of the individual. A useful and accurate profile is dependent on:

- 1 Proper and thorough recovery methods at the scene: has everything been found?
- 2 Background research and interviewing of relevant individuals: can the landowner provide some insight regarding the recent history of the property?
- 3 Detailed description of the physical condition of the remains in the lab: have all modifications been identified, and do they form clear signatures?
- 4 Knowledge of relevant taphonomic factors that apply in various environments: how does this scene differ from others?
- 6 A comparative ecological approach.

In other words, taphonomy must be holistic as it is applied in forensic settings, and the analyst must be able to shift easily between—and integrate—laboratory analysis and fieldwork.

There is considerable research that can be conducted in the future to help guide the discipline. Because of the great variety of environmental factors and the unpredictable length of time that potentially passes before the discovery of remains, it is difficult to design comprehensive experiments that can control for even the most important variables. To date most forensic taphonomy studies have been largely anecdotal, drawing primarily from casework rather than from experimental data obtained from rigorously controlled settings. The biggest drawback of such retrospective studies is that they may have significant gaps in the data; the deaths encountered in a single jurisdiction in a given time frame are unlikely to encompass all of the factors relevant in a particular ecosystem, nor are the associated criminal and forensic investigations likely to provide all of the relevant details necessary for rigorous hypothesis testing at the conclusion of the case. Even controlled experiments are disadvantaged by a lack of statistical power; the variance in relatively small samples must be partitioned across many potentially-relevant independent (environmental) variables.

Nonetheless, the ecological approach has the potential to revolutionize the way we view old problems. For example, Megyesi and associates (2005) attempted to generate a more precise method of estimating time since death from decomposing soft tissues using crime scene temperature data. Applying the concept of accumulated temperature as borrowed from entomology, they were able to account for 85% of the variance in soft tissue decay in a sample of 69 forensic cases with known postmortem intervals (Nawrocki 2011). Subsequent studies on both pigs (Schiel 2008) and humans (Madaj 2012) have validated this approach. The strong association between accumulated temperature and soft tissue decay not only provides a more quantitative way to estimate time since death, it also suggests that traditional attempts to generate regionally specific models of decomposition in different parts of the country may be unnecessary once temperature is properly controlled for (Nawrocki & Latham 2013).

Perhaps the most crucial issue facing future researchers is that of differentiating between perimortem and postmortem modifications, and particularly between death-related trauma and injuries that occur after death but still within the perimortem “fresh” interval. Of the issues that the anthropologist is likely to testify on in a court of law, the identification and the clarification of skeletal trauma are probably the most common. Only recently have detailed primers on the topic been developed (Galloway 1999; Symes et al. 2014), and most practitioners have traditionally relied on their experience after excavating and examining thousands of bones from diverse settings. Ironically, there are far more publications regarding the construction of the biological profile than of the taphonomic profile, yet few anthropologists actually testify on biological procedures, because final positive identification is generally the purview of other experts. Clearly,

interdisciplinary efforts to identify trauma are sorely needed, including controlled experimentation as well as comprehensive case reviews.

Unfortunately, those of us who train forensic anthropologists have noticed a significant decline in recent decades in our students' familiarity with the natural world; relatively few have substantive experience in farming, hunting and fishing, or manual labor in outdoor settings, and this trend seems to be inversely related to the growth of our information-based society and our increasing reliance on electronic substitutes for experiencing the world (Nawrocki & Latham 2012). As a result, students do not arrive with an innate understanding of the earth's natural cycles, cannot easily identify causal relationships in the ecosystem around them, and fail to recognize how natural processes can modify the objects in their environment. Extensive hands-on experience with—and immersion in—nature provides the most crucial foundation for a taphonomist.

Finally, anthropologists must themselves recognize that their training and expertise give them a much broader mandate to assist in medico-legal casework than has generally been acknowledged. Archaeology, as a valid subfield of anthropology and one that is not taught by any other discipline, is clearly needed in medico-legal investigations throughout the world (Dirkmaat & Adovasio 1997; Nawrocki & Latham 2012). The unique position of anthropologists is such that they can offer expertise both in the laboratory and in the field, and this dual role gives them a unique perspective that should greatly assist in the guidance and development of the science of forensic taphonomy.

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Burned Human Remains

Tim Thompson and Priscilla F. Ulguim

Burned human remains have been the focus of study by anthropologists and archaeologists for over 70 years.¹ The complexity of the heat-induced transformation process, in conjunction with the sheer range of contexts in which it is found, has allowed for an exciting range of studies to be undertaken. While previous work (for example, Thompson 2009) has argued that we know little of the effect of burning on bone, recent work (often the sustained work of specific research groups) has revealed much about the response to heat of this complex biomaterial. Nonetheless, it is still a challenge to apply this knowledge to archaeological and forensic situations involving burned human remains.

This chapter provides a summary of the work conducted in this field to date. Initially, research and practice are placed within a social framework, followed by a consideration of the current knowledge base. Finally, we explore future development of the subject.

Much has already been made of the lack of integration concerning the study of burned remains (Thompson 2005, 2009). First, there is a lack of communication between the three main disciplines that study the subject (forensic anthropology, archaeology, and medicine), which still manifests as a lack of cross-discipline publication, citation, and collaborative research. Second, there is a disjunction between the study of the soft and hard tissues. However, while acknowledging this disjunction, this chapter focuses on the effects of burning on the hard tissues, mainly because of the fact that bone and teeth fall more within the remit of the anthropologist and archaeologist, and the relative complexity of the transformations of the hard tissues compared to the soft tissues. Good summaries of the effects of burning on the soft tissues can be found in Payne-James, Busuttil, and Smock (2003), Saukko and Knight (2004), and Thompson (2015).

The Context of Burned Human Remains

The context of discovery is important for practicing forensic anthropologists and archaeologists, because the location, recovery, and examination of burned human remains are often extremely challenging, occurring in scenes often highly significant in a judicial context. Initial problems that must be overcome include the collection of highly fragmented material from a mass of fire damaged debris without delay, together with the stabilisation and storage of this fragile source of evidence (McKinley & Roberts 1993; Dirkmaat 2002; Mayne Correia & Beattie 2002; Hill, Lain, & Hewson 2011; Waterhouse 2013; Berketa 2014). Recent detailed excavation methodologies use principles of archaeoethnatology and GIS technology to investigate such commingled deposits (Naji et al. 2014); however, integrated curation protocols are also required to ensure remains are stored without loss of information. Forensic practitioners may also require

adequate storage for other types of burnt human tissue, potentially on a huge scale—for instance, following mass fatality incidents (Meyer 2003).

Furthermore, the techniques employed to create an accurate biological or osteological profile of an individual generally rely on unmodified bone dimensions. Unfortunately, heat-induced dimensional change to osseous elements is highly significant and can result in long-bone length change of up to 30% (Thompson 2005; Gonçalves, Thompson, & Cunha 2013).

An understanding of the heat-induced transformation of the human body is important for forensic anthropologists and archaeologists, since the range of contexts from which burned bodies can be recovered is broad. Interpretations are further compounded by the fact that fire and burning are used in a variety of ways, including as a functional medium for transformation or as a potent symbol in its own right. In all these situations, however, the study of burned remains inevitably leads to the study of humans and their actions. In this respect context is all important: burned human remains do not simply occur in a vacuum but are, rather, mostly the result of human agency.

Many terms have been used poorly and interchangeably within the literature to describe burned human remains and their contexts—examples include *burned remains*, *cremations*, *cremains*, and *calcined remains*. However, they do not all mean the same thing. To describe the remains themselves, we should limit ourselves to the use of *burned human remains* or simply *burned remains*. *Cremation* is a term that relates to particular social practices involving the burning of human bodies, such as funerary practices, in the approach to current Western cremations within dedicated crematoria and associated postprocessing, or pyre-based cremation events that may encompass combustion of a pyre-structure, the corpse, and associated pyre-goods until the formation of a cooled ash-bed (Marshall 2011). Subsequent buried remains may be referred to as a *cremated deposit*, indicating the bone and related burnt debris selected for subsequent deposition or burial (Marshall 2011). *Calcination* is a physical process of transformation within bone, and since it is unlikely to affect the entire skeleton or set of remains the term *calcined* inherently implies that the entire entity has progressed through this process. Similarly, *charred* or *carbonised remains* refer to change as a result of the burning process; as material is heated it may initially blacken and carbonise (Symes et al. 2008). The word *ashes* is sometimes used to describe such remains but more closely relates to the product of grinding than combustion. Finally, the conjoining of the words *cremated* and *remains* is unnecessary: we do not conjoin dismembered remains, weathered remains, or any other taphonomic process: there is no need to in this instance either.

Historical Themes and Prior Developments

Early analyses of burned bone tended to be isolated or preliminary studies (for example, Wells 1960; Binford 1963; Bradtmiller & Buikstra 1984; Buikstra & Swegle 1989). Interesting though they are, the result has been a lack of a cohesive, coherent body of knowledge. These early publications focused on obvious heat-induced changes, visible to the naked eye or, at most, with scanning electron microscopy. However, one early study turned out to be one of the more progressive. Van Vark (1974, 1975) appreciated that, owing to the occurrence of heat-induced changes in bone, multivariate statistical methods were needed to improve the precision and accuracy of anthropological techniques. There are two methodological limitations, however, with Van Vark's work. First, his multivariate functions often cannot be applied to burned remains with only a small amount of recovered hard tissue (Van Vark 1974). This is likely to be a common situation, especially when one is dealing with archaeological remains. Second, he states that often only proportional measures, that is, indices, can be used (Van Vark 1974). In theory this is a

sound principle, his rationale being that proportional measures will not be affected by shrinkage. However, more recently it has become clear that bone does not shrink uniformly (Gonçalves, Cunha, & Thompson 2013). This fact will therefore affect the outcome of indices owing to the changing relationship between the variables being measured (McKinley 2000; Thompson 2002; Gonçalves, Thompson, & Cunha 2013). Unfortunately, subsequent studies moved away from this rigorous statistical methodology.

The next series of enquiries tended to focus on the use of actualistic experimental studies for understanding the effects of burning on bone. Studies such as those undertaken by Thurman and Willmore (1981); Gilchrist and Mytum (1986); Buikstra and Swegle (1989); and Spennemann and Colley (1989) aimed to provide explanations of how and why burned bones looked as they did. It is important to appreciate that forensic anthropology and archaeology were still very much in their infancy at this time, meaning that these early studies derived from archaeological questioning. One of the key arguments in these studies (Baby 1954; Binford 1963; Thurman & Willmore 1981; Buikstra & Swegle 1989) was that specific bone fracture patterns allow one to state whether remains were fleshed, recently defleshed, or dry when burned, which has important medicolegal and archaeological implications. Thurman and Willmore's (1981) experimental study on dry bones recorded longitudinal and perpendicular fractures and the presence of gridded patterns. Buikstra and Swegle (1989) later noted that longitudinal fractures occur along the length of the bone but that transverse fractures are less frequent than in fleshed remains. This observation supports the observations of other publications (including more recent ones) that have argued that the fracture patterns of fleshed remains are less linear, less regular, and have frequent elliptical cracking (Baby 1954; Binford 1963; Thurman & Willmore 1981; Mayne Correia 1997; McKinley 2000). See Gonçalves and associates (2011, 2014) for recent work.

Colour change was examined in these early studies; concluding that bone altered from its natural colour of creamy white, through dark greys and black, and then, if burning continued, through light greys to white. Colour change has been suggested, with varying degrees of conviction, as a means of predicting the temperature of the fire in which the remains were burned (for example, Shipman, Foster, & Schoeinger 1984; Chandler 1987; Grevin et al. 1998). However, later work has shown this idea is likely to be flawed owing to the actions of many other variables (Thompson 2004). Colour change is better described as the loss of carbon from the osteological matrix (Mayne Correia 1997). Shipman, Foster, and Schoeinger (1984) were the first group of anthropologists to use a standardised colour chart for defining colour in the examination of heat-induced change. Currently researchers are improving the systematisation of colour recording and performing analysis of quantifiable data, facilitating a more nuanced understanding of fire dynamics and surface exposure variation (Walker, Miller, & Richman 2008; Ellingham et al. 2014; Sandholzer 2014; Thompson et al. *In press*).

Studies of burned bone and hard tissues subsequently evolved in two ways: either (1) continuing the theme of examining why bones looked as they did, but through the application of more revealing technologies, or (2) examining implications of the effects of burning for anthropological information. Shipman, Foster, and Schoeinger's (1984) classic study of the effects of burning on bone and teeth examined the changing nature of the crystal structure of the inorganic matrix. Using X-ray diffraction (XRD), these authors noted a gradual increase in hydroxyapatite crystal size, associated with temperature increase. They explained this phenomenon as a function of some crystals enlarging at the expense of others. Shrinkage was also recorded and noted to range from 3% to 45% (for example, Shipman, Foster, & Schoeinger 1984; Gilchrist & Mytum 1986; Buikstra & Swegle 1989; Holland 1989; Spennemann & Colley 1989; McKinley 2000). Differences were likely due to variance in experimental protocol.

Recent Themes and Current Developments

Understanding the macroscopic changes to bone as presented by earlier studies is extremely important and highlights the significant effect that burning can have on skeletal remains. However, these macroscopic alterations in themselves are not enough to explain the relationship between heating and bone change, since these macroscopic changes are actually caused by more fundamental dynamics. Thus these macroscopic changes (such as colour change or fracture patterns) are termed *secondary-level changes*, and underlying microscopic changes are called *primary-level changes* (Thompson 2004). Added to these changes are the realisation and acknowledgment that both primary and secondary-level changes of bone affect the results of anthropological techniques, which in turn may affect attempts at human identification (Gonçalves 2011, 2014; Gonçalves, Cunha, & Thompson 2013; Gonçalves, Thompson, & Cunha 2013).

Innovative Microscopic Investigative Techniques

As the focus moved toward closer investigation of primary-level heat-induced changes in bone, it became necessary to adopt new methods of study, assimilated from other disciplines, such as physical chemistry and soil sciences (Table 26.1). These new approaches are of great relevance for forensic casework since they often permit the analysis of burned bone to reach the Daubert standards, allow for greater interlaboratory comparison, and provide more robust understanding of the nature of the burning event. The first issue of interest concerned the influence of burning on the elemental composition of bones. Changes in trace-element composition may result from heat-induced recrystallisation of the inorganic phase evicting elements from the bony matrix or uptake of elements from the soft tissues, firewood, or burning context (Grupe & Hummel 1991). Experimental analyses allowed Grupe and Hummel (1991) to produce linear regression equations to describe the changes in certain trace elements. Changes in calcium, phosphorus, and strontium provided the most robust formulae. Changes in barium and lead were less robust, whereas changes in copper, zinc, and magnesium appeared to be unrelated to temperature change. However, Herrmann and Grupe (1988) and Grupe and Hummel (1991) warn that recorded increases in trace elements may not simply be due to elemental uptake but to reductions in the organic component of the bone, thereby increasing element concentration relatively, not absolutely. Sillen and Hoering (1993) advanced these notions by attempting to use the concentrations of elements to state whether bone

Table 26.1 Advanced analysis of burned human remains

Method	Application in Studies of Burnt Bone	Useful References
Histology	Bone structural change	Hanson and Cain 2007; Harbeck et al. 2011
XRD	Bone crystal structure and porosity	Holden et al. 1995a
FTIR	Bone crystal composition	Thompson et al. 2009
SAXS	Bone crystal parameters and morphology	Hiller et al. 2003
Trace element Analysis	Elemental composition	Shipman et al. 1984; Grupe and Hummel 1991
DNA extraction	Species and individual identification	Schwark et al. 2011
Immunology	Species identification	Cattaneo et al. 1999

had been burned or not. Unfortunately, with regard to changes in the mineral component, heat-induced diagenesis is so similar to normal bone diagenesis (Herrmann & Grupe 1988; Koon, Nicholson, & Collins 2003) that trace element concentration alone can identify only whether bone has suffered some form of diagenesis, rather than the cause. More recently, trace element ratios have been used to analyse isotope preservation in calcined bone, such as strontium, which may indicate area of origin (Harvig et al. 2014; Snoeck et al. 2014), while other studies have focused on the known impact of combustion-related carbon exchange on radiocarbon dating (Olsen et al. 2013; Snoeck 2014).

Following the examination of heat-induced elemental alteration, researchers began to focus on issues surrounding physical changes to the bone microstructure, specifically through studies of crystal structure and porosity. X-ray diffraction has been repeatedly used to examine the changes of the microscopic crystal architecture of bone due to burning (Shipman, Foster, & Schoeinger 1984; Newesely 1988; Holden, Phakey, & Clement 1995a; Stiner et al. 1995; Rogers & Daniels 2002). Results from Rogers and Daniels's X-ray diffraction experiments suggest an increase in crystal size associated with increasing burn temperature. Thus crystals transform from their small but highly anisotropic state into one with a significantly larger equidimensionality (Rogers & Daniels 2002). They place the key transformation section point at around 800°C, which is consistent with Holden, Phakey, and Clement (1995a), whose experiments placed this between 600°C and 1,000°C. Furthermore, large highly ordered crystals (associated with higher burning temperatures) produce higher splitting factors than small disordered crystals (Stiner et al. 1995; Roberts et al. 2002). However, the apparent crystal changes may actually be due to alterations in crystal size distribution rather than simply size (Rogers & Daniels 2002)—that is, the resorption of small crystals being interpreted as crystal growth.

Small-angle X-ray scattering (SAXS), a technique for discerning subtle changes to bone nanostructure, has been shown to accurately detect crystal size, shape, and orientation changes within bone (Hiller et al. 2003). SAXS results show that bone crystallites begin to alter in the first 15 minutes of heating to 500°C or above. They then appear to stabilise to a temperature-specific thickness and shape with prolonged heating. SAXS has also shown that burning causes the crystals to become more plate-like, rather than needle-like as in unburned bone, progressing toward a polydisperse crystal shape (Hiller et al. 2003). Within teeth SAXS has also provided evidence for an increase in crystal thickness, decrease in alignment, and shape change that can be related to temperature increase (Sandholzer et al. 2014).

Methods such as Fourier Transform Infrared Spectroscopy (FTIR) have also been applied to investigate crystal structure using infrared spectra (Thompson, Gauthier, & Islam 2009). This method allows the calculation of ratios such as the Crystallinity Index (CI) or Infrared Splitting Factor, which measures the order of crystal structure within the bone matrix. This structure increases with temperature as crystals become larger and more organised within the lattice (Stiner et al. 1995; Thompson, Gauthier, & Islam 2009). Such methods have been applied in conjunction with histological and histomorphometrical analysis of microscopic structural changes resulting from burning that occurs within the bone matrix. Progressive histological changes can be linked to the stages of transformation for burned bone: structures deteriorate from approximately 200°C, up to total loss of structures around the important 800°C point (Herrmann 1977; Bradtmiller & Buikstra 1984; Thompson 2005; Hanson & Cain 2007; Harbeck et al. 2011; Squires et al. 2011; Castillo et al. 2013).

The extraction of DNA from burned human remains poses unique challenges, mainly because DNA begins to denature at around 100°C. As average house fires reach 700°C, if not more, the probability of successfully recovering DNA from the hard tissues for identifying the deceased in fire death scenarios appears low. Von Wurmb-Schwark and colleagues (2004,

2005) extracted DNA from bone from crematoria but concluded that this was contamination. However, other experimental studies have managed to tease out this biomolecular fingerprint; Imaizumi and associates (2014) in bone heated to 250°C or lower, and Schwark and colleagues (2011) from black burned bone, and sporadically from blue-grey coloured bone, when using techniques for amplifying degraded DNA (miniSTRs, SNPs, mtDNA). Few reliable results were obtained for blue-grey-white bone—that is, bone approaching calcination. Such results indicate that DNA preservation in burned hard tissues remains is possible but dependent on heat exposure and duration. This result suggests that sufficient DNA may survive sporadically during the dehydration and decomposition phases of transformation (Thompson 2004) but not beyond.

Indeed, colour change is suggested as a macroscopic indicator of DNA preservation in burned bone as this indicates carbon, and therefore possible organic, preservation (Walker, Miller, & Richman 2008). However, techniques such as FTIR are also now used to indicate ancient DNA preservation and suitable methods for analysis (Fredericks et al. 2012). What is clear from the literature is that, despite progress in the studies presented here, further study into DNA extraction and amplification from burned human remains is of critical importance and should be the focus of future research.

Novel Approaches to Visualising Heat-Induced Change

As secondary-level changes in bone are often visually clear, early studies relied on simple photography (and currently, digital photography) to aid examination of these changes. However, as researchers have been investigating primary-level changes, new imaging modalities have been introduced. The potential of scanning electron microscopy (SEM) has been appreciated for a number of years and has been used in studies examining the effects of burning on bone (for example, Holden, Phakey, & Clement 1995a, b; Quatrehomme et al. 1998; Herrmann & Bennett 1999) and teeth (for instance, Carr, Barsley, & Davenport 1986; Wilson & Massey 1987). Koon and associates (2003) showed the potential of transmission electron microscopy in differentiating unburned bone from that heated to low temperatures.

Preliminary studies using magnetic resonance imaging (MRI) (Thompson & Chudek 2007) have revealed the potential to obtain high-resolution images of external and internal changes of the compact and cancellous bone simultaneously. However, more impressive has been the application of micro CT in providing data on heat-induced hard tissue change, including actual heat-induced dimensional change in teeth. Recent research revealed that heat-induced shrinkage occurs uniformly across teeth from approximately 400°C, although negligible until 800°C, and even over 800°C tooth shape endures with minor contraction of the distal root (Sandholzer et al. 2013).

Impact of Heat-Induced Change on Human Identification

The undeniable, unavoidable conclusion of all these studies is that bone can change dramatically as a result of heating. Thus we must assume that heat-induced changes to bone affects any anthropological techniques applied to the bone, although the influence varies according to the direct and indirect effects of the heat-induced changes (Thompson 2004). Although the impact on identification techniques has been of general interest previously (VanVark 1974, 1975; Bradtmiller & Buikstra 1984), only with current research is it being specifically addressed.

In essence, the question is not whether burning will affect human identification, but to what extent. Current studies tend to focus on two areas: (1) assessing and enhancing morphological and metric techniques; (2) whether antemortem features survive the burning environment. In the former, experimental studies combined with statistical analyses reveal conventional metric

methods of sex determination as highly vulnerable to the effects of heat-induced changes (Thompson 2002, 2004, 2005; Gonçalves 2011, 2014) potentially resulting in the misclassification of sex. Thus the development of relevant reference data has an important role (Gonçalves, Cunha, & Thompson 2013; Gonçalves, Thompson, & Cunha 2013). Experimental studies have provided a number of interesting results: that antemortem sharp- and blunt-force trauma are distinguishable from heat-induced features (Herrmann & Bennett 1999; De Gruchy & Rogers 2002); that gunshot trauma was not distinguishable (Herrmann & Bennett 1999), although this is not true in every case (Pope & Smith 2004); and that evidence for antemortem injuries present in the surrounding soft tissue can be suggested from skeletal evidence (Pope & Smith 2004). However, De Gruchy and Rogers (2002) note that the likelihood of finding antemortem trauma on burned remains is dependent on the anatomical region that was traumatised, with ribs (and any associated antemortem trauma) more likely to be completely destroyed by fire. These studies also note the danger of neglecting heat-induced shrinkage in the interpretation of trauma from burned bones. Evidence for pathological lesions and conditions can be preserved in burned remains (Reinhard & Fink 1994), including porotic hyperostosis, cribra orbitalia, periodontosis (Ulguim 2015), and arteriosclerotic plaques (Warren et al. 1999). Tooth morphology does appear to be relatively well-preserved (Schmidt 2008; Sandholzer et al. 2013) while dental devices often support identification (Woiseschlager et al. 2011). Finally, recent research has scientifically refuted myths surrounding spontaneous human combustion (De Haan & Nurbakhsh 2001; Christensen 2002) and the perceived tendency for heads to explode in fires (Pope & Smith 2004).

Future Development

Future research into the effects of burning on the human body must focus on three topics if the discipline is to move forward. First, further research is needed to continue the research lines outlined in this chapter, but with larger and more varied samples and taking greater consideration of the influence of other external factors (such as soft tissue, personal effects, and the nature of fuel for the fire). Second, future research will benefit from better integration of the research from the various subject disciplines with a vested interest in this area. Third, and most crucially, new-found knowledge and methodologies must be applied to forensic casework and the results communicated back to burned body researchers.

Conclusion

The analysis of burned human remains holds an important place within the remit of the forensic anthropologist and archaeologist. The remains themselves are complicated, requiring practitioners to consider a range of heat-induced changes throughout the tissues of the body, changes that themselves are highly dependent on the relationship of the fire to the body, the type of tissues involved, and even the topographical region of the tissue. In addition, the forensic scenes in which burned remains are recovered are complex, fragile, and criminalistically significant. Thus this aspect of forensic anthropology and archaeology is exciting, allowing for great scope in research projects and interdisciplinary collaborations. At all times, however, we must not lose track of the question that should be driving our research forward: how well do we fulfil our current and future context-based requirements and demands? A tremendous foundation has already been created within the study of burned human remains, and the future developments and direction predicted here will allow for this foundation to mature and become firmly established within the context of forensic anthropological and archaeological practice.

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Note

1 For earlier reviews, see McKinley (2000) and Mayne Correia (1997).

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Craniofacial Identification

Techniques of Facial Approximation and Craniofacial Superimposition

Carl N. Stephan and Peter Claes

When the identity of a skeleton cannot be established through the usual anthropological methods, DNA, or dental record comparisons, craniofacial identification methods that couple the anatomy of the skull with the surface anatomy of the face may offer some assistance (Krogman & İşcan 1986). Such methods take two forms: comparison of skulls of unknown identity to antemortem faces of known identity (craniofacial superimposition) and prediction of faces from skulls of unknown identity (facial approximation).

Superimposition

In craniofacial superimposition skull-face comparison is undertaken via the overlay or mixing of an image of a skull with a face to determine if there is an anatomical match of the two (Figure 27.1). These methods are consequently employed when the skeletal remains are suspected to represent the individual of whom an antemortem photograph(s) exists. Assuming that method protocols are correctly followed, a match of the skull to the antemortem face suggests that the remains could belong to the person depicted in the image; a no match result indicates that the remains do not. Clearly, antemortem images of recent origin should be used so that differences due to age/growth do not complicate the comparisons. Clear images with known photographic parameters are favored, and information about the age of the subject can be obtained by locating the photographer who took the original image. Individual circumstances will dictate the quality of photographs and the known parameters that are on offer to the investigators.

Nowadays superimposition is usually conducted using video or computer equipment. The skull is typically positioned in front of one video camera, while an antemortem photograph of the face of the person suspected to provide a match is positioned in front of another camera of identical make and model (Taylor & Brown 1998). After the cameras are positioned to replicate antemortem photographic conditions, the two subsequent images are overlaid (superimposed) at varying opacities with a video mixer. To determine if the skull fits in the correct anatomical position “beneath” the face, the orientation of the skull is adjusted to that of the person in the photograph. Known soft-tissue depth distributions and anatomical face relationships (examples follow) are used to assess degree of fit (Helmer 1984; Austin-Smith & Maples 1994). Computerized methods also exist that enable semiautomated alignment of the skull and face



Figure 27.1 Video superimposition showing a possible match between the skull and the face. Essentially all 12 criteria reported by Austin-Smith and Maples (1994) are fulfilled. (i) The skull outline completely falls within that of the soft tissue (anterior cranium fits forehead, mandible fits jaw; (ii) anterior temporal line of skull fits that of the face; (iii) eyebrows follow the supraorbital margin; (iv) orbits encase eye, and medial and lateral folds align with relevant bony features; (v) breadth and height of nose fit dimensions of nasal aperture of skull; (vi) general contours of face fit those of skull—for example, contouring of cheeks fits the zygomatic bones, and contouring of chin fits the mental eminence. Exhibited from left to right is the skull, antemortem-face photograph to be compared, superimposition of face on skull, and superimposition of face on skull with a left-side half-face wipe.

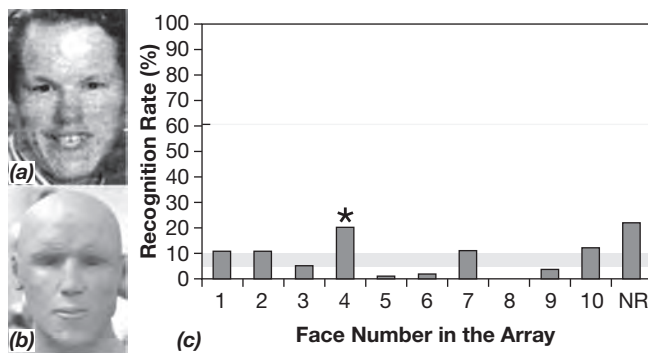


Figure 27.2 Example facial approximation with recognition results: (a) target face; (b) facial approximation; and (c) recognition in a 10-individual face array (target face=4; $n=259$ assessors; NR=no recognition response; grey bar=chance response level; * indicates statistical significance $p \leq 0.05$) (images reproduced from Stephan & Henneberg 2006, and graphs reproduced from Stephan & Cicolini 2010, all with permission from Elsevier)

using evolutionary algorithms and user-nominated landmarks, thereby reducing some of the subjectivity that rests with the practitioner (Campomanes-Alvarez et al. 2014).

Facial Approximation

The prediction of a person's facial appearance from a skull (facial approximation) may be conducted when there are no leads as to whom the remains are suspected to belong or when recent photographs of such persons cannot be obtained/do not exist. The face construction can be accomplished by drawing, sculpting in clay, or computer rendering. Regardless of which facial approximation technique is used, the process depends on analyzing the morphology of an unknown skull and estimating the facial appearance from this information under blind conditions (Figure 27.2). When complete, the constructed face is presented in the media, often

with accompanying case findings/descriptions, in the hope that the person to whom the skull belongs is recognized.

Method Aims

Both superimposition and facial approximation methods aim to contribute information helpful for the establishment of the identity of a set of skeletal remains, and it is under these broad terms that techniques can be referred to as “methods of identification.” This contribution should not be confused with the ability to *provide an identification* (that is, positive identification). Facial approximation and superimposition are generally not considered to be potent enough to stand alone for this purpose (Ubelaker 2002). Problematic is the non-uniqueness of human face anatomy between genetically related individuals (for example brothers, sisters, and identical twins), non-uniqueness between unrelated individuals (so-called lookalikes or doppelgangers), and the lack of method standardization/validation.

The aim of superimposition is to provide a measure of a match between each skull and face considered. Heavier weights are generally assigned for exclusion, and, although positive identifications are not typically obtainable, there may be exceptions if dental characters are clearly evident on the skull and facial photograph (Webster et al. 1986). The ultimate aim of facial approximation is purposeful facial recognition; however, the methods may frequently act as a vehicle for successful identification by drawing public attention to the advertised case and facilitating identification via other means (Haglund 1998).

Both craniofacial superimposition and facial approximation have been successfully used in high-profile cases (Helmer 1987; Prag & Neave 1994), and they serve a vital role in offering new hope in cases that have exhausted all other identification avenues. Improvements in method fidelity are constantly being sought and new avenues to integrate genetic analysis into their protocols add further promise on this front.

History of Methods

Modern craniofacial identification methods arose from attempts by European anatomists in the late 1880s to authenticate the identities of skeletons suspected to represent well-known historical figures—for example, Schiller (Welcker 1883) and Bach (His 1895). It is from these origins that mean facial soft-tissue depths set a fundamental basis in both approaches (Welcker 1883; Kollmann & Buchly 1898).

The first published report of superimposition in forensic casework was by Glaister and Brash (1937). These authors were able to corroborate the identity of two individuals using tracings derived from antemortem photographs (for example, Figure 27.3). Methods then progressed to recording superimpositions by photographs alone, whereby magnification effects were of primary concern up until the 1970s. With the development of video recording by Ginsburg’s team

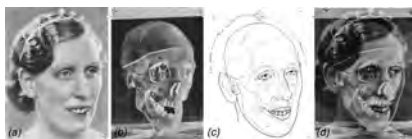


Figure 27.3 Craniofacial superimpositions carried out by Glaister and Brash (1937) using a $\frac{3}{4}$ -view studio portrait photograph of Mrs. Ruxton: (a) facial photograph; (b) skull photograph; (c) superimposed outlines of (a) and (b), as used to draw conclusions that the two “fit”; and (d) photographic superimpositions (used by Glaister and Brash for illustrative purposes only) (images reproduced from Glaister & Brash 1937)

in 1951 and the video revolution of the 1970s (for instance, replacement of Betamax format with VHS), motion-picture cameras replaced traditional still-frame equipment. Thus video superimpositions were first conducted in 1976–1977 (Snow 1976; Helmer & Gruner 1977).

The uptake of these methods in the 1980s was rapid (Koelmeyer 1982; Brown 1983; Bastiaan, Dalitz, & Woodward 1986; Delfino et al. 1986; Iten 1987), but, despite this, few quantitative studies of method accuracy were documented. Perhaps the most comprehensive is that conducted by Austin-Smith and Maples (1994), who found that false positive matches were obtained for the comparison of three skulls to 97 lateral and 98 frontal images of non-target individuals (anterior dentition was not evaluated). For lateral images alone, false-positive matches were found in 9.5% of cases. For frontal images alone, the false positive rate was 8.5%. These rates were reduced to 0.6% when frontal and lateral images were used in conjunction with one another. The Austin-Smith and Maples study thus demonstrated that without anterior dentition, craniofacial superimposition is reliable when two photographs of the subject (representing different angles) were used for comparison. With anterior dentition analysis it is generally recognized that positive identifications can be more readily established (McKenna, Jablonski, & Fearnhead 1984; Webster et al. 1986; Austin-Smith & Maples 1994).

Facial approximation, however, has its roots in early face prediction methods called *facial reconstruction*, after the German *plastischen Rekonstruktion*. The first published reports of facial reconstruction casework predate those of superimposition. In 1916 facial reconstruction produced its first recorded success in a New York forensic investigation (Wilder & Wenworth 1918)—however, success was not via facial recognition. Instead, Dominick La Rosa was almost certainly recognized by the colored necktie retrieved from the remains of the body and which dressed the facial reconstruction. In the subsequent years face prediction was adopted by a Russian archaeologist, Gerasimov (1955), who became renowned for it. The mistranslation of Gerasimov's work led to popular classification of facial reconstruction into one of three protocols: (1) American methods were said to depend on average soft-tissue depths alone; (2) Russian methods were said to depend on skull anatomy; and (3) combinations methods were said to rely on a mix of the two approaches. In reality, however, Gerasimov's work heavily relied on average soft-tissue depths (Gerasimov 1955; Ullrich & Stephan 2011, In press), his method excluded many facial muscles (Ullrich & Stephan 2011, In press), and his technique shared the exact same (European) origins as American methods, making them one of the same approach (ibid.). In the 1970s forensic artists also became heavily invested in facial reconstruction methods (Prag & Neave 1997; Gatliff & Taylor 2001; Gibson 2008) giving rise to the introduction of multiple “artistic rules of thumb” for facial feature prediction.

Facial approximation emerged from this context as a synonym for facial reconstruction (George 1987; Haglund & Reay 1991; Stephan & Henneberg 2001). However, shortly thereafter it became transformed into an independent pursuit as evidence for the approximate nature of the task grew, while in parallel, facial reconstruction denied any inaccuracies (for review see Stephan 2015). Under the banner of facial approximation, the entire basis of facial reconstruction was laid open to critical review, error measurement, and accuracy assessment. To date this has given rise to multiple improved face prediction rules.

Facial reconstruction and approximation have been subject to several tests (casework success, comparisons of resemblance, and laboratory recognition arrays), largely with inconsistent results—facial reconstruction reports high-performing and accurate methods (Wilkinson 2004), while facial approximation finds much greater room for improvement (see, for example, Figure 27.2). Irrespective of which school is followed, few studies have overcome difficulties in obtaining large samples of skeletons for testing and/or assessors genuinely familiar with the person to whom the skull belongs. One study avoided the latter problem by warping average

faces to the exact same (2D) face shape of living target individuals to produce synthetic facial approximations that could be assessed by individuals familiar with the target person (Stephan, Norris, & Henneberg 2005). Since exact face shapes were replicated in this study without any estimation error, the performance for real-life casework is likely to be much less than the observed c. 40 % correct recognition rate.

Method Principles

Biological Profile

Craniofacial identification requires a comprehensive assessment of a skeleton's biological profile (see Sauer, Wankmiller, & Hefner, Chapter 18, this volume [ancestry]; Rowbotham [sex]; Rogers [age]; Willey [stature], and Cunha & Pinheiro [pathology]), together with distinguishing craniofacial characteristics and occlusion patterns, before methods are undertaken.

Depth of Soft Tissue Cover

Metrics of the soft-tissue thickness over the skull are routinely employed as an indicator of space occupied by the soft tissues (Helmer 1984; Wilkinson 2004). Arithmetic means have popularly been used, with subclassifications into groups where small differences by sex, age, and ancestry exist (Wilkinson 2004). These means are not very precise estimators, with recent studies showing 95% confidence limits to be as large as 12mm (Stephan 2015). Regression-based facial soft-tissue thickness estimators, utilizing body mass (De Greef et al. 2009) and craniometrics (Sutton 1969; Simpson & Henneberg 2002; Guyomarc'h et al. 2013), have also been suggested. However, the usefulness of these equations are problematic, because body mass cannot be easily predicted from skeletons, and craniometrics are plagued by the lack of reproducible results and much lower R-square values.

Since facial soft-tissue depths are often skewed to the right side (Stephan, Simpson, & Byrd 2013), two alternate summary statistics are useful: one approximating the peak of the data (the shorth) and one approximating data in the right tail (the shormax). Essentially, this splits the data distribution into two and uses two central tendency indicators for prediction, rather than a single mean, reducing prediction error and systematizing methods (ibid.). The choice of the shorth or the shormax is straightforward in superimposition where the weight of individuals (light or heavy) can often be gauged from facial photographs. In facial approximation the shorth should be used for the first face construction and the shormax for a second face if the first one fails to elicit any useful leads, thereby doubling media exposure (ibid.).

The large overlap of data between facial soft-tissue depth groups, combined with large sampling and measurement errors (up to 30% of the original measurement), suggests that the pooling data to average out noise and boost sample sizes is a worthwhile exercise (Maat 1998–1999; Stephan et al. 2005; Stephan & Simpson 2008). Rolling means calculated across samples serially increasing size have shown mean thickness values to stabilize at c. 2,000 individuals (Stephan 2014), highlighting the limits of small sampled single studies.

Extrapolation of Facial Features from an Examination of the Skull

Relationships of covariance between the skull and face are applicable to all craniofacial identification methods, no matter from which subdiscipline they are derived. The facial feature prediction guidelines reported in superimposition tend, on the whole, to be more conservative (for example, Austin-Smith & Maples 1994; Taylor & Brown 1998) than those originating

from within the realm of facial reconstruction (for instance, Gerasimov 1955; Wilkinson 2004). Within facial approximation evidence-based guidelines have been a priority for pursuit; however, major gaps remain (Stephan 2015). Arguably, the features for which no tested guidelines exist should be conservatively utilized in any of the methods.

The following section summarizes some of the empirically elucidated soft-tissue prediction/assessment guidelines; however, an exhaustive review is not possible owing to space limits. Well-established and conservative methods used in superimposition (for example, eyes within bony orbits; nasal aperture within dimensions of soft-tissue nose) are not discussed. Deviations from the stipulated guidelines will probably be needed with changes in posture, pose, and facial expression. This aspect largely limits the usefulness of soft-tissue prediction guidelines in superimposition where real-world photographs are used (Taylor & Brown 1998).

Eyes

Contrary to popular thought (Krogman & İşcan 1986; Wilkinson 2004), the eyeballs are not centrally positioned within the orbit nor does the apex of the cornea fall on a tangent from the mid-antero-superior orbital rim to the mid-anteroinferior orbital rim (Stephan 2002a). Anatomically, the eyeballs are offset 2–3 mm from the center and closer to the lateral orbital wall and roof (Stephan & Davidson 2008; Stephan, Huang, & Davidson 2009; Guyomarc'h et al. 2012). Also, the eyeballs are also not too deeply set. The leading edge of the lateral orbital wall is on average 16 mm posterior to the cornea (Dunsky 1992; Barretto & Mathog 1999; Goldberg, Belan, & Hoenig 1999; Stephan, Huang, & Davidson 2009; Guyomarc'h et al. 2012). The endocanthus and ectocanthus lie close to the same vertical position of the malar tubercle on each side (Stewart 1983). When the malar tubercle is absent, 5%–25% of individuals (Whitnall 1911; Stewart 1983), the attachment of the lateral canthal ligament can be approximated 11 mm below the frontozygomatic suture (Whitnall 1911), while the medial canthal ligament lies 10 mm inferior to the level of the frontozygomatic suture (Stewart 1983).

Nose

Nose width has been shown to be best determined by dividing the nasal aperture width by 0.6 (or equivalently multiplied by 1.67), in contrast to fixed additions to nasal aperture breadth (Hoffman et al. 1991; Rynn, Wilkinson, & Peters 2010). Nose projection can be simply and accurately estimated using three measurements prescribed by Rynn and associates (2010) (also see Mala 2013). Controversy exists on the utility of Gerasimov's infamous two tangent rule—one following the distal angulation of the nasal bone and the other the nasal spine (Stephan, Henneberg, & Sampson 2003; Rynn & Wilkinson 2006, 2010; Rynn, Wilkinson, & Peters 2010). Rynn and associates (2010) present data that support the following formulations: that the position of the crista chonchalis marks the height of the alar wing; that nasal-tip form is influenced by the angle of intersection of nasal aperture with the nasal spine in profile view; and that nasal-spine form corresponds to nasal tip form (for example, bifid nasal spine indicates a cleft nasal tip).

Mouth

The mouth width can be approximated using the distance between the canines—divide by 0.75 or multiply by 1.33 (Stephan & Henneberg 2003; Stephan & Murphy 2008). A gross approximation may also be made using the location of the infraorbital foramina (Stephan & Murphy 2008). The popular soft-tissue prediction guidelines that mouth width is equal to intercanine width

or the distance between the pupils have been demonstrated to be inaccurate (Stephan 2003a; Wilkinson, Motwani, & Chiang 2003). The stomion falls within the lower third of the central incisor height for females and within the lower quarter for males (George 1987). Wilkinson and colleagues (2003) provide regression equations for determining the height of the lips from the height of the enamel on the central incisors.

Eyebrows

On average, female superciliares fall close to the plane of the lateral iris, but this trend does not seem to hold well for males (Stephan 2002b). In general, the eyebrows display considerable variation (Rozprym 1934). Oestreicher and Hurwitz (1990) have shown a trend for eyebrows to become more inferior with increasing age, but absolute differences are small (0.7 mm from <40 to >59 years). Females typically have eyebrows that are 2 mm higher than males' eyebrows (Oestreicher & Hurwitz 1990).

Ears

Few legitimate guidelines exist for determining the morphology of the ear from the skull, and many widely advocated recommendations have not found empirical support (Guyomarc'h & Stephan 2012). Irrespective of these limits, there are some general relationships that hold. For example: the cartilagenous opening of the external auditory meatus is approximately 5 mm more posterior and superior than the bony canal (Montagu 1939); the mean ratio of ear breadth to height is approximately 0.6 (Ferrario et al. 1999; Sforza et al. 2009; Guyomarc'h & Stephan 2012); males tend to have slightly (4–5 mm) larger ears than females have; ear width increases slightly with age (R -square=0.33); free earlobes tend to be more frequent in non-Asian groups (for review see Guyomarc'h & Stephan 2012). Cross-validated regression equations for determining ear height, using sex and age as input variables, have been presented (R -square 0.15–0.46, SEE c. 5 mm; Guyomarc'h & Stephan 2012). If the height of the nose (se–sn) is used to estimate the ear height (sa–sba) as commonly recommended, then an average underestimation of 6–8 mm can be expected (Guyomarc'h & Stephan 2012; see also Farkas, Forrest, & Litsas 2000).

Global Feature Analysis

Modern-day imaging techniques and computing power have opened up relatively “new” methods that enable craniofacial relationships between the skull surface and the face surface to be mapped numerically and in global fashion. While multiple approaches exist (see Vandermeulen et al. 2012 for a review), they all require the capture and analysis of three dimensional (3D) skull and 3D face data, as point clouds, from living individuals (for example, using computed tomography scanners). Global geometric relationships within each subject can then be mapped and patterns across subjects evaluated, for example, using principal component analysis (Tu et al. 2005; Claes et al. 2006). Drawing on the correlations present in the training dataset, statistically plausible face morphology can be created for newly encountered skulls that did not form part of the training sample (Berar et al. 2006; Claes et al. 2006). This, of course, is directly applicable to facial approximation. The training set may also be used to warp a skull surface (with accompanying face mesh) to match the new or novel skull, so that same algorithm applied to the face surface produces the predicted face. The certainty of this face can be modelled from principal component analysis using the leftover variance between faces for other skull–face transforms in the training set (Turner et al. 2005).

These computerized approaches offer unparalleled capabilities in terms of bulk data processing, control, and automation of repetitious routines, but, although they are often impressive, they should not be pedestalled above their limits. For example, the precision and success of these methods hinge on the quality of the training set, both in terms of how representative it is of the population at large and how meticulously it can capture real-world detail (that is, scan resolution and noise). They also depend on the ground truth strength of the underlying craniofacial relationships and the capacity of the software algorithms to accurately model them without compromise to obtain practically workable real-world solutions. As one example of the latter factor, landmark position accuracy may be compromised to minimize deformation stress when applying nonrigid thin plate spline deformations (Tu et al. 2003).

Genetic Determinants of Face Morphology

In instances where DNA can be successfully extracted, but no match found against a database or reference sample, a DNA-based prediction of visible external features can now be undertaken to supplement and assist craniofacial identification techniques (Claes et al. 2014). Example characteristics that can be predicted from DNA today with different levels of accuracy include: eye and skin color (Spichenok et al. 2011; Dembinski & Picard 2014); hair color (Branicki et al. 2011; Walsh et al. 2013); genomic background or genetic ancestry (Shriver et al. 1997); and sex (Reynolds & Varlaro 1996). This process is termed *molecular photofitting* (Frudakis 2010).

Within the context of craniofacial identification, molecular photofitting is of tremendous value, not only for the previously mentioned characters but also for face shape. In theory, prediction of face shape should be possible given the strong evidence that facial features are under rather tight genetic control (Kohn 1991). For example, remarkable facial similarity exists within identical twins (Weinberg et al. 2013); families (Johannsdottir et al. 2005); geographic populations (Hopman et al. 2014); and the sexes (Claes et al. 2012). Moreover, distinctive facial features are associated with particular genetic conditions (Hammond 2007; Baynam et al. 2013). Heritability studies performed on twins and parent–offspring sets often show moderate to high degrees of heritability on craniofacial parameters, particularly in terms of vertical height measurements, and, on a local facial feature scale, highly heritable features include the orbits, the nose, the jaw, and the teeth (Naini & Moss 2004; Johannsdottir et al. 2005; Martínez-Abadías et al. 2009; Weinberg et al. 2013).

The value of molecular photofitting also extends to ancestry, where local adaptations to climate and diet acting over the long-term must, by necessity, become manifested at the genetic level. Long-distance migration coupled with progeny production introduces “noise”, but so long as gene flow does not outpace adaptation in generic terms, background patterns that inform face shape will remain. To avoid falling into typological traps, however, one must use proper unsupervised modeling techniques on genomic relationship matrices—for example, high-dimensional and *continuous* representation of genetic background and facial features should be employed.

So far, most craniofacial genes have been discovered through the study of craniofacial disorders such as cleft lip and palate (Dixon et al. 2011a, b), animal (most commonly mouse) models (Song et al. 2009; Attanasio et al. 2013; Pallares et al. 2014), genome wide association studies (GWAS) of normal craniofacial variation (Liu et al. 2012; Paternoster et al. 2012; Fatemifar et al. 2013), or the combination thereof (Boehringer et al. 2011; Wolf et al. 2014). Before the identification of craniofacial genes can aid in the prediction of facial features, their effects on normal-range facial morphology needs to be investigated and visually exposed as recently achieved for a European-African admixed population (Claes et al. 2014). Using a full arsenal of 3D facial analysis techniques in this study, the effects of 20 craniofacial candidate genes (POLR1D, CTNND2, SEMA3E,

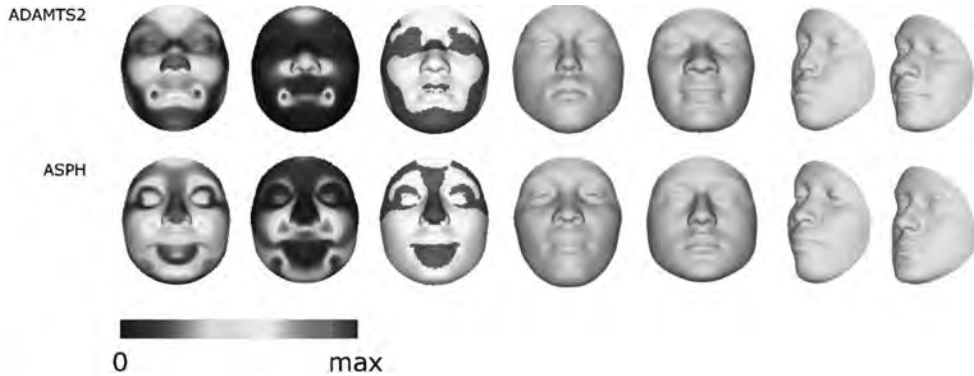


Figure 27.4 Mutations in the human *ADAMTS2* (OMIM#604539) gene located on 5q35.3 can cause Ehlers-Danlos syndrome, type VIIC (OMIM#225410). The facial features of Ehlers-Danlos VIIC include epicanthal folds, a depressed nasal bridge, micrognathia, large eyes, a small chin, sunken cheeks, a thin nose, and thin lips. The normal-range results of the SNP rs3822601 in *ADAMTS2* indicate effects in midface, lower nose, and lips as well as in the nasal bridge and forehead. The most prominent perceptual differences between both shape transformations include the width of the nose, the size and spacing of the orbits and eyes, and the shape of the lower face. The mouse homologue for the human aspartate beta-hydroxylase (*ASPH*) gene (OMIM#600582) when knocked out leads to a shortening of the length of the snout, mild palatal changes, and syndactyly of both front and rear paws. Statistically significant normal-range effects of the SNP rs4738909 in *ASPH* are depicted in the figure with the strongest effects located in the midface/philtrum area and the mandible as well as the eyes and orbits. A strong change of the facial profile from concave to convex is observed in lateral shape transformations.

SLC35D1, *FGFR1*, *WNT3*, *LRP6*, *SATB2*, *EVC2*, *RAI1*, *ADAMTS2*, *ASPH*, *DNMT3B*, *RELN*, *UFD1L*, *ROR2*, *FGFR2*, *FBN1*, *GDF5*, and *COL11A1*) were visually exposed such that *post-hoc* comparisons between their normal-range effects and the known clinically significant effects could be performed. Two example genes, *ADAMTS2* and *ASPH*, are shown in Figure 27.4. Recently the prediction of facial features from DNA alone was also undertaken (Claes et al. 2014).

In that approach, genomic background (ancestry) and sex, respectively represented as a continuous and categorical variable, were used to create a base-face. This represents an average sex and ancestry background matched face. Subsequently, the results from Claes and associates (2014a) are overlaid on the base-face forming the predicted-face in a process akin to a photo-montage or image blending. The gene-effects maintain the physical accuracy while significantly increasing the distinctiveness of the facial predictions, which is anticipated to be helpful by reducing false positives in perceptual identification tasks. The practical deployment of these first preliminary methods remains a future vision.

Of course, the genetic determinants of facial morphology are complex, and the initial studies (outlined above) have not unraveled the full breadth of genes and gene-interactions (Hallgr msson et al. 2014). Future studies similar to the ones outlined previously that investigate different aspects of craniofacial variation in the context of genetic variation are important to elucidate matters further. This complexity calls for a concerted and multidisciplinary gene discovery effort to move to the next stage (Claes & Shriver 2014). Nevertheless, the preliminary results obtained so far are promising and provide both the impetus and analytical framework for future effort (ibid.). One such concrete future step, within the context of craniofacial identification, is the development of facial approximation techniques starting from both the skull structure as well as DNA. This intertwining of methods would seem mutually advantageous,

since facial features challenging to one method may be more easily solved by the other—eye color prediction is an excellent case in point because this morphology is not determinable from macroscopic inspection of bone morphology.

Conclusions

Under the right circumstances, methods of craniofacial superimposition and facial approximation are indispensable for identifying unknown skeletal remains. Superimpositions can be conducted when facial images of potential matches exist in addition to a skull. Ideally, at least two images of the subject taken from different angles should be used, and pictures with visible anterior dentition should be sought. When facial images of potential matches do not exist, attempts to predict the anatomy and the appearance of the face can be made. The constructed face can then be advertised in the media (along with a case description) with the hope that someone may recognize the person concerned.

Superimposition is recognized to be most useful for excluding individuals to whom the remains do not belong, but with a number of facial views (and/or visible dentition on both skull and face photo) confidence can be high in determining a match. The reliability and accuracy of facial approximation are presently less than superimposition, at least when good quality photographs and known photographic parameters are possessed for the superimposition. The primary mechanism through which facial approximation achieves success is unclear, but a combination of contextual and case-specific information, chance, and purposeful face recognition is likely responsible. This breadth of features boosts the methods casework utility. Improved understanding of skull-face covariation are key to improving craniofacial methods, both in terms of anatomical extrapolations from the skull and underlying genetic encoding of these morphological traits.

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Biomolecular Applications

Lori Baker

Molecular analysis is a routine part of forensic investigations. Deoxyribonucleic acid (DNA) from hair, teeth, bone, blood, muscle tissue, semen stains, cigarette butts, fingerprints, and even dandruff are potential sources encountered by forensic anthropologists and archaeologists. Though morphological skeletal analysis is vital for assessment of sex, age at death, and stature of the decedent, DNA analysis is often necessary to distinguish individuals that share similar skeletal profiles. New technologies such as high-throughput sequencing and DNA phenotyping are being developed to generate genetic information quickly and inexpensively. In addition, these approaches have the potential to identify genetic markers for hair color, skin color, facial shape, stature and age.

There are two genomes found in nearly all cells in the human body: the nuclear genome located in the cell nucleus and the mitochondrial genome located in the mitochondrial cytoplasmic organelle. Nuclear DNA is arranged along the 46 chromosomes, 23 contributed by each parent. Mitochondrial DNA is contained in a small circular genome and is contributed only by the mother. Both nuclear and mitochondrial DNA are discussed in this chapter.

Skeletal Sampling

Principles, protocols, and procedures for selection, cutting, and packaging of skeletal remains are similar in both forensic and ancient DNA analyses. Anthropologists and archaeologists often must decide which skeletal elements to sample and the quantity of bone that is necessary for analysis. The amount of time and high cost of genetic testing make it essential to determine which samples are the most likely to provide good genetic information.

Like other biological tissue DNA immediately begins a process of degradation immediately upon death. It has been demonstrated that environmental conditions have more influence on DNA preservation than time (Hoss et al. 1996; Poinar et al. 1996; Colson et al. 1997). DNA is best preserved under neutral or slightly alkaline conditions, in dry low temperatures and in the absence of microorganisms (Burger et al. 1999; Iwamura, Soares-Vieira, & Muñoz 2004). Counterintuitively, several studies have shown that the general appearance of the bone is not a good indicator of successful analysis (Faerman et al. 1995; Burger et al. 1999; Baker 2002).

Cortical bone such as weight bearing long bones (femur, tibia, metatarsals) and teeth are considered the best choices for successful DNA analysis. Success rates of skeletal elements used for high-throughput identification efforts like that of the United States Armed Forces DNA Identification Laboratory, the International Commission on Missing Persons, and the World Trade Center disaster have been reported and can inform collection decisions (Edson et al. 2004; Milos et al. 2007; Mundorff, Bartelink, & Mar-Cash 2009; Edson & Ah Sam 2015). Mundorff

and colleagues (2009) systematically examined DNA from the entire skeleton of the same individual as well as DNA from multiple individuals for a subset of elements to establish and empirically rank skeletal elements best for testing. They found that bones such as the first distal hand phalanx, capitate, and patella have consistent amounts of DNA and may be underutilized sources. In addition, technological advances in DNA extraction procedures have facilitated a decreased amount of bone required as well as improved success rates (Loreille et al. 2007; Edson & Ah Sam 2015). Sampling decisions should be made in consultation with the laboratory that will perform the analyses and based on the extraction methods utilized and type of DNA that will be analyzed.

Sample Handling

Appropriate precautions should be employed at all times to prevent the transfer of the examiner's DNA or other exogenous DNA to the specimen being analyzed. Gloves should be worn at all times when one is excavating, collecting, and analyzing skeletal remains. Molecular techniques have advanced enough that DNA from a single fingerprint or a flake of skin can compromise genetic testing (van Oorschot & Jones 1997; Lowe et al. 2002). Proper sample preparation may limit the presence of surface contamination but does not guarantee its elimination altogether (Edson & Christensen 2013). When possible, it is best to send a whole bone to the genetics laboratory, ensuring that bone samples can be taken in a controlled environment.

Bones should not be cut until all osteological measurements and analyses are completed. Care should be taken not to remove a portion of bone that will destroy areas crucial for osteological analysis. Sites that have antemortem or perimortem trauma or pathology formation must also be avoided. A typical sample size should be at least 5 grams. Gloves should be changed between each sample and should never touch unbleached surfaces or one's body, because this may transfer genetic material to the glove and potentially to the bone or tooth being analyzed. Equipment, such as bone saws and blades, should be made free of extraneous DNA by cleaning it with bleach before and between each sample to avoid cross-contamination. Ideally, the surface of the bone should be sanded and then washed with bleach before the bone is cut. Remains should be dried before they are packaged and placed into paper instead of plastic to inhibit the colonization of bacteria and fungi that may hinder DNA analysis. Sampling teeth is easier with preference to molars and premolars, but all tooth types can provide sufficient DNA. It is advisable to select two intact teeth without any caries or amalgamations with closed, unbroken roots.

DNA Extraction

The proper extraction of DNA from the biological matrix is critical to maximize a robust sample of DNA while excluding cellular materials known to inhibit downstream enzymatic reactions. Although there are many different laboratory-specific protocols and variations on extraction methodologies, standard procedures rely on one of three main methods of bone and tooth DNA isolation: (1) organic extraction, (2) Chelex, and (3) solid-phase methodologies.

Organic extraction is the original method used in forensic and ancient DNA analysis from bone and teeth and effectively extracts high molecular weight DNA (Hagelberg & Clegg 1991; Stone & Stoneking 1993). In this procedure sodium dodecylsulfate (SDS) and proteinase K are incubated for several hours with ground bone or tooth powder to release DNA from the cell and to break down proteins. A phenol/chloroform solution is then added to separate the proteins from the DNA, followed by a series of alcohol precipitations to remove inhibitors. Some protocols have replaced the alcohol precipitations with a Centricon filter (Millipore, Billerica,

MA) for a process called *diafiltration* (Comey et al. 1994). The drawback of the organic extraction method is that it involves the use of hazardous chemicals, requiring care to protect the user. In addition, small DNA fragments are not always extracted efficiently with this method.

Chelex is a rapid DNA extraction procedure (Sivolap et al. 2001) that can be used for the extraction of DNA from bone; however, it does not eliminate organic inhibitors with the efficiency of phenol-chloroform extractions (Hoff-Olsen et al. 1999). The chelating-resin suspension Chelex 100® (Bio-Rad Laboratories, Hercules, CA) is an ion-exchange resin that is added as a suspension to the ground bone or tooth sample and boiled (Walsh, Metzger, & Higuchi 1991; Faerman et al. 1995). The sample is then washed and centrifuged to separate the Chelex resin and cellular debris from the DNA. The supernatant can be removed and used for polymerase chain reaction (PCR) amplifications.

Solid-phase methodologies, such as silica extraction procedures have been proven effective for yielding DNA from ancient and degraded bone and tooth samples while simultaneously purifying the DNA from inhibitors that are typically coextracted (Hoss & Pääbo 1993; Götherström & Lidén 1996; Stone & Stoneking 1998; Baker, McCormick, & Matteson 2001). DNA is bound to silica particles in the presence of high concentrations of chaotropic salts; the small fragments of degraded DNA are not lost during subsequent alcohol washes (Boom et al. 1990). This method is exceptionally sensitive and, therefore, extreme care must be taken to avoid contamination by extraneous DNA. There are several commercially available kits that have been developed that use silica-based DNA binding. QIAquick by QIAGEN, Inc. (Valencia, CA) and the DNA IQ System from Promega Corporation have both been effectively applied to bone DNA extraction (Yang et al. 1998; Ye et al. 2004).

Regardless of the extraction protocol used, proper cleaning techniques must be employed at all times. For example, only one sample should be cleaned and prepared for extraction at a time. Prepare for extraction by removing all traces of soft tissue and soil remnants using a sterile brush and detergent. The bone should be sanded, washed, or soaked with bleach and then rinsed with deionized water to remove traces of the bleach. The bone should be air dried in a sterile laminar flow hood in a DNA extraction clean room. Tooth samples should be soaked in bleach for 10 minutes, and a sterile brush should be used to remove any extraneous material. The tooth should be rinsed with deionized water and air-dried.

The core PCR protocols are relatively straightforward. PCR makes copies of targeted regions of DNA at an exponential rate, ensuring that even a single copy of starting template can be examined. A number of commercially available high-fidelity polymerases and master mixes have further enhanced PCR sensitivity.

Nuclear DNA

Short Tandem Repeat (STR)

The most commonly used forensic DNA typing utilizes a core set of Short Tandem Repeat (STR) loci. STRs are DNA regions with repeated units 2–6 base pairs (bp) in length. The number of repeats for these highly polymorphic loci varies among individuals making them very effective for human identification purposes. Autosomal STRs are inherited biparentally and as the number of STRs analyzed increases, the chance of two individuals having the same DNA profile is decreased. It has been determined statistically that a DNA profile of 13 loci gives a unique profile (Chakraborty et al. 1999). Last, STR alleles are small and therefore require only small target areas (~100–400 bp) to be amplified. This fact makes STR markers useful in forensic applications where degraded DNA is common and potentially useful for the analysis of skeletal samples.

STR loci used in human identification are selected using the following criteria (Carracedo & Lareu 1998; Butler 2005): STR loci in human identification applications have a high discrimination power (>0.9 , with observed heterozygosity $>70\%$), are located on separate chromosomes, are robust when multiplexed with other markers, and have predicted allele lengths that fall into the range of 100–500 bp and therefore are suited for degraded DNA analysis (Alonso et al. 2001). In fact, several ancient DNA studies have successfully used STR markers (Gill et al. 1994; Zierdt, Hummel, & Herrmann 1996; Hummel et al. 1999; Ricaut et al. 2005).

Standardization of STR loci used in forensic typing is important, because information is shared domestically between laboratories at the state and federal level as well as by the international community. A common nomenclature was developed to aid in comparisons of data and for database applications (Bar et al. 1994, 1997; Gill et al. 2006). The International Society of Forensic Genetics (ISFG) issued guidelines for designating STR alleles (Bar et al. 1994, 1997). The FBI Laboratory's Combined DNA Index System (CODIS) utilizes 13 core loci: CSF1PO, FGA, TH01, TPOX, VWA, D3S1358, D5S818, D7S820, S8S1179, D13S317, D16S539, D18S51, and D21S11 (Budowle et al. 1998; Butler 2006). The International Crime Police Organization (INTERPOL) currently includes seven STR loci (TH01, VWA, FGA, D21S11, D3S1358, D8S1179, D18S51) used in all European laboratories (Martin, Schmitter, & Schneider 2001). Commercially available kits have aided standardization and quality control by providing high-quality products that contain core sets of loci.

DNA used for STR typing must be quantified before amplification, because too little or too much DNA in an STR reaction will give poor or erroneous results (Andelinovic et al. 2005). Hummel and colleagues (1999) demonstrated that the yield of STR products decreases with increasing product size and large STR products fail to amplify with low quantities of degraded DNA. Since DNA fragments as a function of time and environmental insults, shorter STR amplicons are more successful for forensic specimens containing low amounts of degraded DNA (Chung et al. 2004; Coble & Butler 2005). Targeted STR loci have been reconfigured to—STRs for increased success for degraded samples (Butler, Shen, & McCord 2003; Opel et al. 2006; Parsons et al. 2007). Normal STRs range in size from 100–400 bp, and mini-STR amplicon sets range from 20–200 bp.

Y-Chromosome

The Y-chromosome is one of two sex chromosomes found in the cell nucleus and has paternal inheritance making it useful for tracing lineages through time. It is present only in male individuals and, with only one copy per cell, is difficult to analyze in degraded samples. Y-chromosome DNA can be useful in missing persons identifications but is much less variable than DNA found in the mitochondrial control region. Even with these challenges, analysis of the Y-chromosome is being utilized in forensic circumstances (de Knijff et al. 1997; Jobling, Pandya, & Tyler-Smith 1997; Kayser et al. 1997; Underhill et al. 2000). While not useful for distinguishing between paternal relatives, it can be very useful in sexual assault cases where there is an overwhelming female component and a small male genetic component. The current recommendations of the Scientific Working Group on DNA Analysis Methods (SWGDM) include 11 core Y loci for forensic analysis. These can be found in commercially available kits that also provide additional loci.

DNA Sexing

Sexing skeletal remains is typically performed by forensic anthropologists or bioarchaeologists and can be a fairly straightforward task when a complete set of unfragmented adult remains is present (see Rowbotham, Chapter 19 this volume). Unfortunately, postmortem taphonomic

influences (see Nawrocki, Chapter 25 this volume) can render remains difficult to sex, and the sexing of subadult remains is not currently possible with any reliability. Consequently, sexing through the use of genetic markers can provide information in certain circumstances that is impossible to obtain through other methods.

Human somatic cells contain two sets of each chromosome and the sex chromosomes: an X- and a Y-chromosome in males and two X-chromosomes in females. With the exception of extremely rare chromosomal abnormalities, the physical presence of a Y-chromosome indicates male skeletal material. However, the failure of molecular techniques to detect Y-specific sequences is not sufficient evidence to classify samples as female. Errors in the PCR amplification process may provide alternative explanations for non-detection. For example, DNA may be too degraded for detection, or technical problems may inhibit the amplification process. As a result, it is imperative that genetic-based sex determination analyses have an internal control.

The amelogenin gene is involved in the formation of tooth enamel and tooth development (Buel, Wang, & Schwartz 1995) and has copies on the X- and Y-chromosomes (Nakahori, Takenaka, & Nakagome 1991). The amelogenin gene on the X-chromosome, however, contains a 6 base pair deletion of the first intron, creating a slightly smaller PCR product. Since the size differentiation is within the same PCR primer set, DNA from the X and the Y genes can be amplified simultaneously and distinguished from each other via a variety of methods, including gel and capillary electrophoresis. Because males and females carry at least one X-chromosome, an error in amplification is indicated when the X copy is not detected. Genetic sexing using this methodology has been performed on numerous forensic and ancient skeletal remains (Pascal et al. 1991; Mannucci et al. 1994; Palmirotta et al. 1997; Santos, Pandya, & Tyler-Smith 1998; Stone et al. 1999; Matheson & Loy 2001). Typically, a small fragment is targeted for amplification (112 bp for the Y and 106 bp for the X because of the deletion), making amelogenin useful in the analysis of degraded DNA.

Several commercially available STR kits, such as AmpFLSTR® PCR amplification kits (Applied Biosystems, Foster City, CA) and PowerPlex® System kits (Promega Corporation, Madison, WI), amplify as many as 15 STR loci as well as the amelogenin segment. Promega also offers the GenePrint® Sex Identification System in which amelogenin testing can be analyzed alone or added to other reactions. Note that amplicons generated by these kits are 212 bp and 218 bp for the X and Y, respectively, rather than the more typical 106 bp and 112 bp. Unfortunately, amplification of these larger segments may not be possible from bone samples in which the DNA has degraded below the 200 bp threshold.

Although extremely useful, the amelogenin gene approach is not infallible (Roffey, Eckhoff, & Kuhl 2000; Michael & Brauner 2004). There have been reported cases in which the Y portion of the amelogenin gene used for sex identification has not amplified from known male samples owing to a deletion in the targeted area (Chang, Burgoyne, & Both 2003; Kashyap et al. 2006). The frequency of failure varies, depending on the population tested. Santos and associates (1998) reported a 0.6% frequency of failure from 350 specimens from around the world. Frequencies have been reported to be as high as 1.85% in Indian males (Thangaraj, Reddy, & Singh 2002; Chang, Burgoyne, & Both 2003) and as low as 0.018% in the Austrian National DNA database (Steinlechner et al. 2002). The addition of another Y locus can help to reduce mistyping of males in these situations. The Sex-Determining Region Y (SRY) is important for testis formation and even most XX males who lack a Y-chromosome still have a copy of SRY on their X-chromosome. Therefore, the addition of this locus will confirm that the DNA is from a male individual (McKeown, Stickley, & Riordan 2000).

Mitochondrial DNA

The human mitochondrial genome is a maternally inherited small circular genome consisting of approximately 16,569 base pairs (Hutchinson et al. 1974). Hundreds to thousands of copies of the genome can be found per cell, making mitochondrial DNA (mtDNA) a very useful tool for genetic analysis of small amounts of degraded DNA.

The mitochondrial genome is divided into coding and noncoding regions. The mtDNA non-coding control region of the genome mutates 5–10 times faster than nuclear DNA and contains three hypervariable sections as well as two variable regions. The high rates of genetic polymorphisms in these areas decrease the likelihood that maternally unrelated individuals will share the same sequence variation (Greenberg, Newbold, & Sugino 1983; Wakeley 1993; Excoffier & Yang 1999; Meyer, Weiss, & von Haeseler 1999; Stoneking 2000). According to Budowle and associates (2003), there is an average of eight nucleotide differences between any two Caucasian individuals and 15 differences between any two individuals of African descent. In addition to the coding region's utility in forensic examinations, this nucleotide segment has been targeted for population genetic studies. Its high mutation rate may provide insight into short- and long-term evolutionary events, as well as ancestry and population migrations (Krings et al. 1997; Relethford 2002).

Genetic analysis typically involves the sequencing of two of the hypervariable segments located in the control region; these two segments contain most of the genome variation between individuals. Hypervariable region 1 (HVI) spans nucleotide (nt) 16,024 to nt16,365 (342 bp in length) and hypervariable region II (HVII) spans nt73 to nt340 (268 bp in length). Ideally, each region can be amplified in one or two separate reactions and sequenced. Unfortunately, DNA degrades to fragments of 100–200 bp in length (Pääbo, Gifford, & Wilson 1988; Pääbo 1989), making the amplification of larger full-length fragments difficult or impossible. As a result of the typically degraded DNA obtained from forensic bone and tooth samples, laboratories are forced to amplify very small overlapping regions (~80 bp) within the target sequence and reconstruct consensus sequences for HVI and HVII (Gabriel et al. 2001).

Sample sequence variation is determined by comparison with the published Cambridge Reference Sequence (CRS) (Anderson et al. 1981), which was slightly modified in 1999 (Andrews et al. 1999). The CRS assigns each nucleotide a specific number, and only the sites that differ from the CRS are reported by using the nucleotide number and the base that represents the change. For example, if position 16111 has a T instead of the C described in the CRS, it would be reported as 16111T. Any site not reported is assumed to have the same nucleotide base as the CRS.

MtDNA is inherited only from the mother and does not recombine. Therefore, direct comparison can be made between unidentified remains and any maternal relative, such as a mother, grandmother, sibling, aunt, uncle or cousin, because they should have identical nucleotide sequences. The maternal mode of inheritance can be advantageous in cases involving missing persons, when often only extended relatives are available for comparison. Alternatively, a negative consequence of maternal inheritance of mtDNA is that many related family members share a common sequence, providing a circumstantial identification and not a positive identification. Although not as powerful as nuclear STR analysis, given the proper context, mtDNA provides a method for putative identification in many challenging cases.

There are several other limitations that should be noted with regard to mtDNA analysis. Most individuals are homoplasmic, having one detectable nucleotide at a given sequence position; however, heteroplasmy, indicated by two detectable nucleotides at a given sequence position, occurs on occasion and at different rates for different tissues (Gill et al. 1994; Comas, Pääbo, & Bertranpetit 1995; Bendall, Macaulay, & Sykes 1997; Wilson et al. 1997; Carracedo et al. 2000; SWGDAM 2013). In addition to the issue of heteroplasmy, reference population databases need to be maintained and

increased to know the true frequency of sequence haplotypes (groups of samples with shared sequence variation). Paternal leakage and recombination have been claimed and disputed in the mitochondrial genome (Budowle et al. 2003). Last, inconsistent nomenclatures with regard to changes from the CRS and subjective interpretation of results have to be standardized among all those working in both forensic and anthropological genetics to ensure the most accurate assessments of population variation. Each of these issues should be monitored and evaluated in every laboratory. To ensure consistent results, general guidelines for mtDNA analysis have been addressed (Budowle et al. 1999; Holland & Parsons 1999; Carracedo et al. 2000; Tully et al. 2001; SWGDAM 2013).

From a technical perspective, forensic mtDNA sequence analysis is a labor-intensive and time-consuming process. Sequence specific oligonucleotide probes (SSOP), as well as linear array analysis, have provided faster alternative methods to examine variation in the control region (Stoneking et al. 1991; Divine et al. 2005). Both systems target the most variable sites in the control region to screen for variants. Linear array analysis is well suited for use in mass disasters and has been successfully utilized in the analysis of remains from mass graves (for example, Gabriel et al. 2003).

In the mid-2000s, single nucleotide polymorphisms (SNP) started to be examined outside the control region and have been found to further differentiate between individuals with similar mtDNA sequence haplotypes (Coble et al. 2004, 2006; Just et al. 2004; Kline et al. 2005; Niederstatter et al. 2006). The use of multiplex panels of SNPs to supplement control region sequencing has provided increased discrimination to mtDNA analysis.

Databases for missing persons often utilize mtDNA because of its unique characteristics. The FBI's National DNA Index System (NDIS) holds DNA profiles of unidentified persons and family reference samples. In 2005 Mexico launched a new missing persons database that also has a DNA component named System for the Identification of Remains and Localization of Individuals (SIRLI) (Baker 2006). The mtDNA analysis is performed at Baylor University and has focused on the identification of deceased, undocumented Mexico/U.S. border crossers and successfully identified roughly 75 skeletal cases from Arizona, California, and Texas. The Armed Forces DNA Identification Laboratory (AFDIL) is the most active laboratory in the United States for mtDNA analysis. AFDIL receives over 800 bone samples from unidentified bodies and between 1,500 and 2,000 family reference samples per year.

Emerging DNA Technologies

DNA Phenotyping

Forensic DNA phenotyping uses genetics to predict externally visible characteristics (EVCs) from biological samples (Kayser 2015). This use can provide investigative leads regarding unidentified persons. A commercially available system (IrisPlex) uses six SNPs from six genes to predict blue and brown eye color with a high degree of accuracy, 89% and 94%, respectively (Kayser & Schneider 2009). This system is further expanded by HIrisPlex, which targets 24 informative DNA variants for eye and hair color and provides hair color with 79% accuracy on average and which has successfully analyzed samples up to 800 years old. Prediction of human DNA-based pigmentation phenotype prediction has shown promise (Pospiech et al. 2014; Liu et al. 2015). An exciting application of this technology relates to unidentified persons cases involving decomposed or skeletal remains as well as for ancient historical remains.

Stature and face shape have also been estimated from DNA profiles. Wood and colleagues (2014) identified 697 variants from the genome-wide data from 253,288 individuals that account

for 20% of height heritability. In addition, there is improved accuracy in height-associated SNPs for predicating tall stature in addition to novel secondary associations for extreme tall stature (Liu et al. 2014).

There are a few small U.S. companies that offer DNA phenotyping services to law enforcement agencies, but results are not yet permitted in court. The Netherlands restricts the use to traits that are publically visible, and Belgium and Germany do not allow DNA phenotyping.

High-Throughput Sequencing

High-throughput sequencing, also known as next-generation sequencing (NGS), allows the sequencing of DNA and RNA much more quickly and inexpensively than Sanger sequencing. In addition, it is extremely sensitive and can provide information from samples with highly degraded DNA and low copy number DNA in the form of single-molecule sequencing, and it can simultaneously analyze multiple loci of forensic interest in different genetic contexts.

DNA databases of STRs have been established in more than 60 countries worldwide making them a standard for DNA comparisons and identification. It is necessary to incorporate STR loci into the information generated by these new technologies. Bornman and colleagues (2012) demonstrated that NGS can accurately identify the 13 CODIS STR loci as well as the amelogenin gene. Advantages of NGS for STR analysis include the simultaneous detection of large numbers of STR loci on autosomes as well as sex chromosomes, the ability to distinguish alleles with similar length or digital read count and it can facilitate the identification of mixed DNA samples. NGS could potentially increase the efficiency and cost-effectiveness of legal cases.

Mitochondrial DNA analysis typically only involves evaluation of polymorphism in the hypervariable regions. NGS could be implemented analyze the whole mitochondrial genome. Gunnarsdóttir and colleagues (2011) sequenced the whole mitochondrial genomes of 109 Filipino individuals simultaneously. This not only increases the amount of genetic information collected but also reduces time and cost for analysis. NGS has also increased the efficiency and data generated for Y-chromosome analysis. In one instance, over 10 million nucleotides were compared between two individuals who shared an ancestor 13 generations ago (Xue et al. 2009).

Forensic microbiological analysis as well as animal and plant DNA analysis may also be expanded in use with NGS technology and database development. However, before NGS technology can be used in a medicolegal context, guidelines must be established to address issues such as low-level contamination, error rate, low-template number, type estimations, and the use of data mining (Børsting & Morling In press).

Advisory Boards

To ensure uniform quality between laboratories, molecular techniques and nomenclature must be standardized; there are several organizations around the world tasked with defining and reviewing standards and guidelines for forensic DNA analysis. The International Society of Forensic Genetics (ISFG) (www.isfg.org/) has members from over 50 countries and working groups that include the European DNA Profiling group (EDNAP), the DNA Commission, and seven language-specific working groups.

In the United States the Scientific Working Group on DNA Analysis Methods (SWGDM) meets twice a year to discuss possible alterations to the national DNA standards. There is a transition from Scientific Working Groups (SWG) to the Organization of Scientific Area

Committees (OSAC), and the existing SWG documents will remain in effect until they are updated and disseminated. Some SWGs will continue to operate (<http://www.nist.gov/forensics/osac/>). The DNA Identification Act of 1994 recommended standards for quality assurance guidelines and standard operating procedures for forensic analysts and laboratories performing DNA analysis.

Conclusion

Forensic Molecular analysis has become increasingly utilized as advances in technology have allowed for the DNA amplification from challenging sources such as bone, teeth, and hair samples. Forensic archaeologists are in many instances the first in the chain of protectors of genetic information and therefore are relied on to take necessary precautions to preserve a variety of potential data. Increasingly archaeologists are performing genetic analyses and learning first hand how current molecular applications may be employed in the context of the field of archaeology. With new advances in high-throughput genome sequencing technology, archaeologists and geneticists will continue to find a rich common ground for collaboration.

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Forensic Odontology

John Clement

This chapter presents a broad overview of forensic odontology. Beginning with defining the discipline of odontology, it then discusses the role that forensic dentists play in identifying deceased individuals. A brief overview of dental structures is provided, followed by a discussion of the types of dental records that may be used by the forensic dentist. The odontologist's contribution to dental ageing and superimposition are also discussed. Current research being undertaken to improve ageing adults is outlined. The chapter concludes with a discussion of forensic odontology's shared responsibilities in advocacy for human rights.

Definition of the Discipline

Within the panoply of dentistry *odontology* is taken to mean “forensic odontology.” It is currently one of the fastest emerging subspecialties within the practice of dentistry and in the context of the broader subject of dental science. In the past it has been known as “forensic dentistry” and in Scandinavia as “forensic odontostomatology,” but neither of these alternate names really encompasses the scope of the discipline. As implied by its modern generic title, the legal process requires dental experts to observe, gather, record, and interpret meaningfully dental evidence in all its manifestations for the benefit of courts of law and the justice system. In essence, the forensic odontologist has to be an experienced practitioner of clinical dentistry and is, as such, usually required to be currently registered with the local professional licensing authority. However, many of the leaders and pioneers in the field often have academic appointments and higher degrees in dentistry or expertise in a relevant related discipline, such as anatomy (comparative and human) and biological anthropology. These additional skills obviously broaden the skill base of the forensic odontologist to the point where his or her expertise may overlap the margins of closely related disciplines such as archaeology and mainstream physical anthropology.

In the last two decades, opportunities—although rare—have arisen for postgraduate training specifically in forensic odontology. Hence, in the past, dentists have largely had to be self-taught, and it took many years to amass sufficient experience to become truly expert in all aspects of the discipline. When a practitioner does have the benefit of specifically targeted training, one can safely assume that he or she is not only expert in his or her own right but has a broad familiarity with the fields of expertise of all the other experts with whom he or she may have to work in a professional capacity. Although these experts obviously include pathologists, anthropologists, and archaeologists, they also include cultural heritage officers, the police, and other officers of the legal system in the prevailing jurisdiction.

Although forensic odontologists may have an increasingly important role to play in the investigation of circumstances and situations that have led to claims of negligence and malpractice

against other dentists and parodontal professionals, their main focus in day-to-day casework still remains primarily the corroboration of identity of deceased persons from a comparison of antemortem records and postmortem findings. Visual identification from the face or body is vulnerable to genuine mistakes and fraud or other attempts to pervert the course of justice and should not be used without corroborating evidence. The role of forensic odontology extends beyond contemporary events to the interpretation of ancient remains and therefore clearly has significance to archeological and cultural investigations as well.

Even before contemporary scientific investigative methods were conceived, let alone applied, there were numerous historical accounts of famous persons being identified accurately postmortem by the recognition of certain peculiarities within their dentitions. Keiser-Neilsen (1984) collated many of these cases. Since the late 1990s, and growing out of both historic and contemporary areas of activity, emphasis on the ethical context of the application of forensic dental expertise has been increasing. In dental practice this emphasis may relate to such issues as fitness for intellectually impaired persons to consent to treatment or an examination for the purposes of a criminal investigation. At the other end of the scale, it may relate to the position of the dental profession at large with respect to issues related to its complicity in torture (International Dental Ethics and Law Society 2006).

Forensic odontology has a vital role to play in identification for three main reasons. First, the teeth are durable in life and postmortem, often in extremely adverse conditions that have destroyed many other parts of the body. Second, the teeth are the only skeletal elements to have been visible and hence recorded in life by means of photographs or dental records in their various forms. Finally, there is a wide range of variability in the form of the teeth and the dental arches and parodontal anatomy.

Success in using odontology for identification has recently been emphasised by the outcome of the Disaster Victim Identification (DVI) process in Phuket, Thailand, following the Boxing Day 2004 tsunami in which thousands of people perished. The widespread assumption of investigators at the outset of the investigation (including the odontologists involved) was understandably that DNA would provide the major means of identification, particularly because Phuket is a region where many foreign tourists died and where it would be possible to obtain well provenanced antemortem biological samples for comparison. Unfortunately, and surprisingly, this proved not to be the case. Although it remains difficult to get reliable figures for the success rates of the various methods used to identify the victims, the disparity between the success of forensic odontological methods and DNA was huge, with dental methods contributing to the identification of approximately 70% of the victims identified, whereas DNA identified approximately only 1% in its own right. The problems with DNA analysis in very large-scale investigations are numerous: they range from an inability to obtain antemortem samples for comparison when the victims' homes have disappeared and the problems of locating close relatives (many of whom may also have perished) to problems of an inability to maintain continuity of evidence for samples, laboratory overload, multiple centres using different analytical protocols, and technical problems related to sample degradation caused by postmortem putrefaction (see Baker, Chapter 28 this volume).

Durability and Uniqueness of Dental Structures

The teeth are the most durable organs in the bodies of vertebrates, and thus interpretations of our past and evolution rely heavily on remnant dental evidence found as fossils (Tobias 1990). Teeth can persist long after other skeletal structures have succumbed to organic decay or destruction by some other agency, such as fire. Teeth and bone can be heated to temperatures approaching

the melting point of skeletal mineral ($>1,600^{\circ}\text{C}$) without appreciable loss of microstructure or tertiary architecture (Clement, Olsson, & Phakey 1992; Holden, Clement, & Phakey 1995a, b, c) (Figure 29.1). This phenomenon seems paradoxical, because the ashing of tissues implies that all which remains is powder. Anyone who has seen the remains of a modern human cremation knows this is not the case. It may be argued that dental enamel, the hardest skeletal tissue, is not a tissue at all in the strictest sense but virtually a fossilized secretion from the time of tooth formation within the bony crypts of the alveolar processes of the jaws and hence before tooth emergence into the mouth. The amount of organic matrix remaining in mature enamel is minimal ($<2\%$ w/w), but the inorganic fraction is 96% w/w, comprising submicroscopic crystals of an impure form of hydroxyapatite (HA) that are very long compared to their width (so long to have eluded measurement by any method applied to date). Nevertheless, the crystals' aspect ratio can definitely be expressed in many orders of magnitude, with the "c" axis of the crystals being very long compared to either the "a" and "b" axes, which are similar to each other. Following combustion of the residual organic matrix and the purging of any moisture in the enamel, it could be argued that the complex tertiary structure of enamel (in which long crystals are woven into complex prismatic patterns during tissue formation) holds the tissue together. Although this argument may have a role to play, other factors are at work.

When bone is heated similarly, it, too, retains its structure, albeit in a friable state; yet it is known that bone mineral is deposited as much smaller, shorter crystals lacking the filamentous nature of those found in enamel (see also Thompson & Ulguim, Chapter 26 this volume). Why then does burnt bone not disintegrate? As the collagenous and mucopolysaccharide components of bone burn and the accompanying water is driven off, the remaining inorganic components (also an impure form of HA) retain structure so well that osteons and even bone cell spaces are preserved. This process occurs because, on heating and cooling, the original, impure apatite recrystallises with its smallest crystals becoming sintered to their larger neighbours. It is this sintering that holds the remnants of the tissue together and enables it to be collected and examined histologically or in a

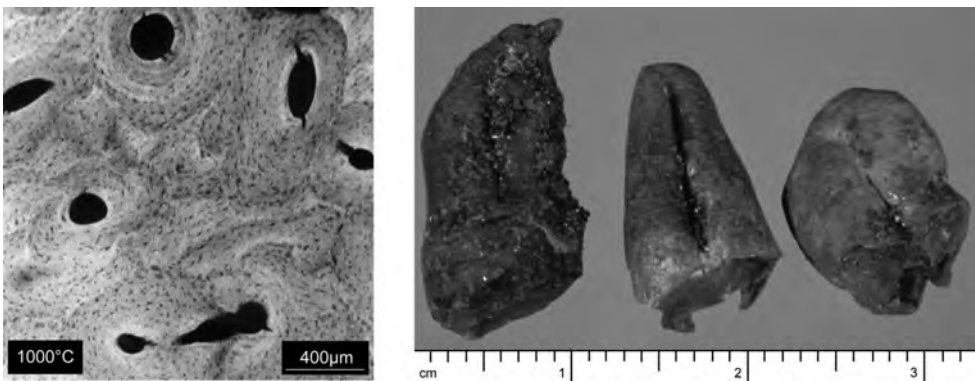


Figure 29.1 (Left) Transverse section of mid-shaft of human femoral cortex incinerated for 2 hours at $1,000^{\circ}\text{C}$. Haversian systems and osteocyte lacunae can still be clearly recognized despite some cracking and shrinkage of the original tissue. No organic matrix remains, and yet the structure appears almost intact. This mineral skeleton is very friable, and such evidence needs to be identified, stabilized, and collected by an expert. *(Right)* Three human teeth recovered from a fatal fire. Much of the bone of the craniofacial and appendicular skeleton was destroyed, but the teeth are remarkably intact. Dark colour would indicate incomplete combustion of the organic matrix owing to brevity of the fire or temperatures lower than 800°C (or a combination of both factors).

scanning electron microscope. The recrystallized mineral results in a more purer apatite than the original together with small quantities of a minor, secondary phase, beta-tricalcium-phosphate. From the relative proportions of major and minor phases, the lack of stoichiometry (the calculation of measurable relationships of the reactants and products in chemical equations) of the original mineral can be calculated, and from this inferences can be made about taxonomic origins of the tissue. The combination of histology and knowledge of crystal chemistry can reveal genus differences, and in the case of morphologically unidentifiable fragments of skeleton comprising any of the collagen-based hard tissues (bone, dentine, and cementum), this may be important for the correct interpretation of both crime scenes and archaeological sites (Miles 1963).

Dental Treatment, Dental Records, Nomenclature, and Notation

Much of the utility of dental findings for identification purposes derives from the almost universal need for people in economically developed countries to attend a dentist for an examination of their oral health status. The inevitable by-products of such visits are the dental records of the person in life. Such records comprise much more than just written clinical notes; plaster casts of the patient's mouth, clinical photographs, and, in particular, radiographs (dental "X rays") are invaluable for the forensic odontologist's comparison of antemortem status and postmortem findings (Figure 29.2). However, in the past it was commonly (and erroneously) assumed that if no treatment has been provided, then dental records would be of little or no use for identification. This assumption was a serious misconception.

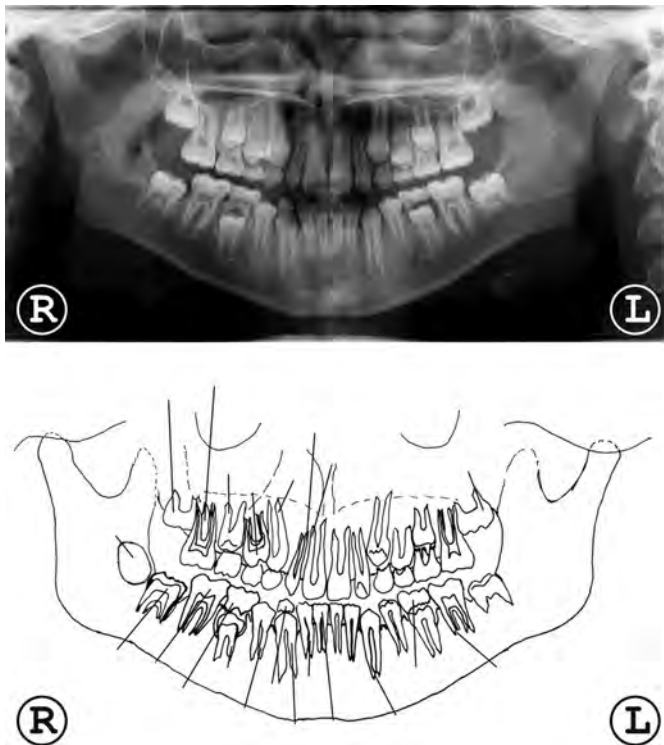


Figure 29.2 Clinical radiograph of a 10-year-old Caucasian girl

With the optimization of the fluoride content of the drinking water supply (to maximize its anti-caries effects), combined with educational efforts to improve diet and oral hygiene, many young people in economically developed countries no longer have any dental decay. Although such people obviously do not have any dental restorations, which themselves are made of durable materials and that might have been used for identification purposes, most still have radiographic examinations of their teeth done routinely to check for early signs of dental decay beginning at the regions of contact between adjacent teeth in the dental arches. In older people similar radiographs are taken to monitor periodontal health.

Furthermore, a decline in dental decay in modern, prosperous populations is invariably accompanied by an increasing societal emphasis on aspects of oral health status that were once generally considered less important, or a luxury. The growth in orthodontic practice in Western societies is a good example of this change in attitude and sophistication (Kingman 1997).

Typically, full, lateral cranial radiographs are taken as part of the orthodontic examination. Plaster casts of the patients' mouths are always made for assessment, diagnosis, and treatment planning. These casts record tooth number, size, crown form, and tooth position very accurately. Occlusal relationships are also recorded and can also be important for identification purposes, particularly if reconstruction of facial features on remnant skull evidence or the use of superimposition techniques is required. Given the combination of the durability of the dental structures, the likelihood that the dental status of many people is recorded in detail by professionals known to be hoarders and who retain records for as long as is practicable, often far in excess of that mandated by law, there obviously exists a very powerful resource for the identification of remains. However, using this resource is not without its difficulties.

One problem frequently encountered in international situations relates to the fact there are several different conventions currently in use for the dental nomenclature used by dentists in their records. In part these can be divided crudely across geopolitical boundaries. The United States and smaller countries within its direct sphere of influence use a system of dental nomenclature known as The Universal System. The rest of the world tends to employ a system agreed on by the Federation Dentaire International (FDI). Some older United Kingdom/European systems, such as Palmer/Zigmondy and the Scandinavian Haderup system, still have some exponents; however, these tend to be older dental practitioners. But we remember that not all bodies are examined promptly after death, and not all dental treatment was carried out in the last six months. The remains of many people are discovered only many years after they have died and in a skeletonised state. In such circumstances the only antemortem records that may exist could well be recorded in archaic form. Applying the analogy of languages to this situation, we should also remember that dialects and even individual variations exist to the main charting conventions. For this reason it is very unwise for anyone without dental training to attempt to decipher clinical dental notes. Experience has shown that when such an attempt is made, not only are mistakes made with respect to the interpretation of the records to hand but, worse still, the existence of other records, made by specialists elsewhere, often goes unnoticed.

Another reason why the expertise of a forensic odontologist needs to be drawn on relates to the fact that the dental and radiographic examination of a corpse or skeletonised remains is quite different from the more common dental examination of a living person, irrespective of whether he/she is awake and cooperative or anaesthetized and unresponsive. These skills in postmortem radiography are not taught as part of any undergraduate dental curriculum.

Another difficulty relates to the fact that some practitioners chart only work to be done and not work done previously, perhaps by a previous dentist. Modern codes of practice deem this to be unethical, yet many incomplete records still exist and are still useful. When combined with other partial records, they can build up a complete composite antemortem record that can then be compared with the postmortem findings.

It has been estimated that with 160 tooth surfaces existing in a full adult human dentition, the combination of sites of dental decay and the fillings placed in teeth to restore them and other features of the mouth could provide “an astronomical” number of unique combinations that may be depicted in a single dental chart, and when radiographic evidence is added, then the number of possibilities “approaches infinity” and “no two sets of teeth are identical” (Mertz 1977: 47). Although this set of circumstances may exist theoretically, such statements can also be highly misleading. Dentists are aware that certain tooth surfaces are more likely to decay before others and are therefore more likely to have been restored in a similar way (Clement 1998). Comparisons between antemortem and postmortem dental charts alone can erroneously create the incorrect impression that a “match” exists when an examination of the body or the inclusion of radiographic comparisons would show that it does not. For this reason, it is important to note that although modern, purpose-built software for the handling of large quantities of dental data, such as might constitute a missing persons’ database or be used in DVI situations and can suggest “candidate matches,” the final arbiter has to be a clinician capable of appreciating all the subtleties between records. Detailed morphological characteristics of teeth and individual restorations need to be sought and compared before the expert can determine a match and make the appropriate recommendation to the investigating authorities for their final arbitration on the identity of the deceased.

Less Commonly Used Features for Comparison

Antemortem X-ray images of the head and oro-dental region are excellent evidence for identification purpose. The size, shape, and dimensions of many structures are very stable in the skeleton of the head after early childhood, particularly those relating to the cranial base in the region of the anterior cranial fossa. The paranasal sinuses are small early in life, but the pneumatization of the bones of the face and base of skull with growth to adulthood gives rise to a series of large air-filled cavities that are complex in form and unique in outline. The frontal sinuses housed in the ridge of bone just above the eye sockets have numerous chambers with lobes separated by walls or septae. These sinuses are ideal for comparison between antemortem records and corresponding postmortem views. The comparison can be made by overlaying the antemortem and postmortem films either directly, if to the same scale and taken with the same geometry, or in an electronic environment where some adjustments can be made (Andersen & Wenzel 1995; Clement, Officer, & Sutherland 1995; Ranta & Kerosuo 1995), provided an audit trail of image manipulations is recorded. The biggest impediment to the more widespread use of this technique is attributable to the relative rarity of antemortem postero-anterior (PA) radiographs of the skull. This situation applies to many types of medical treatment, and when the medical and/or dental records exist they are excellent. Unfortunately, from an identification requirement, they are rare; far more people still have their teeth checked, compared to, for example, having their hips replaced.

The maxillary sinuses are similarly both complex and stable in form in adulthood. Their images are frequently recorded on dental radiographs. It is only in panoramic views such as an orthopantomograph (OPG) that they are seen in their entirety. Their images are often poorly recorded, because the bones surrounding them are very thin. The films taken to record the health status of the teeth and their associated alveolar processes (both of which are much more radiopaque than the sometimes eggshell thin bones of the face) overexpose air-filled sinuses in antemortem dental films (see Figure 29.2). However, when their shape and form are clearly depicted, they are excellent for comparison purposes, and postmortem many different exposures can be taken in the same projection so that if one combines all the information, both teeth and bones can be imaged clearly and their anatomical relationships visualized.

In addition to skeletally based methods for corroborating identification, the characteristics of the oral soft tissues and lips have occasionally been used (Kasprzak 1990). The less deformable and the better protected such structures are, the more potential value they possess. Therefore, whereas lip prints on rigid objects can be compared with impressions or photographs of the lips of living subjects, postmortem changes or other destructive processes such as burning quickly destroy any individualizing characteristics. Conversely, structures such as palatal rugae, protected within the mouth from fire and predation, survive for comparison (Thomas & Kotze 1983). Mirror-image impressions of these features, which are stable in life and durable postmortem, are commonly recorded on the fitting surface of dentures.

What Can Be Achieved in the Absence of Antemortem Records?

In some cases when skeletal remains are found, it is not immediately obvious whether the remains are human or not. Fortunately, the teeth and facial skeleton of humans are highly characteristic, differing significantly even from anthropoid apes, our nearest evolutionary relatives. Nevertheless, a good knowledge of comparative dental anatomy finds application from time to time. This knowledge may be for the identification of certain genera from skeletal and dental remains *per se* in archaeological finds through to the identification of a particular species of shark and calculating the size of an individual fish from fragments of teeth and wound patterns found in victims of shark attack. Other bitemarks, such as those inflicted by dogs, large cats, and crocodiles, can be interpreted fully only if the dental anatomy of the animal implicated is understood.

Once remains have been determined to be human (see Mulhern, Chapter 15 this volume), then one must consider the possibility of commingling of multiple remains (see Byrd & Adams, Chapter 17 this volume). This consideration requires the expertise of the anthropologist, but the forensic odontologist can assist by inferring age from patterns of calcification and emergence of teeth in subadults and commenting on the age-related changes to erupted teeth in the adult. Most of the post-emergence features, such as tooth wear, are highly dependent on culture, diet, and lifestyle of the deceased. For this reason, it is hazardous to allow oneself to be pressed to give opinions in cases involving living persons, because the precision demanded of the courts just cannot be provided, and the consequences of error can be catastrophic for the individual.

A common situation encountered today is that involving recent immigrants or refugees charged with a serious offence. If deemed a minor (say, <16 years of age in some jurisdictions), then the person will be subjected to a more lenient and supportive experience within the legal system. Problems arise when the alleged offender is suspected of having lied about his or her age previously in order to gain residency within a particular country—there can then exist an incompatible discrepancy between the previously declared age and the current claim to still be a minor. Unfortunately, the precision of age estimation from dental maturity, although better than any other physical indicator in early life, is just not good enough to definitely determine whether a person is 15 or 17 years old, and yet that may be what the law seeks to discover. Notwithstanding this problem, during the 19th century in Britain, children were precluded from working in factories until their second permanent molars had erupted (Saunders 1837), which occurs approximately around 12 years of age.

Combining age estimates based on dental maturity with other anthropological age indicators may add to precision and accuracy, but it is highly unsafe to be too didactic when ancestral variation, past nutritional status, and population statistics reflecting secular trends are unavailable. Unfortunately, much of the original data on which widely accessible tables of

tooth emergence (often misleadingly described as “eruption”) were based were gleaned from small samples of dubious validity. Logan and Kronfeld’s studies (for example, 1933) that were brought to a much wider readership by Schour and Massler’s later publication (1941) were based on the chronology of dental development in a small group of terminally ill children. Even in dental schools, this fact is not widely known, and for convenience Schour and Massler’s charts of tooth development are still very widely used for reference. Add to this fundamental problem the general trend toward earlier attainment of physical maturity in recent times, and it becomes apparent that the old data should not be regarded as directly applicable today. Last, it is important to draw a distinction between dates of tooth emergence into the oral cavity, in which there is considerable individual variation, and the chronology of tooth development. Although the two processes are linked, there are important opportunities for discrepancies to arise. A more reliable indicator of age would appear to be radiographic assessment of the level of the chronology of the whole process of tooth development for every individual tooth within the dentition, but ethical constraints should limit this application in living subjects unless they give informed consent.

A representative reassessment of tooth development and emergence patterns for all contemporary populations is urgently required. Because of differences in genetic background and general environmental conditions in the world, it is extremely inappropriate to use what may be excellent data gathered in one place long ago (Moorrees, Fanning, & Hunt 1963) and apply them to an entirely different population without first establishing their validity in the new context. In each case, published standards need to be validated for the population to which they are going to be applied (Liversidge 2003).

The excellent system of “scoring” tooth development devised by Demirjian and Goldstein (1976) has recently been refined by Willems (2000). It would be particularly valuable if other researchers could use this methodology, which, requiring only quite low technology and often simply access to patients’ notes, would enable data from various sources to be compared. Meanwhile, the courts rely on experts who, through years of experience, have acquired sufficient experience to make the necessary local adjustments to the standard data tables, often without realising it.

Age Estimation in Adulthood

Although there remains room for improvement for studies of chronology of dental development, age estimation in adulthood is even more problematic (see Rogers, Chapter 20 this volume). In Sweden a system for ageing extracted or lost, previously fully erupted teeth was developed by Gustafson (1966). Essentially, Gustafson made longitudinal ground sections of teeth and then scored features known to change over time. These changes included progressive wear on the biting surfaces of the teeth; the reduction in the volume of the pulp chamber by continued slow, hard tissue formation on its walls (secondary dentine accretion); the continued deposition of cementum, a bonelike tissue, on the external root surface; and the increase of translucency in the dentine due to continued mineralization together with changes that may take place as the soft tissues of the periodontal tissues recede over time. By examining many teeth taken from individuals of known age and combining scores of the status of the age-related changes, Gustafson was able to construct a regression curve. Thereafter, when unknown teeth were found, they would be sectioned, the various features scored, and then, by reference to the regression curve, the age of the person from whom they came was derived.

Although this method worked well in Sweden at the time, it very likely would be much less applicable, even in Sweden, 40 years later. At the time that Gustafson’s method was developed,

Sweden was a remarkably stable society. Not having experienced much recent migration and virtually none from outside Scandinavia and Northern Europe, the gene pool was settled, and the prevailing political system effectively meant most people experienced a similar level of prosperity, education, living conditions, and diet.

By contrast, in other countries, or even Sweden in the 21st century, Gustafson's method, or its derivatives, is unlikely to be very useful. In many parts of the world, political instability and poverty have forced people to move from countries each with their own idiosyncratic customs, lifestyles, and diets to countries where these conditions may be very different. This situation can, and often does, have a profoundly confusing effect on age-related changes to the dentition; although some, such as the slow increase in root translucency with increased deposition of intratubular dentine (commonly misnamed "peritubular dentine") over time may be largely physiological, others such as occlusal wear and the pulpal reactions to it may be dictated much more by the abrasiveness of the diet than increasing age *per se*.

Ancestral Traits in the Teeth and Dentition

Dental anatomists and anthropologists study the human dentition in two ways: metrically and non-metrically. There have been a multitude of studies in which the sizes of tooth crowns have been measured. Foremost among the exponents of this "metric" methodology are Garn, Lewis, and Kerewsky (1965, 1968); Goose (1963, 1971); Keiser (1990); Moorrees (1957); Moorrees and associates (1957); Moorrees and Chandha (1962); Moorrees and Reed (1964); Townsend (1980); and Townsend and Brown (1978). The populations studied usually represent geographically or culturally separate populations who are therefore assumed to share some common genetic features or exhibit the effects of some important environmental effects. The resulting measurements are therefore taken to be descriptive of, and may be unique to, that particular group. Large numbers of measurements are made on large numbers of teeth from large numbers of individuals. For living subjects, plaster casts are frequently used as an intermediate step, whereas with skeletal remains of past populations measurements can frequently be made directly from the remains. Obviously, care has to be exercised. It is possible for a particularly important reference set of remains to have been examined so frequently that they become abraded by frequent measuring and then become less useful. Although such studies are very useful for identifying evolutionary change within the dentition or investigating general patterns of inheritance of tooth size and form or the shape of the dental arches on a population basis, they can be used with much less certainty in the forensic situation that often requires the examination of the dentition of a specific individual.

Another way in which tooth form has been studied has been to recognize the presence, absence, or degree of expression of features that vary in their prevalence among individuals. These "non-metric" studies have been made semi-quantitative to bring some consistency to the interpretations made by widely separated investigators. To this end, identical sets of dental casts have been manufactured from type specimens and distributed in an attempt to standardize scoring of any particular feature that is being described (Dahlberg 1945, 1949, 1963; Turner, Nichol, & Scott 1991; Buikstra & Ubelaker 1994). It is more common for non-metric variations of tooth form to find application in forensic cases, because the local forensic odontologist is very well aware of the prevalence of certain characteristics, for example, the prevalence of Carabelli's trait, in the teeth of some of the people making up their own local populations. Again, it must be emphasised that experience has shown that there is no dental trait that is proof-positive of any ethnic group under all circumstances.

Predictable Future Scientific Advances

The determination of age at death of unidentified remains is still problematic, particularly when the remains of adults are involved and when the effects of environmental factors known to modify the dentition during life are unknown. One method that has had some sporadic exploration of its usefulness but that is certainly worthy of further research is the slow but irreversible conversion of left-handed (levo) amino acids into their right-handed (dextro) enantiomers in proteins following the time of their deposition (Kvenvolden & Peterson 1973; Davies 1975; Ogino & Ogino 1985, 1988; Ohtani & Yamamoto 1990a, b, 1992; Arany et al. 2004).

Aspartic acid has, to date, been shown to be the amino acid with a suitably rapid conversion rate that also correlates better with period-since-deposition than either glutamic acid or alanine (Ohtani & Yamamoto 1991). At some time, all the hard tissues of the body have been investigated as source material for such determinations, but bone is problematic, because it is in a constant state of turnover, so an elderly person may have bone tissue within the bone organs that may be only very recently deposited. Cementum is very sparse and exhibits continued deposition throughout life, with the later deposited material possibly swamping any determinations derived from the scant veneer of first-deposited material closest to the tooth root surface. Dental enamel has been explored (Ohtani & Yamamoto 1992), but because it is 96% mineral by weight, again there is very little organic material to be collected and sampled.

Because collagen is the major proteinaceous component of dentine and dentine constitutes the bulk of all teeth, there is a strong possibility that time-related chemical transformations shown to occur in collagen will be useful for ageing of dentine. This situation is made more favourable since in most adult teeth the period of deposition in any single tooth would rarely exceed nine years, and any secondary dentine laid down during later life always resides on the pulpal surface from which it can be removed if required.

Furthermore, if from its morphology the particular tooth can be identified, then the time window during which it was formed can be estimated. If this information can be combined with an estimation of the degree of aspartic acid racemization that has taken place, then using regression equations, one can determine age at death. One recent study concluded that age determination using this technique with fresh cadavers predicted age to within two to four years of the true age (Ohtani 1995). Unfortunately, other laboratories have not always been so successful, with Mornstad, Pfeiffer, and Teivens (1994) predicting age with a confidence interval of 95% of about ± 12 years, which would be much less useful. The anatomical position of the teeth sampled has been shown to have an effect, and it has been postulated that teeth (and tooth surfaces) deepest from the body surface and farthest from the opening of the mouth undergo a more rapid conversion of aspartic acid, because they are held at a higher temperature than are their more superficial counterparts (Ohtani 1997; Ohtani, Ito, & Yamamoto 2003).

Postmortem conditions are also an important consideration in evaluating the usefulness of aspartic acid racemisation. Fixation of tissues in formalin stops the racemization of aspartic acid (Ohtani et al. 1997), as does desiccation. Conversely, the conversion rate may be accelerated in alkaline environments, becoming progressively slower through water, acid, and dry conditions (Ohtani 1995). Reviews by Waite and associates (1999) and Yekkala and colleagues (2006) suggest that the general method is rather technique sensitive, and there are other factors to be taken into account before too much reliance can be placed solely on the results of a biochemical assay. For example, the dentine from deciduous teeth has been shown to exhibit double the conversion rate of dentine from permanent teeth (Ohtani, Kato, & Sugeno 1996). There are problems with the interpretation of very old skeletal material (Kvenvolden & Peterson 1973), and the consequences of sampling slabs of material cut transversely from various parts of the

tooth, compared with longitudinal sections, do not always seem to have been understood. A midline longitudinal section collects material from the whole period of the tooth's formation, which is a longer time window than any horizontal section through crown or root would provide. Nevertheless, given all of the aforementioned shortcomings, aspartic acid racemization would still offer the possibility of providing objective estimates of time since death. It also offers opportunities for ageing living persons if biopsy techniques can be developed and ethical issues addressed (Helfman & Bada 1975; Ritz et al. 1995).

Another area of forensic odontological practice that is still problematic, yet highly likely to benefit from further scientific study, is the inference of facial appearance from the skeletal remains of the cranium, mandible, and associated dentitions. This process of reconstructive anatomy has been called "facial reconstruction" or rather more pedantically "facial approximation" (see Stephan & Claes, Chapter 27 this volume). The techniques for achieving results are many and varied yet all rely on an assumption that the external form of the face can be inferred from the form of the underlying skeleton. This has never been proven. Moreover, in all attempts to visualise, or harder still quantify, the range of variation obtained when multiple operators using a range of methods—but all working from identical replicas of the same skull and given the same details about body mass index (BMI) and sex—have been so widely divergent that the value of attempting facial approximation has to be questioned (Stephan & Henneberg 2001). This observation is countered by practitioners who claim high success rates over chance with reconstructions (approximations) obtained in their laboratories. Such claims are rarely verifiable. (A good review of the history of facial reconstruction is provided by Wilkinson 2004).

Nevertheless, the scepticism of investigators often finally succumbs to the fact that facial reconstruction is a technique of last resort, and nothing is to be lost by attempting it. Haglund (1998) argues that the success of forensic art has as much to do with the timing and style of publicity afforded to any reconstruction of facial likeness as it has to do with the fidelity of the reconstruction itself. At the time that Haglund wrote this, it was highly likely to be the case, but more recently facial reconstruction is moving from empirical artistic roots to a science much more rooted in engineering and computer modelling and 3D visualization, which are innately more amenable to quantitative methods.

One very exciting possibility that will add greatly to knowledge in this area is the capacity to utilize data arising from the routine CT scanning of cadavers as part of the forensic autopsy to study interrelationships among skull, dentition, and face for the first time in a truly holistic manner. Modern mathematical methods of analysis free the investigator from historical reliance on hard-to-locate landmarks, and the access to modern contemporary data from relevant populations gives the results immediate applicability.

Forensic Odontology's Shared Responsibilities in Advocacy for Human Rights

In common with other colleagues in the forensic disciplines, the forensic odontologist has a responsibility to ameliorate any potential harm to those incarcerated and/or subjected to torture. The forensic odontologist is expert in the examination, documentation, and, when early treatment can be instigated, the healing of those with oro-facial injuries. These injuries can take several forms and collectively may clearly represent a systematic pattern of abuse over time. Prisoners may be beaten and suffer fractures of oro-facial structures. Alternatively, they may have been forced to consume corrosive liquids or have been burned, both of which may leave characteristic patterns of scarring. Careful documentation including the use of photographs and radiographs can provide compelling evidence for courts at a later date. In the case of examination

of skeletal remains of past populations, the prevalence of oro-facial trauma in the skeletons of children can be used to estimate whether domestic violence was more or less common in societies that no longer exist. Such estimates can then be compared with the circumstances under which those people are thought to have lived (Walker, Collins-Cook, & Lambert 1997).

At the other extreme, the humanitarian responsibilities of the odontologist extend to a role in the prevention of massacres and other atrocities. In concrete, practical terms perhaps the most important role for the forensic odontologist and others such as the pathologist and anthropologist is to gather evidence that mass murder has been committed. Again, the role of all forensic professions is to document the evidence from mass gravesites in such a meticulous and comprehensive manner that it can withstand the closest scrutiny by the courts, international tribunals, and the most critical historians of future generations. This type of evidence has been used in The Hague for the prosecution of those charged with crimes against humanity, including mass murder. A clear understanding from the outset on the part of potential perpetrators that crimes committed against humanity will be investigated and the perpetrators will be brought to trial may deter some who may be contemplating genocidal acts. However, we should not be naïve about such hopes; monsters go, or are deposed, often only to be replaced by others of the same ilk, the situation in Iraq in 2006 being a ghastly example in recent times. However, in a civilised society all of us have a duty to hope and, if nothing else by our actions as expert witness forensic odontologists with our peers in other related disciplines carry the responsibility to bear witness and document the facts for future generations to hear and judge. For this reason, reputation and a capacity to demonstrate independence from those with vested interests are vital.

People missing as a result of armed conflict, internal violence, or civil unrest are currently a harsh reality for many families around the world. This is not only very distressing for those directly concerned, but it may also hamper reconciliation and peace efforts by contributing to further outbreaks of violence. Of course, it is impossible to document every atrocity. To give some perspective to recent events, Human Rights Watch gives an estimate for the numbers of victims who “disappeared,” many presumed murdered, during Saddam Hussein’s reign in Iraq at almost 300,000 (Human Rights Watch). In addition and more controversially, Burnham and associates (2006) have estimated that following the invasion by America and its allies a further 655,000 extra deaths have occurred, many of these as a result of sectarian violence. For the remains of a significant number of these people to be exhumed and identified and have the manner of their death recorded are beyond the capacity of the world’s forensic community at this time, and so new strategies have to be formed to bring finality to the next of kin and allow the affected communities to rebuild themselves. The International Committee of the Red Cross has begun work on “The Missing,” a project that aims to shift the emphasis of investigations into the fate of persons who disappear during civil conflict from a prosecution focus to one with broader humanitarian objectives (The Missing Project 2003).

In the past, when mass murderers were caught or handed over to the authorities, it was necessary only to prosecute them for the deaths of a few identified persons rather than identify all the victims. This situation left the traumatized communities with no definite end-point to their wish to know for certain the fate of their friends, neighbours, and kith and kin. “The Missing” project has been exploring the feasibility of identifying all the deceased as far as is practicable and developing strategies to do so. The expert forensic odontologist will certainly have an important role to play in the education and training of local workers, who will inevitably have to shoulder the bulk of the burden for the identification of victims of atrocities to the satisfaction of their surviving relatives. The aim of “The Missing” project is to heighten awareness among governments, the military, international and national organizations—including the worldwide Red Cross and Red Crescent networks—and the general public about the tragedy of people unaccounted for as a result of armed conflict or internal violence and about the anguish of their families.

Conclusion

The identification of persons from the unique peculiarities of their teeth and oral structures has been practiced since antiquity. In the last century this practice became a scientific discipline within dentistry but with close links to related disciplines, particularly anthropology. In common with other forensic sciences, forensic odontology is practiced on behalf of the family and friends of the deceased. For people to know for certain of the death of a loved one can be a comfort from the anguish of continuous uncertainty. In this way, individuals may find it easier to rebuild shattered lives and, in the aftermath of atrocities that have resulted in mass murder, it may form a basis for a gradual reconciliation between past adversaries.

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Part IV

The Crime and Disaster Scene

**Case Studies in Forensic Archaeology
and Anthropology**

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Investigative and Legal Aspects of a U.S. Federal Death Penalty Case

*Dawnie Wolfe Steadman, William Basler, Michael J. Hochrein,
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The role of forensic anthropology in domestic cases in the United States has expanded tremendously in the last two decades. Forensic anthropologists routinely assist law enforcement and medical examiners in the search and recovery of human remains, provide skeletal evidence of personal identity, estimate the postmortem interval, and interpret skeletal trauma. Forensic anthropologists and archaeologists can work in human rights and humanitarian and mass fatality, as well as in domestic contexts. Because most forensic anthropology practitioners work within their local jurisdiction they must have a clear understanding of the state and federal laws of their home country, particularly when they are involved in the investigation of a criminal case. Moreover, the postconviction “life” of a case, especially a death penalty case, can involve lengthy appeals processes and require the attention of forensic experts for many years after a case was seemingly resolved by a conviction.

This chapter provides a detailed report of a complex federal case that illustrates the multidisciplinary nature of domestic homicide investigations and that highlights the role of forensic anthropology and archaeology. This case demonstrates the various forms of physical evidence that can be recovered from single and mass graves when standard archaeological procedures are correctly applied and underscores the critical need for cooperation between forensic pathologists and anthropologists in trauma analysis. As in many anthropological cases, the protracted period between disappearance and recovery necessitated consistent investigative attention until critical information came to light as to the whereabouts of the remains.

In July of 1993 Lori Duncan,¹ her two little girls, Kandace and Amber, and a man she had met only weeks earlier, Greg Nicholson, disappeared from Lori’s home in Mason City, Iowa. Four months later, another man, Terry DeGeus, disappeared as well. The sole known connection between the cases was that both men had been involved in a drug distribution ring headed by Dustin Honken. Nicholson had recently agreed to cooperate with federal prosecutors and testify against Honken in an upcoming federal trial. Months and then years passed without any trace of the five missing persons. Although it was quickly apparent to the federal authorities that the missing people were victims of foul play, it took over a decade for a team of investigators, prosecutors, and forensic scientists from a variety of federal, state, and local agencies to locate and recover the victims’ bodies and bring to justice their murderers, Dustin Honken and his girlfriend and accomplice, Angela Johnson.

The Investigation

Dustin Honken was born and raised in northern Iowa. Though intellectually gifted, he was an academic underachiever. On graduation from high school he attended a local community college and excelled in chemistry but eventually dropped out of school and moved to Arizona to live with his older brother. While in Arizona Honken perfected a methamphetamine production method and began distributing this drug to two individuals in north Iowa, Greg Nicholson and Terry DeGeus, who, in turn, sold the methamphetamine to street level dealers. When one of Nicholson's customers was arrested, he agreed to cooperate with the police, and Nicholson was arrested. Nicholson was also given the opportunity to cooperate with the police, which led to Honken's arrest during March of 1993 when he made a business trip Iowa.

Honken was charged in federal court for distribution of methamphetamine and, during the pretrial proceedings, learned that Nicholson had been responsible for his arrest. On July 8, 1993, Honken negotiated a plea agreement and was scheduled to plead guilty on July 30. He was released from jail in the interim. Before his arrest, Honken had become romantically involved with Angela Johnson, the ex-girlfriend of Terry DeGeus. Johnson was a high school dropout with a history of drug abuse and an assortment of occupations. Near the time of Honken's release, Angela Johnson purchased a Tec-9, a semiautomatic 9-mm handgun, from an area pawnshop. Investigators would later locate witnesses who described efforts by Honken and Johnson to learn the whereabouts of Greg Nicholson. A few days before Nicholson's disappearance, Honken received a tip that Nicholson was hiding out in the home of Lori Duncan.

Following his release from jail Greg Nicholson learned that Honken was looking to silence him and sought refuge in a variety of locations around Mason City, Iowa. In early July a friend had introduced him to one of her coworkers, Lori Duncan. Lori was a divorced mother who worked at a factory to support herself and her two daughters, Kandace, age 10, and Amber, who was 6 years old. Although she was uninvolved in any criminal activity, Lori agreed to assist Nicholson, who moved into the Duncan home in mid-July. All four members of the household were last seen alive by relatives, friends, and neighbors on Sunday, July 25, 1993.

On Monday morning, July 26, Lori Duncan uncharacteristically failed to report to work. Later that day a welfare check at Lori's home turned up only a note indicating that Lori had to leave on short notice but would be in contact soon. Just four days later, at his scheduled court appearance on July 30, 1993, Honken informed the federal prosecutor that he no longer intended to plead guilty and told the prosecutor that the case against him was "not as good as you think it is."

With Nicholson unavailable and his whereabouts unknown, the case against Honken was in jeopardy. The government attempted to resurrect its case by pursuing information regarding Terry DeGeus, Honken's other drug distributor. On October 27, 1993, Angela Johnson was subpoenaed to testify before the grand jury and was questioned about DeGeus's drug business and his involvement with Honken. A few days later, on November 5, Johnson left a telephone message for Terry DeGeus telling him to meet her that evening in Mason City. After leaving for that meeting, DeGeus was never seen alive again.

Because Nicholson and DeGeus could not be located, all charges against Honken were dismissed in September of 1995. However, Honken was arrested again during the early spring of 1996 for assembling a methamphetamine laboratory in Mason City. Honken was released from jail pending trial, this time wearing an ankle bracelet that allowed authorities to monitor his whereabouts. Honken's best friend was also arrested in 1996, and investigators pressured him to tell them about Honken's drug activities. He cooperated with the authorities in a plea arrangement. Honken's friend told the police that Honken was trying to learn how to electronically

defeat the ankle device and that his intentions were to kill the current witnesses against him, including police, informants, and laboratory personnel. He also stated that, although Honken never told him so directly, Honken had hinted that he had killed the people who were missing since 1993. Finally, Honken's friend told investigators that he had helped Honken disassemble, melt, and discard the remnants of a gun during the winter of 1993–1994. Although the friend was unfamiliar with firearms, he drew a sketch that closely resembled the profile of a Tec-9, the model that had been purchased by Angela Johnson.

Honken's pretrial bond was revoked in light of this new information, and he was incarcerated until his trial. However, Honken apparently believed he could continue to escape justice by killing witnesses. While awaiting trial in jail in 1996 Honken unsuccessfully solicited the murder of the best friend who had betrayed him. Years later this conspiracy would be added to the murder charges arising from the 1993 disappearances.

Because of the information provided by Honken's best friend, the investigation was rejuvenated in 1996 and focused on both Honken and Johnson as the persons responsible for the five disappearances. Finding the bodies became even more crucial, yet there were few reliable leads, and investigators hit several dead ends. For instance, one investigative theory was that DeGeus, who had worked at his father's excavation/demolition business at the time of his disappearance, may have participated in the killings of Nicholson, Duncan, and her two daughters and that the bodies may have been buried at the site where DeGeus was working at the time. It was further theorized that DeGeus may have later been killed to ensure his silence. Following this theory the investigators found the site where DeGeus was working on July 26, 1993, a farm field where buildings had been knocked down and buried. Investigators examined the site utilizing ground-penetrating radar and cadaver-trained search dogs, but no human remains were found.

The investigation continued without significant progress until 1999. Honken had finally pled guilty to the 1996 federal drug charges and was serving a 20-year sentence in a Colorado prison. In the summer of 1999 the first of several prisoners contacted federal authorities in Iowa to provide information that Honken was bragging to fellow inmates that he had "killed his rats." Honken shared details of the killings to at least one inmate that would ultimately be corroborated by forensic scientists.

In November 1999 prosecutors began presenting evidence to a grand jury in pursuit of murder indictments against Honken and Johnson. One of the persons subpoenaed was Angela Johnson's best friend during 1993. Although this woman had been interviewed and summoned to the grand jury several times, she always claimed that she had no information about the disappearances. During the summer of 2000 she was interviewed yet again and finally admitted that Angela Johnson had confessed to assisting Honken with the kidnapping and murders of Nicholson, Duncan, and the two young girls. Specifically, Johnson had obtained entry to the Duncan home by posing as a lost saleslady and then used a handgun to control the victims until Honken arrived. They bound the adults then transported all four victims to a wooded area in the country. Johnson related to her friend that Honken took Greg Nicholson and Lori Duncan a distance from the car before shooting and killing them both. He then returned to the car, where Johnson was holding the two frightened girls. Honken executed each with a bullet to the head. All four were buried in one grave. Johnson further told her friend that Nicholson was killed so that he could not testify against Honken, and the others had been murdered because they were potential witnesses to Nicholson's abduction. Johnson's friend further disclosed that, on a separate occasion, Johnson had confessed that she and Honken had murdered Terry DeGeus. On the day DeGeus disappeared Johnson told her that she had called DeGeus and asked him to meet her in Mason City, which he did. Johnson then took DeGeus to a remote location where

Honken was waiting. Honken killed DeGeus with a gun and an aluminum baseball bat and buried him in a hand-dug grave.

Unfortunately Johnson did not disclose the location of either grave to her friend. Nevertheless, with this information the case against Johnson was now stronger than the case against Honken. Although Johnson had included Honken's activities in her confession to her friend, this information could not be used against Honken, since rules of evidence based on the 6th Amendment Right to Confrontation would prevent using Johnson's confession against him. Thus, changing the focus of the investigation, and despite the fact that the bodies of the five murder victims had still not been recovered, authorities sought and obtained an indictment of Angela Johnson on five counts of murder. On the seventh anniversary of the Nicholson-Duncan disappearances, Angela Johnson was arrested and transported to the Benton County jail in Vinton, Iowa, to await trial.

The Benton County jail is a relatively small facility, housing both male and female prisoners in separate cells on the same floor. Prisoners are able to communicate with one another by talking through the walls and passing notes, often using books on the jail's book cart. Using these methods Johnson was befriended by a male inmate who, though currently serving a life sentence in another state for conspiring to import heroin into the United States, was temporarily in Iowa to testify in another case. He told Johnson that he knew a prisoner at the federal prison in Leavenworth, Kansas, who was serving a life sentence and had no hope of ever being released. He told her that he thought he could convince this federal prisoner to admit to committing the five murders, which would set Johnson free, and she could then sue the federal government for false arrest. The only problem with this plan, he explained, is that the prisoner would need something to prove his credibility to the authorities, such as maps of where the bodies had been buried. Johnson eventually provided two maps to her jailhouse friend, detailing where the bodies could be found and information about the bodies. In hopes of exchanging this information for potential leniency in his own case, the inmate turned the maps over to federal authorities.

Recovery of a Mass Grave

Johnson's two hand-drawn maps identified street names and other landmarks. Iowa detectives quickly located two areas near Mason City, which, according to the maps, should contain the clandestine graves. Iowa authorities then contacted the St. Louis, Missouri, FBI Evidence Response Team (ERT) for forensic assistance. Additional assistance was requested of Omaha Division's FBI ERT and the ERT Unit (ERTU) based out of the FBI Laboratory in Quantico, Virginia. After securing federal search warrants that authorized examination of two possible burial sites, the ERT began its site investigations on the October 11, 2000. The first scene was an abandoned farmstead and adjacent corn field along Killdeer Avenue in Cerro Gordo County. Soil coring and probing limited further subsurface searching to an area approximately 10m x 50m along the actively cultivated corn field. A cadaver dog and handler were unable to locate buried or surface-scattered remains. However, geophysical prospecting in the form of ground-penetrating radar identified so many subterranean anomalies as to make the technique ineffective (see Holland & Connell, Chapter 13 this volume for further discussion on the search and detection of human remains). The ERT selected what appeared to be the most promising area among the numerous anomalies and dug a 1 x 1 m test pit. However, the excavation revealed only the approximately 30-year-old burial of a calf, a large segment of metal rail, and other debris buried 63 cm (24.8 in) below the surface. Following a day of test excavations and sampling, the ERT decided to complete a site map of the farmstead and preliminary surveys for

future searches that would entail removal of the upper levels of the cornfield plow zone using heavy equipment. This work proved crucial: investigators would return to this site a month later and find the remains of Terry DeGeus.

The following morning the ERT continued mapping the Killdeer Avenue site while other investigators began to search the second potential site, located on Lark Avenue. Here, certain landmarks were found that appeared consistent with one of Angela Johnson's jail house maps. Searchers were drawn to two discarded vehicle tires beneath a bush in the area of Lark Avenue and a railroad right of way. They understood from Johnson's description that tires were placed over or near the grave. Again, a cadaver dog failed to alert to the area, but ground penetrating radar (GPR) indicated the existence of a subsurface anomaly. Confirmation of possible buried remains was first received when a small piece of bone was found in the upper 20 cm of a soil core sample. This sample prompted more intrusive testing of the spot.

The excavation began by digging a small, controlled test pit, or "window," in what was thought to be the center of the anomaly as delineated by GPR. That small (40 cm x 35 cm x 30 cm) (16 x 14 x 12 in.), rectangular pit revealed commingled animal and human bones. Above and among the clavicles of an adult human were what would later be identified as the bones of an opossum (*Didelphis virginiana*) and short-tailed shrew (*Blarina brevicauda*). If this was a mass grave of murder victims, the commingling of nonhuman remains at the top of the grave was initially puzzling. However, subsequent excavation revealed an infilled burrow, or "krotovina," which extended from the area of the opossum and shrew bones toward and through the eastern edge of the grave. What originally appeared as the intentional burial of road-kill, or a family pet, on top of human victims was demonstrated through archaeological excavation, geological characteristics, and zoological consultation to be the natural wintering and death of an opossum inside another rodent's abandoned chamber. A less controlled excavation and documentation of the remains and associated geotaphonomic evidence of bioturbation could have resulted in an incorrect or inconclusive explanation for the coexistence of the nonhuman and human occupants of the grave (see also Nawrocki, Chapter 25 this volume).

The creation of the initial excavation window, beyond offering the first confirmation of buried human remains, established a starting point for full excavation. It also provided an idea of how to orient the mapping system that would be used to record those excavations and their finds in three dimensions. A grid system of 1 x 1 m stringed units was established at ground surface over the interpreted size and orientation of the grave. After the existing surface was defoliated and its contours and cultural debris were mapped in relation to the three-dimensional grid system, excavation proceeded by expanding the initial excavation window across the exposed human remains toward the original edges of the grave feature. This expansion involved carefully slicing, in effect thin-sectioning, the fill from above the remains, keeping a vertical wall, or profile, of fill in front of the excavator throughout the process. As a result, evidence encountered in the excavated vertical profiles could be photographed and mapped *in situ* preserving their contexts in relation to the human remains and other features of the grave. To preserve potential geotaphonomic tool marks, and to better clean the excavation, a vacuum was carefully used to clean loosened fill. All excavated fill was screened through a minimum ¼-in hardware cloth to recover smaller evidence possibly overlooked in the excavation. Screening was critical in that a decision was made to collect the skeletal remains of each victim's hands and unclothed feet *en masse* rather than detail each phalange or carpal/tarsal. Although this technique did reduce excavation time in a situation in which multiple victims were interred, its downside was that some hand bones became commingled between victims, and a small number were not recovered.

After 24 hours of continuous excavation Individual 1, the uppermost skeleton in the grave, was completely exposed. Individual 1 was lying supine and slightly curved at the waist on top of

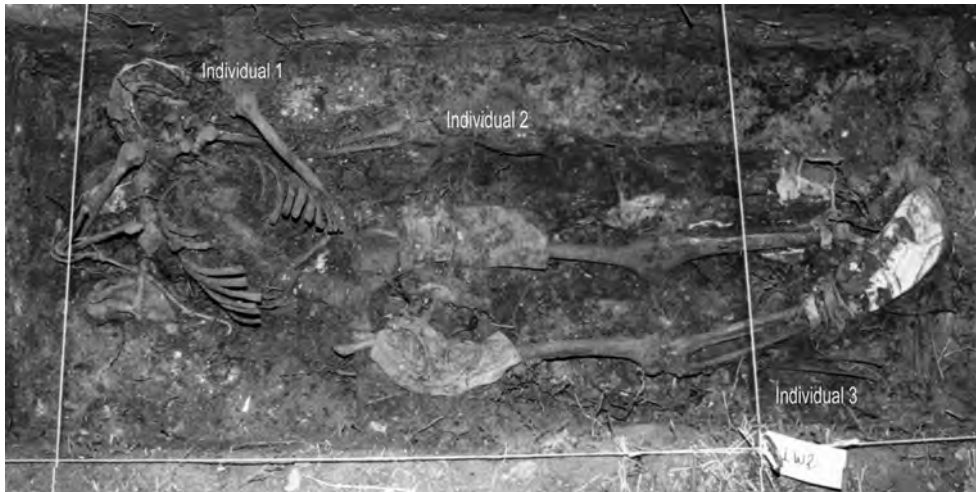


Figure 30.1 Excavation completed to the top of Individual 1 resulting in the partial exposure of Individuals 2 and 3 (photograph Lavone Tienken, used with permission of M. Hochrein)

Individual 2 (Figures 30.1 and 30.2). The wrists were bound by a clothesline-type ligature. Duct tape was wrapped around the eyes and nasal regions of the individual. A child's green synthetic fabric sock protruded from the mouth. Stitching around the torso indicated this individual was interred while wearing a natural fiber shirt or undershirt. Remnants of denim type pants or shorts included only the pocket linings, stitching, zipper, and some rivets. Behind the right hip was a billfold found to contain a driver's license bearing information for Gregory Nicholson. The right foot of the individual bore a white athletic sock and athletic shoe, and the left foot was covered only by a white athletic sock.

Bioturbation and root activity effectively sewed the remains of Individual 1 to the fill and to portions of Individual 2, extending the excavation time. Below the plow, or root, zone subsequent victims were less affected and more easily extracted from the grave. Individual 2 was found immediately below Individual 1 at depths between 40 cm (15.7 in.) and 65 cm (25.6 in.), and there was no stratigraphic evidence of fill or detritus between the skeletal remains. The skeleton was face down with clothesline-type ligatures around the left wrist and both ankles. As with Individual 1, duct tape was wrapped around the head, and another small green synthetic fiber sock protruded from the mouth. Deteriorated segments of cloth and stitching indicated a shirt-type garment was worn at the time of disposal. Beneath the remnants of that garment was an intact brassiere. Additionally, this victim appeared to wear dark-colored sweat pants and white athletic socks. One athletic shoe was found between the feet.

As with Individuals 1 and 2, the lack of stratigraphy between Individuals 2, 3, and 4 indicated all were buried contemporaneously. Individual 3 was found immediately below Individual 2 at depths between 40 and 70 cm (15.7 and 27.6 in.). The articulated remains were situated face down. Clothing associated with Individual 3 included a dresslike garment and apparent underpants, or panties. At depths between 50 and 77 cm (19.7 and 30.3 in.), the remains of the smaller of the two juvenile victims were encountered directly beneath those of Individual 3. The articulated remains of the fourth victim lay supine. Most of the torso lay under and between the legs of Individual 3, and the legs were flexed into a frog or squatlike position. A shirt-type garment was pulled up and over the head, thus trapping the hands in the garment sleeves above the head.

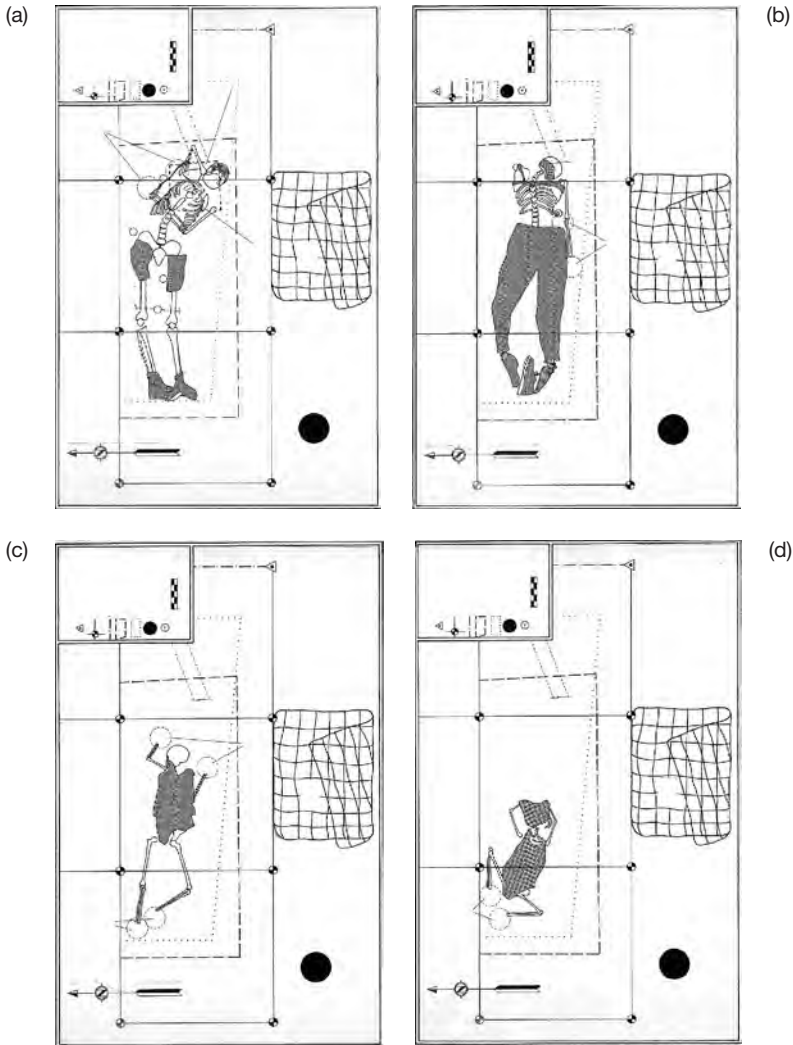


Figure 30.2 (a–d) Plan views of Individuals 1–4 recovered from the mass grave (map by M. Hochrein)

Other clothing associated with Individual 4 included a single piece, multicolored synthetic fiber swimsuit covering the torso.

Following 36 hours of excavation, mapping, and photography, all the human remains were removed from the grave. Documentation of the geotaphonomic record continued, however; as the grave was measured, a metal detector was used to search for additional evidence, and the grave walls were examined for evidence of possible tool marks. No additional ballistic evidence was recovered from the grave fill or beyond the grave walls. Although no tool marks were identified, clues of the grave's construction were reflected in its dimensions and microstratigraphy above the remains of Individual 1. The horizontal dimensions of the grave seemed just large enough to accommodate Individual 1, the tallest of the victims. All four victims were deposited in a grave that had a maximum depth of 77 cm (2.5 feet). The stratigraphy above Individual 1

consisted of individual lenses of soil consistent with the amounts of soil held in each shovel-full of backfill. Given these geotaphonomic characteristics, the conclusion was reached that this grave was excavated and filled using one or more hand shovels rather than heavy equipment.

A large root that had grown over the femora of Individual 1 was later examined by a University of Missouri botanist. The dendrochronological conclusions were that a minimum of four growing seasons had passed in order for the root to grow to its collected size from the bush located on the south side of the grave. Although botanists who examined the root segment collected from the scene advised that the more complete collection from above the remains to the trunk of the bush from which it grew would have allowed for an even more specific determination of the time it took to grow through the grave, the proposed timing from the dendrochronology analysis was consistent with the purported timing of the victims' disappearances and supposed deaths approximately seven years before.

Detailed maps of the grave and contents were produced by hand using baseline measurements (see Figure 30.2). At the time of this forensic recovery, electronic total station survey technology was relatively common in law enforcement's reconstruction of vehicular accidents, but less often applied at outdoor or indoor crime scenes. The total station is a three-dimensional surveying tool that combines horizontal and vertical angle measurements using the theodolite or transit with slope or line of sight distance measurement by an electronic distance measuring device (EDM) component. Measurements are taken as a pulsed laser emitted from the instrument is reflected off a reflector, or prism, positioned over the point being measured or, in reflectorless mode, to the item or substrate itself. Total station technology has been used successfully for decades in recording micro- and macro-features on archaeological sites around the world (Rick 1996; Hester, Shafer, & Feder 1997; Kvamme, Ernenwein, & Markussen 2006; and Bedford, Pearson, & Thomason 2011).

In this case, the use of total station technology would have significantly decreased the amount of time required for the excavation while increasing the number of measurements, or spatial data, compiled. For example, consider the decision to map the general location of the bones of each victim's hands and then remove them, *en bloc*. This option was chosen over that of individually uncovering and mapping each element *in situ* owing to the time involved using tape measures and plumb bobs. Total station mapping of individual bones, including individual hand and foot bones, could have been accomplished without appreciably adding to the time it took to document each victim's position within the grave. Documentation of geotaphonomic features could have also been rapidly accomplished with the total station. In addition, the efficiency of using the total station would have far exceeded that of the transit and stadia rod employed on what turned out to be a frigid northern Iowa day when crime scene investigators returned to record the clandestine graves location in the context of local roads, topography, and water features. For these reasons total station technology is now commonly employed by forensic archaeologists and law enforcement crime scene investigators.

Anthropological Analysis

Methodology

The autopsies of the first four victims were conducted jointly by the forensic pathologist and anthropologist at the Iowa Office of the State Medical Examiner in Des Moines. Each set of remains was placed on a separate gurney to be radiographed, unwrapped, cleaned, and analyzed. The protocol was the same for all individuals and included an inventory of the bones and teeth present, a description of all clothing, ligatures, and personal effects, radiography, development of

a biological profile, description and interpretation of perimortem and postmortem trauma, and photographic documentation. Soil from the clothing and pelvic and cranial cavities was carefully screened for additional physical evidence, such as projectiles. There was commingling of bones at the bottom of the grave. These were reassociated with the youngest two victims based on bone size and development.

It was quickly evident that all four individuals suffered gunshot trauma. Typically, when a bullet penetrates a bone at or about a 90° angle it produces a circular defect that is widest, or beveled, away from the weapon. In other words, beveling occurs on the internal surface of a bone in an entrance wound and on the external surface for an exit wound (DiMaio 1999). These physical characteristics allow reconstruction of the trajectory of the bullet as it passed through the bone (Smith, Berryman, & Lahren 1987; Kimmerle & Baraybar 2008). If a projectile strikes the bone tangentially, then the bullet may graze the bone and produce a keyhole-shaped defect. The circular, internally beveled portion represents the entrance wound, whereas the adjacent triangular portion, surrounded by external beveling, is created when all or part of the bullet exits (Dixon 1982). Thus, the triangular portion points to the direction of fire.

In any case of violent death blunt trauma to the skeleton must also be a concern for the anthropologist. However, since the bodies were buried for over seven years, it is possible that fractures occurred after death and decomposition via bioturbation, surface pressures, and excavation. Thus, it is necessary to distinguish perimortem and postmortem fracture patterns (see Loe, Chapter 24 this volume). In general, perimortem fracture margins will be the same color as the surrounding bone, because the exposed margins have experienced the same postmortem processes. In this case, the bones were dark brown, the color of the soil, and so recent fresh postmortem fractures were easy to discern because the margins were much lighter in color than the surrounding bone. In addition, perimortem long-bone fractures may splinter and have adherent fragments with jagged edges, whereas dry bone is more brittle and will shatter into fragments of similar size (Maples 1986; Sauer 1998).

Analysis of the Victims

The skeleton of Individual 1, found at the top of the grave, was nearly complete and well preserved. Bindings of the face and appendages were observed as described above (Figure 30.3). The individual was estimated to be a 30–40-year-old male of European descent who stood between 67 and 73 in. (175–183 cm). Antemortem pathology included spinal arthritis, a healed fracture of the right second metatarsal, and antemortem tooth loss. Dental records confirmed these were the remains of Greg Nicholson, who was 34 years old at the time of his disappearance.

A circular defect was located on the left occipital, immediately behind the left mastoid process. The internal beveling indicated this defect was a gunshot entrance wound and was accompanied by fractures that radiated through the basicranium, face and left side of the skull. A bullet was located within the cranium in the posterior nasal aperture, and there was no exit wound. The trajectory of the gunshot was therefore back to front and slightly left to right. Another gunshot wound was observed on the right 5th rib near the vertebral end. Beveling characteristics indicated a back to front trajectory. Finally, multiple perimortem fractures of the neural arch of the 4th cervical vertebra suggested direct trauma and/or severe rotation of the neck.

Individual 2 was buried immediately below Individual 1 in the mass grave and also had ligatures around the ankles. The remains were of a 30–40-year-old female of European descent with a stature of 61–67 in. (159–167 cm). The spine and left shoulder exhibited osteoarthritis, and there were multiple dental restorations and some antemortem tooth loss. The remains



Figure 30.3 Skull of Individual 1, Greg Nicholson, with duct tape and a child's sock over the face (photograph taken and used with permission of D. W. Steadman)

were identified via dental records as those of Lori Duncan, who was 31 years old when she disappeared.

Of all of the victims in the grave Lori Duncan suffered the greatest amount of perimortem skeletal trauma. A large defect above the left orbit had extensive external beveling, indicating a gunshot exit wound. The shape was irregular, since it abutted a preexisting fracture radiating from the other side of the skull (Figure 30.4), but it appeared to be an example of an exit key-hole wound (Dixon 1984). Both the circular and triangular portions exhibited external beveling, and there was little internal beveling. A semicircular defect in the fractured greater wing of the right sphenoid was suspected to be the entrance wound, although this area of bone is too thin to demonstrate beveling (Quatrehomme & İşcan 1999). If this was the entrance wound then the trajectory of the bullet was right to left and slightly upward. The facial skeleton was extremely fragmented and detached, as was the right side of the skull. There was also gunshot trauma of the proximal left ulna and at least two ribs. Though the trajectory of the bullet could not be determined for the ulna, one of the ribs demonstrated beveling that indicated a back to front bullet path. The findings suggested that there was a minimum of two gunshots, one to the head and one to the thorax. This is a conservative estimate, since the two rib wounds could have resulted from the same projectile and the ulna could have been wounded by the same bullet that hit either the thorax or skull. Finally, the left 4th metacarpal and right ilium exhibited perimortem fractures due to blunt trauma.

Individual 3 was buried just below the adults and is the older of the two juveniles. Sex cannot be estimated reliably for juvenile skeletons, because sexual characteristics of the pelvic and cranium do not appear until after puberty (see Rowbotham this volume). Based on the dental and long-bone development, age was estimated to be between 8 and 11 years. The skeleton did not exhibit antemortem pathology.



Figure 30.4 Gunshot wound of the left frontal of Individual 2, Lori Duncan. Probable exit keyhole wound (photograph taken and used with permission of D. W. Steadman).

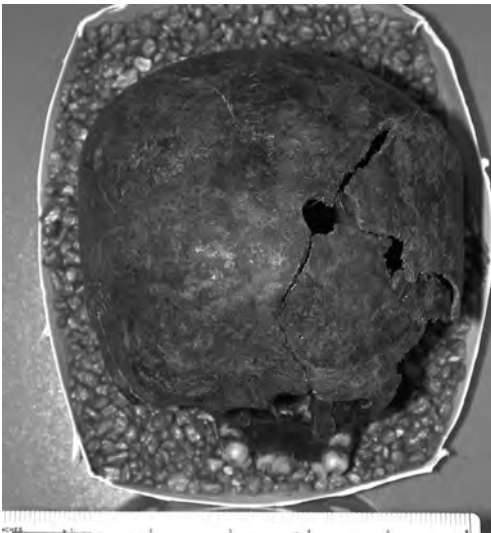


Figure 30.5 Gunshot entrance wound on the occipital of Individual 3, Kandace Duncan (photograph taken and used with permission of D. W. Steadman)

A gunshot entrance wound was present on the right superior occipital bone immediately below the Lambdoid suture and approximately 1.7 cm to the right of midline (Figure 30.5). Fractures radiated from the defect onto the right frontal, basicranium, and left and right parietals. No distinct exit wound was identified, but the bullet likely exited through the upper facial region near the midline as evidenced by the jagged margins around areas of missing bone in the superior nasal aperture and left maxillo-orbital region. The facial bones were traumatically

separated and could not be reconstructed. The findings were consistent with a gunshot wound to the back of the head.

The last victim, Individual 4, was placed in the grave first and was the youngest juvenile. Based on dental and epiphyseal development, the age was estimated to be between 5 and 7 years. Sex was not estimated, and there were no skeletal pathologies.

A gunshot entrance wound was on the superior occipital bone just right of Lambda, very similar in location to that of Individual 3. Fractures radiated from the defect onto the right side of the skull and the basicranium. Part of the right temporal and sphenoid was detached from the skull, and the facial bones were too fragmentary to reconstruct. The bullet likely exited the face near the midline, as evidenced by the jagged margins of the fractured superior nasal aperture. As with Individual 3, the trajectory of the gunshot was back to front.

The biological profiles were consistent with the missing individuals, and the identifications of the adults were ultimately confirmed by dental analysis (see Clement, Chapter 29 this volume). Lori Duncan's children lacked dental records, so mitochondrial DNA (mtDNA) was sampled from the bones of Individuals 3 and 4 and compared to mtDNA of Lori Duncan's mother, who was still living (see Baker, Chapter 28 this volume). Unlike nuclear DNA, which is contributed by both parents, mtDNA is inherited only from the mother. In addition, mtDNA has a much lower statistical specificity than does nuclear DNA, since all maternally related individuals have identical mtDNA. Thus confirming identifications in this case relied on multiple modalities. The mtDNA of both juveniles were identical to each other and to Lori's mother, and the biological profiles were consistent with the missing girls. In addition, the clothing was identified by Lori's mother, and Lori's children were known to have disappeared at the same time as Lori. Through these means 10-year-old Kandace and 6-year-old Amber Duncan were positively identified.

The skeletal evidence demonstrates that the Amber and Kandace were each shot in the back of the head, and the adults suffered multiple gunshot wounds as well as blunt-force trauma. Although it is not possible for the anthropologist or pathologist to reconstruct which victim was killed first, the two children were placed in the grave first, followed by the two adults. The bullet recovered from Nicholson's skull, the only projectile recovered from the grave site, was too badly damaged to yield significant class information.

The Search for Terry DeGeus

Following the identification of the first four victims, investigators turned their attention to finding the body of Terry DeGeus. By November of 2000 the Killdeer Avenue site that had previously been searched by the ERT without success was now more accessible, because the corn had been harvested. Using heavy equipment investigators gradually removed thin layers of topsoil until they observed an area of soil that differed in color. When a boot was brought to the surface by heavy machinery, hand excavation of the grave began. The grave revealed the skeletonized remains of an adult buried face down with the legs tightly flexed such that the feet were above the buttocks. This matched the description on Angela Johnson's map on which she had written: "The 1 is buried on his knees like he would make me be when I would beg for my life (face down)." The skeleton was clad in a sweatshirt with a hood that covered the head, a jean jacket, pants with metal accoutrements, underwear with the name of "DeGeus, Terry" handwritten on the band, a leather belt with a Harley Davidson buckle, socks, and leather work boots. Personal effects were also recovered from the grave, including a pack of cigarettes, money, a cigarette lighter, nail clippers, and a watch.

The anthropologist employed the same protocol as before to derive the biological profile and to interpret perimortem injuries. The remains were those of a 30–40-year-old male of European descent who stood between 65 and 71 in. (170–178 cm) tall. Antemortem pathologies included

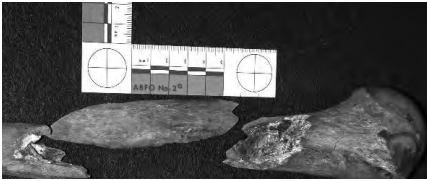


Figure 30.6 Gunshot trauma of the left humerus of Terry DeGeus (photograph taken and used with permission of D. W. Steadman)

osteoarthritis of the spine, a healed fracture of the left acromion process, and a well-healed fracture of the left fibula. The remains were positively identified as those of Terry DeGeus, aged 34 years, by comparison of antemortem and postmortem dental radiographs.

The skeleton exhibited extensive perimortem trauma. The skull was highly fragmentary, and much of the anterior frontal bone and right inferolateral vault were missing, each area exhibiting multiple radiating fractures. Green staining, consistent with oxidizing copper, was noted on the internal aspect of the right temporal fragments. The location and distribution of the stains suggested perimortem fragmentation of the temporal bone, after which some bone fragments were in contact with metal during decomposition. A copper jacket was found inside the sweatshirt hood that covered the skull. A semicircular defect was present on the greater wing of the right sphenoid, as was seen in Lori Duncan's skull. The bullet likely entered the right side of the skull and exited the left frontal.

A gunshot wound of the 3rd thoracic vertebra was evidenced by bone loss of the anterior centrum and copper staining. Radiographs revealed metallic fragments embedded in the margins of the wound. The left proximal humerus also exhibited gunshot trauma and fragments of bone and metal remained embedded in the medullary cavity (Figure 30.6). The trajectory of these wounds could not be determined. There was also a gunshot wound on the iliac crest of the left ilium. Beveling indicated a back to front and slightly right to left trajectory. Thus, a minimum of three bullets penetrated the skeleton—the skull, thorax, and pelvis. The gunshot to the humerus could have been coincident with the skull or thorax trauma. Perimortem fractures of the dentition indicated Terry DeGeus also suffered blunt trauma.

Federal Criminal Prosecutions of Honken and Johnson

With the discovery and successful identification and analysis of perimortem trauma of all five missing persons, criminal proceedings could move forward against Dustin Honken and Angela Johnson. The investigation of the murders was now over 10 years old, and hundreds of witnesses and informants had been interviewed. Prosecutors waded through scores of boxes of evidence and records to decide who to subpoena to testify in court. The prosecution sought to demonstrate that Dustin Honken masterminded the efforts to eliminate DeGeus and Nicholson so they could not testify against him on the earlier drug charges. The Duncan family was simply collateral damage.

On August 30, 2001, Dustin Honken, now 33 years old, was charged with five counts of federal witness tampering murder, five counts of drug conspiracy murder, five counts of continuing criminal enterprise murder, one count of soliciting the murder of a witness, and one count of conspiracy to tamper with and solicit the murder of a witness. In 2004 Honken was tried in the United States District Court for the Northern District of Iowa. In addition to informants several forensic expert witnesses testified. The maps drawn by Angela Johnson that led investigators to the graves were introduced into evidence, and an FBI ERT specialist testified as to the location and recovery of the remains. Two forensic pathologists from the Office of the Iowa State Medical Examiner testified that the cause of death was gunshot trauma and the manner of death was

homicide for each individual. In Iowa only medical examiners can certify deaths as a manner other than natural (homicide, suicide, accidental, or undetermined). Next, the forensic anthropologist provided lengthy testimony on the perimortem trauma suffered by each individual. Finally, a firearms expert testified that spent bullets recovered from DeGeus had class characteristics consistent with having been fired from a Tec-9, the type of gun purchased by Angela Johnson.

Following a lengthy defense, the jury received the case. After deliberating for 17 hours over three days, the jury returned guilty verdicts on all counts. After a penalty proceeding that lasted seven court days, the same jury sentenced Dustin Honken to life in prison for the counts relating to the murders of the three adults and sentenced him to death for the murders of Kandi and Amber Duncan. The trial, including the penalty phase and deliberations, lasted 11 weeks.

The trial of Angela Johnson began in the same courtroom approximately five months later, in 2005. She faced five counts of drug conspiracy murder and five counts of continuing criminal enterprise murder. The forensic experts again presented their evidence. A new jury was seated and found Angela Johnson guilty as charged on all counts. After a penalty phase proceeding that consumed 15 court days, the jury sentenced Johnson to life in prison for the two counts relating to the murder of Greg Nicholson and imposed a penalty of death in connection with the counts relating to each of the other four murder victims. Johnson's trial lasted 10 weeks.

These cases were remarkable in several respects, not the least of which was the application of the death penalty in the state of Iowa. Though Iowa does not have the death penalty, the death penalty could be applied because these proceedings were in federal court. Although prosecution of a federal death penalty case in a non-death-penalty state is not unprecedented, it is rare. Some local controversy was generated by the fact that for the first (and second) time in more than 40 years a jury of Iowans was called on to deliberate in a death penalty case. In addition, Angela Johnson achieved the dubious distinction of being the first woman in America to receive a federal death sentence since the early 1950s, when Ethel Rosenberg resided on death row.

Postconviction Appeals

While forensic scientists often consider a forensic case "resolved" following the conclusion of a trial, the United States legal system has an elaborate and complicated appeals process, especially for death penalty cases. While the appellate process may differ for each death penalty state, our focus is on the federal appeals system through which the Johnson and Honken cases have progressed since 2005.

According to Assistant United States Attorney C.J. Williams, following a federal death penalty conviction the defendant has an automatic right to appeal to the next highest court, which is the Circuit Court of Appeals. This is called a Direct Appeal and can include arguments that the evidence was insufficient, errors occurred during the trial, or errors occurred in the sentencing portion of the trial. If the appeal is denied the defendant can petition the United States Supreme Court for review. If the Supreme Court denies that petition, the defendant can, within a year, file a Title 28, Section 2255 petition with the original District Court that tried the case. This is a civil proceeding in which a criminal defendant asserts that his constitutional rights were violated in some way that was not already raised on the Direct Appeal. This statement can include claims that his trial counsel was ineffective or can assert that new and convincing evidence was discovered that, if it had been presented, "no reasonable factfinder would have found the movant [defendant] guilty of the offense" (United States Code 2006, Section 2255, Title 28). If the District Court denies the petition, the defendant does not have an automatic right to appeal the decision. Rather, the District Court must certify the Section 2255 claim (agree that one or more points in the claim are meritorious) to progress to the Circuit Court of Appeals. If the District

Court does not certify the case as worthy of appellate review, the defendant may still petition the Circuit Court of Appeals to review the District Court's decision. If the Court of Appeals denies that request, the defendant can petition the Supreme Court asking to order appellate review of the District Court's decision. If this petition is denied by the Supreme Court as well, then the federal appeals process has been exhausted, and an execution date will be set (Bergmann 2009).

Angela Johnson proceeded through the Direct Appeals process unsuccessfully and filed a Section 2255 petition with the District Court. The District Court ruled the original attorneys were ineffective in presenting a history of mental health that may have had bearing on the jury's decision on the death penalty. The court therefore ordered a new penalty phase trial. This essentially requires the government to re-present all of the physical and testimonial evidence to a new jury who would decide on whether Johnson would get the death penalty. Thus, nearly 10 years after the original trial, and more than 20 years after the murders, all the expert witnesses were summoned to testify again at the penalty retrial. This situation demonstrates the necessity of maintaining all case notes, reports, and communications indefinitely so that the expert can be ready to provide professional testimony many years after a case was "resolved." While Johnson's case was pending the penalty phase retrial, her lawyers petitioned U.S. Attorney General Eric Holder to reconsider if the death penalty statute (aggravating and mitigating factors) applied to Johnson. Ultimately, Attorney General Holder decided to instruct the government to terminate the pursuit of the death penalty. As a result, Johnson's sentence was converted to life in prison without parole, which she is currently serving at the Federal Medical Center in Carswell, Texas.

In the meantime Dustin Honken has also been pursuing the same appeals process as Johnson. Following failure in the Direct Appeals process, he, too, filed a Section 2255 petition. The District Court denied his petition and found that it was not worthy of appellate review. Honken asked the appellate court to review the District Court's decision, even though the District Court did not find appellate review appropriate. The Appellate Court denied Honken's request, agreeing with the District Court that the errors he claimed were not worthy of further review. Honken then petitioned the Supreme Court requesting that it order the appellate court to review the District Court's denial of his Section 2255 petition. At the time of this writing, this final petition is being reviewed by the Supreme Court. If this petition is denied review, an execution date will be set. He is currently on death row at the United States Penitentiary in Terre Haute, Indiana.

Conclusion

This case exemplifies the multidisciplinary cooperation required for murder investigations. Dogged perseverance on the part of the investigators kept this from becoming another missing persons "cold case." It must be noted that our discussion has focused on only a small portion of the total forensic effort; there are many other important facets of the investigation not described here, including firearms, document, DNA, and fingerprint analyses.

This case also demonstrates how archaeology, properly applied in concert with other forensic specialties, can be used as a tool for reconstructing the events of a crime rather than merely collecting evidence from a scene. The archaeological excavation of the Lark Avenue grave site demonstrated the amount of contextual information that can be gleaned beyond the victims' skeletons. In this case, plant activity offered chronological information about the victims' interments. The recorded remnants of each victim's clothing, such as a bathing suit, suggested the time of year the murders took place. Geological evidence explained the presence of nonhuman animal activity within the grave. Zoology helped to distinguish the natural versus intentional placement of nonhuman animal remains. Finally, stratigraphic evidence and three-dimensional

mapping of each victim's position within the grave helped to clarify and confirm perimortem activity and to compare that with witness and subject statements.

Perhaps the most salient effect of applying archaeology at this crime scene was the manner in which it allowed for the recreation of the scene for juries in Dustin Honken's and Angela Johnson's federal trials. They could better imagine the horrors of that night in 1993 in seeing how the children were thrown into the grave, their hands so close to their mother's. The jury could reflect on the last moments of Greg Nicholson and Lori Duncan lives—each bound with duct tape around their faces and the children's socks in their mouths. Similarly, the detailed anthropological description of the perimortem injuries, especially of the little girls, created a great deal of tension and sympathy in the courtroom. Although juries have come to expect much forensic fanfare (the so-called CSI effect), careful investigation and analysis allow investigators to accurately and respectfully tell the story of each victim without sensationalism.

Note

- 1 We received permission to use real names of the defendants and victims by the U.S. Attorney General's office, since the trials of those charged for the murders detailed in this case study are complete. All information provided at the trial is in the public record via trial transcripts. We chose not to use the names of various informants.

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Domestic Homicide Investigations in the United Kingdom

John Hunter

Forensic archaeology is now a relatively well-accepted discipline among police forces in the United Kingdom (U.K.). Operational work stems from the late 1980s, and the development of the discipline is well recorded together with summary case studies (Hunter & Cox 2005; Hunter, Simpson, & Sturdy Colls 2013). The work has to be understood within the context of U.K. policing and law enforcement structure; there is no national police force as such, but there has been a steady development in merging the 44 forces in England, Wales, and Northern Ireland into larger regional groups. Scotland, which had eight forces when the first edition of this volume was produced (2009), now has a single policing unit (Police Scotland). Each force is largely autonomous and responsible to its own public Police Authority, each now headed by an elected civilian Police Commissioner. The government department known as the Home Office coordinates certain activities—notably, training, specialist types of operational support, and central intelligence databases—under the newly named National Crime Agency (NCA), but police forces otherwise operate independently. At the time of writing there is only one full-time professional forensic archaeologist in the U.K. Individuals tend to be invited to incidents either because they are known to, or have worked for, the police force on the case or because a police force has requested specialist assistance from the NCA which keeps a central register of experts.

The former Council for the Registration of Forensic Practitioners (CRFP), which was established in 2000 at the behest of the Home Office to produce lists of competent forensic personnel for laboratory, crime scene, and court work, has since been replaced by the office of the Forensic Regulator (based in the Home Office). This new authority has identified forensic subject groups and worked with them to establish competence criteria and validation processes. In archaeology validation has been undertaken in conjunction with the Chartered Institute for Archaeologists (CIfA) in order that professional competence is acceptable to both archaeological and forensic communities. Identified sectors of expertise (including archaeology and anthropology) were encouraged to identify criteria by which individuals could be judged by their peers. In the U.K., *archaeology* is concerned with the recovery and recording of buried remains, whereas *anthropology* is more strictly concerned with the study of (human) skeletal remains, buried or otherwise. The CIfA has set up a Special Interest Group in Forensic Archaeology, and an Expert Panel. Members of the latter (currently numbering about 12 individuals) have satisfied both the archaeological and forensic criteria that define them as being competent within the field of forensic archaeology.

The Investigation of a Scene of Crime

As elsewhere, the investigation of a homicide scene in the U.K. can involve many individuals under the overall management of a senior detective, in the U.K. known as a Senior Investigating Officer (SIO). The scene itself is coordinated by a Crime Scene Manager (CSM) and draws on Scene of Crime Officers (SOCOs), sometimes known as Crime Scene Investigators (CSI) or Forensic Scene Investigators (FSI), for much of the basic recording, sampling, and recovery of evidence. There is also a Scientific Support Manager (SSM) in each force who is responsible for advising the SIO on techniques, specialist equipment, and skill areas that individual incidents might require. There is no state-funded forensic science service in the U.K., and the deployment of specialists must be within budget. Nor is there any obligation for the SIO to take advice or to utilise any forensic specialist (including an archaeologist). However, the growing number of court cases in which defence counsel is requesting independent archaeological comment is making this situation less common.

Other experts might typically include forensic scientists (including specialists in entomology, palynology, fingerprints, and fibres) with whom the archaeologist may need to work closely. It is not a matter of imposing rigid archaeological methodology but ensuring that there is mutual understanding of each expert's evidential requirements. Given the diverse nature of skill backgrounds among the personnel involved in the U.K., there can be a strong element of "mission" in the archaeologist's work, as well as the need to understand the theory and processes of others. Nowhere is this need more important than in the relationship with the forensic pathologist, who plays a pivotal role in any incident in which human remains are involved. Unlike in the United States (U.S.), where the equivalent individual (Medical Examiner) will be largely familiar with the work of anthropologists, in the U.K. the evolution of both anthropology and archaeology is distinctive.

Here archaeology has a very specific field-based origin, whereas in the U.S. it has a more specific historical association with human remains under the umbrella of anthropology. Because of these differences the need to build operational relationships with the forensic pathologists in the U.K. has been more complex but also more rewarding in its success. Ultimately, it is the forensic pathologist who probably carries the greatest weight in court in providing evidence for cause and manner of death, and as a result his or her wishes at a scene will almost certainly be given priority by the SIO. As in all cases the best results derive from considered planning and briefings between those in the front line, typically the pathologist, the archaeologist, and the scene of crime officer; this process is illustrated in some of the cases discussed shortly.

The U.K. criminal justice system also presents some idiosyncratic features that may affect the manner in which an investigation occurs and with which the forensic archaeologist certainly needs to be familiar. There are three pieces of legislation of particular importance to the forensic archaeologist: the Prosecution of Offences Act 1985 (POA 1986), the Criminal Procedure and Investigations Act (CPIA 1996), and the Police and Criminal Evidence Act 1984 (PACE 1984).

In the U.K. the police no longer prosecute offences themselves; this process is undertaken by a body known as the Crown Prosecution Service (CPS) under the terms of the Prosecution of Offences Act 1985 (POA 1986). The CPS is an independent authority that undertakes prosecutions in court; it advises police whether sufficient evidence has been gathered to enable the likelihood of a successful prosecution, or indeed whether it is even in the public interest to prosecute at all. Although archaeologists may be brought into an enquiry and remunerated by the police, they are, like any other forensic expert, expected to provide objective scientific evidence. They will be independent witnesses of the court, whether they have been called by the CPS or the defence. The process is aimed at ensuring that the criminal justice process is played fairly, and this intent now also extends to the sharing of evidence, a process known as "disclosure," by both

adversarial parties under the terms of the Criminal Procedure and Investigations Act (CPIA 1996). Put simply, they require that all records made by investigating personnel in whatever form—written, tape-recorded, photographed, planned, or sketched—are disclosable. All this information is collected, collated, and logged, is made available to the court to both prosecution and defence counsels, and can be used as evidence. In archaeological terms this information includes plans, section drawings, record sheets, notes, and, on longer-term projects, day-books or the like. These items will be open to scrutiny; hence any altered plans, changed interpretations, illegible sketches, lack of completed fields on record sheets, and such can be used to criticise professional integrity. Equally, verbose reports will provide greater opportunity for questioning under cross-examination. There is a fine balance to be made.

The final piece of legislation is particularly relevant in those operations that take place while a suspect is being detained in custody in England and Wales. According to the terms of the Police and Criminal Evidence Act 1984 (PACE 1984), detention in custody is strictly time-limited (see Hunter, Simpson, & Sturdy Colls 2013: 8–10). Initially set at 24 hours, this period of detention can be extended to 96 hours via a series of legal stages after which the suspect must be formally charged with an offence or released; in Scotland, the period is much less. The operational effect of this restriction is that the recovery of appropriate or necessary evidence (for example, locating and excavating of human remains) may have clearly defined time limits imposed. The failure of the investigator to respond successfully during this period of detention may result in the suspect tampering with or moving buried evidence on release. To counter this possibility, the precise archaeological parameters, as well as the logistics in terms of equipment, mechanical excavators, personnel, and other resources, need to be determined well in advance. Knowledge of site history will need to be commensurate with working within the time frame available.

These general points provide the context for a range of domestic case studies in the U.K. that have had an archaeological involvement. All scenarios are different, and it is difficult to divide the various criminal investigations in which archaeology contributes into “types.” Nevertheless, general case experience suggests that archaeological input falls broadly under four main headings: (1) disappearances of named individuals; (2) search and recovery of nonhuman buried items; (3) allegations of anonymous human remains buried in specific locations; and (4) accidental discovery of human remains. These categories are by no means exclusive, but they embrace a typical range of scenes.

Disappearances of Named Individuals

The archaeologists input into the investigation of a missing person (presumed deceased) typically constitutes only a minor part of the forensic archaeological case load but is given preference in this chapter, because it tends to illustrate the full nature of the archaeologist's role and contribution. One must remember that forensic searching for buried human remains is as much about elimination as it is about finding and recovering. Search methodologies tend to target specific locations as being significant, or as a priority, according to suspect movement, psychological profiling, witness account, or other methodologies. Each target area needs to be given defined boundaries, searched thoroughly, and if unproductive, eliminated. Since the previous edition of this volume various techniques (assets) have become increasingly more widely applied, notably the use of Geographical Information Systems (GIS), which allow landscapes to be modelled and analysed in three dimensions; LiDAR (light detection and ranging) for airborne terrain modelling; more sophisticated applications of geophysical survey techniques; and the use of statistical data based on other disappearances. The NCA also has a National Search Advisor available to support searches of this nature.

Many investigators of disappearances now tend to utilise archaeologists very early in the process, especially if there is a high probability of burial. A case in point was that of a young

male, believed murdered during a drugs dispute. His disappearance was reported to the police by family members, but it was unclear where he may have been deposited. The police had very few starting points but had identified through intelligence a number of locations around the country that were known to have been used by the drugs gang. Each of these became the target of a specific search, and an archaeologist was invited to each briefing to give advice and help devise an appropriate strategy.

The availability of aerial photographs was essential to each site, particularly for those sites that might be sensitive to a police presence. Some of the target areas (building sites or wasteland) could be visited safely before devising a strategy. Others relied only on covert helicopter photography, one in particular being a large country house with outbuildings. Nevertheless, this photograph could be used to identify possible foci of interest such as disturbed ground; it could determine which types of geophysical survey (if any) might be effective according to landscape and, by comparison with earlier photographs, show if any outbuildings or terraces had been built since the victim disappeared. On the basis of this photograph, a search plan for the land and the buildings was devised between the investigation team and the police force in whose area the building was located. It involved using the local Police Search Advisors (PoLSAs), who worked closely with the archaeologists to establish an optimum strategy. After careful preparation, this strategy was implemented early one morning after the issuing of a search warrant. Specialist search teams scoured the house and outbuildings, the geophysicists undertook survey work on new terraces and outbuildings, the archaeologists tested potential disturbances identified from the air, and a cadaver dog was used to test any anomalies. The process took less than one working day but was sufficiently thorough to ensure that the whole complex could be eliminated with a high degree of confidence.

Attention then moved to other sites, one in particular lying in the north of England in an open rural area. This site had also been photographed, and a possible disturbed target excavated and eliminated. However, intelligence had also pointed to a corner of a water-logged field nearby that merited attention; it measured some 70 x 50 m and was used as a storage area for horse manure. The logistical issues were such that machine stripping was seen as the best way forward, given that the topsoil/manure layers were relatively shallow and that any disturbance into the yellow clay substrate would be readily visible once the topsoil had been removed. The machine used a wide toothless ditching bucket and was supported by a cadaver dog to test any anomalies found; the machine stripped the higher part of the area, but water-logging made it impossible to machine on the lower part. No large intrusions were found, but the machining did expose a narrow linear feature cut into the clay, presumably a field drain that allowed water to flow down into the water-logged area. Because of the indistinct nature of the feature when first exposed, it was vented (that is, probed carefully to allow any gasses to be emitted) for the cadaver dog. The dog responded in a half-hearted way, but despite further venting in the immediate area it was not possible to focus the dog's response. It was assumed that any source might be higher up the pipeline, but the machine stripping had identified no intrusion.

A few months later, when the water-logging was less inhibiting, the lower part of the field was stripped and revealed a grave-shaped disturbance. This feature was cleaned and defined using trowels and partially excavated by careful sectioning at one end. Evidence of human remains were found, the area was immediately designated a crime scene, and a forensic pathologist was called. Reference to the previous search plans showed that the grave was located along the line of the field drain and only a few metres from the point where the dog had previously responded, but downstream. The sensitivity of the dog appears to have been such that it had picked up the scent of the cadaver *upstream*, rather than downstream from the source as had been assumed.

The discovery was made at approximately 11.00 A.M., but the casework of the pathologist was such that his arrival was not until about 5.00 P.M. During this time the area was made secure, the scene was tented and additional uniformed officers drafted in from the local police force. The pathologist had already worked with archaeologists on previous occasions, which led to a mutually comfortable operational arrangement. After discussion, it was agreed that the two archaeologists would each work in a different half of the grave. A narrow baulk was left between the two halves of the grave to allow the archaeologists to record the nature of the burial infill. This approach allowed the process to proceed more quickly, given that it was winter, the temperature was around zero, and there were strong winds and heavy rain. The method of excavation was to remove the infill in each half in arbitrary spits of about 10 cm each and record them on context sheets. Each spit was numbered, and any exhibit seized was numbered in a different sequence but cross-referenced to the spit number. This approach allowed a coarse but effective method of relocating exhibits in three dimensions at either end of the grave. Electronic recording systems would have been less effective, given the small nature of the area being excavated and the prevailing weather. The deposits of each spit were retained in sealed, numbered plastic dustbins for later attention if required. As the body became more exposed, the pathologist became progressively more involved, checking for trauma, and advising on how the individual might have been deposited, in order to facilitate the excavation and lifting. Water-logging became a major problem: even in the early stages of excavation the grave would fill up, and the excavation of a drainage channel running downhill out of the grave appeared to make little impression. However, it soon became clear that when the grave was originally dug, the field drain had been severed, allowing water to flow continuously into the grave (Figure 31.1). This problem was



Figure 31.1 Photograph showing the excavated grave. The fractured field drain served to provide both positive and negative aspects to the excavation. The channel to the left was the result of an attempt to drain the grave during excavation.

eventually resolved by using the machine excavator to remove a large sump through the field drain upstream of the grave allowing the water to be channelled away from the scene.

The victim had become substantially skeletonized as a result of the bacteria present in the horse manure, and very little soft tissue had survived. This situation made the collection of the smaller skeletal elements difficult in the muddy infill, but it also had the advantage of exposing the bone surface and with that evidence of any hard-tissue trauma. For example, the body was face down and exhibited a projectile entry wound in the back of the head. Until this point the archaeologists had been concerned with maintaining the physical integrity of the remains (before lifting them and before the postmortem examination being undertaken by the forensic pathologist), identifying correctly the grave edges, recording accurately, and checking for foreign materials in the fill. The bullet wound required a new interrogation of the data. Had the victim been shot in the grave, or had he been shot elsewhere and transported to the disposal site? And would it be possible to determine this archaeologically? Would there be projectiles still lodged in the body, or would they have penetrated the grave bottom? With all this in mind, the archaeologists fully exposed the body, recorded and removed the baulk, and lifted the body into a body bag and had it taken away for postmortem examination. This recovery lasted some 8 hours, and the archaeologists returned the following morning to remove the lowest deposits in the grave (that is, those under the body), record the grave profile, and check the grave bottom and walls for projectiles with a metal detector.

Each archaeologist subsequently prepared a statement detailing the process and the findings and supported by all disclosable material such as plans, record cards, and photographs. Under the terms of the CPIA the statements were made available to the defence. When the case came to trial many months later, the archaeological evidence was used as part of the CPS argument but was not cross-examined. The defendant was found guilty and was sentenced to life imprisonment.

Another case involved the disappearance of a young woman and her 3-year-old son in 1976. It represents a cold-case review, and the case remains an issue of local intrigue in the Inverness area of Scotland.

Cold-case reviews of major unsolved crimes occur at regular intervals. Different officers are used, partly to review what has already been undertaken and to consider new options and developed technologies but equally to provide a fresh set of ideas and attitudes. In several long-standing cases, DNA techniques that were unavailable at the time a crime was committed have enabled well-publicised convictions to be made. Similar developments have been made in search techniques, and awareness has increased of the availability of geophysics, the relevance of offender profiling, and of search strategies and recording. Officers faced with a search review may well draft in areas of expertise that were not available or utilised in the original enquiry. Being a relatively recent part of the forensic scenario, archaeology often falls within this category.

The woman had been having an affair; she had separated amicably from her husband and had settled in a different area. Months later her burned-out car was discovered on the main A9 road in Scotland, and subsequent large-scale searches failed to find either her or her young son. A disused sand/gravel quarry nearby was infilled a matter of only days afterward and appears not to have been searched by police until the following year, when excavation work commenced. Part of the infill was removed, but the investigation was halted two weeks later through lack of resources. By then the open quarry had been landscaped, filled with debris and building materials from the road workings, and covered in top soil. The police excavations of 1977 were unproductive, but in the years that followed, local interest and curiosity developed, culminating in a television programme broadcast in 2003 that pointed to the disused quarry as needing renewed investigation.

To their credit the then local police force, Northern Constabulary, reviewed the situation and agreed to have the quarry excavated archaeologically in order to either find the remains of the two victims or to have it eliminated from the enquiry and from local folklore. Various briefings took place with archaeologists, anthropologists, and others through the Centre for International Forensic Assistance (CIFA), and a strategy was devised for its excavation. By then the former quarry was barely identifiable: the edges were unrecognisable, and planted pines had grown to a height of over 12m. Earlier aerial photographs had enabled the quarry perimeter to be defined, and arrangements were made to remove the trees across an area of over 100m in diameter. The depth to the quarry floor was unrecorded, and it was difficult to ascertain exactly how long the project would take. The area was fenced off, temporary office facilities brought in, and the site was manned and made secure for a period predicted to be between four to six weeks. Geophysics was not feasible owing to the potential depth and size of the targets, but ground-penetrating radar (GPR) was considered as a possible method of identifying the sand and gravel quarry base and walls. However, because much of the infill was also of sand and gravel, GPR was rejected as a useful way forward. Before excavation work commenced, a company specialising in 3D recording using an automated reflectorless system surveyed the area.

A machine trench was used to ascertain the depth of the quarry. Trial work showed that at least 3–5m of deposits needed to be removed before the original quarry bottom and terraces could be exposed. Any human remains were considered to lie within the scree on the quarry terraces rather than in the infill. Nevertheless, when excavation took place archaeologists and anthropologists were assigned to each of the two 360° excavators and 20-ton dumper trucks on a watching brief basis. The quarry was effectively half-sectioned, excavated stratigraphically like a large archaeological pit, and recorded contextually: the latest infills were removed first; the trench dug by the police in 1977 was identified and excavated; the quarry landscaping was reversed; and the terraces and floors were returned to their original state of 1976 (Figure 31.2).

Throughout the operation spatial records were made using a total station electronic measurement system (EDM) supplied and operated by the police Accident Investigation Unit. The entire process took over four weeks and required the excavation of an estimated 37,000 tons of



Figure 31.2 Part of the excavated quarry at Dalmagarry showing the original shape of the quarry ledges before infilling and landscaping in 1976

material. The result was the return of the quarry to its original state allowing the terraces and floors to be examined in order to locate any victims. These surfaces were searched thoroughly, including the use of cadaver dogs, but no human remains were found. The ledges were then overcut by machine with a watching brief in order to confirm absence of any further anthropogenic activity. The exercise initially involved two anthropologists and two archaeologists, but as the extent and nature of the exercise became clearer this was changed to three archaeologists and one anthropologist with another anthropologist on stand-by. There were daily briefings with the police, but the strategy decisions were largely made by the archaeologists. At the end of the excavation it was possible for the archaeologist to assert that no remains had been deposited there, as opposed to the fact that no remains had been found. The distinction is significant. The search was also concentrated in the area immediately adjacent to the quarry with detailed records maintained; these will be of value if the area is again subjected to enquiry.

Search and Recovery of Nonhuman Buried Items

The scale of the investigation undertaken in the quarry can be contrasted with the search of a small garden of an urban terraced house measuring c. 10 x 5 m. Neither case had used archaeology previously. However, the focus of the search here was a possible buried firearm, which may (or may not) have been concealed during a particular period of tenancy that lasted only a few years. The investigation was planned very carefully and involved numerous briefings for all concerned. It also necessitated compiling a history of the garden in order to ascertain which elements of the garden (for example, layers of terrace, flower borders, pathways) were created or were used by particular tenants during the occupancy of the house throughout its 40-year life. Operational police personnel had been trained by the archaeologists, and a simulated site had been prepared for trial purposes in advance of the actual operation. Before excavation took place, both GPR and magnetometry were used on site, but only after substantial ferrous features, including doors, were physically removed from the surrounding environment to minimise background “noise.”

Each geophysical method produced its own set of responses and anomalies, some in common; these were investigated by hand and a small number of ferrous objects recovered. However, the nature of the enquiry necessitated more sensitive evidence be collected, including DNA from appropriate relevant stratigraphic contexts. In view of this sensitivity, all the personnel (which consisted of two archaeologists, one of whom was a specialist in conservation, and a small number of archaeologically trained police search officers) were suitably clothed to prevent DNA contamination, and all equipment used was new and additionally cleaned with anticontaminant gel. The garden was excavated stratigraphically, and all soil layers (a total of only some 6 tons, compared to the 37,000 tons in Scotland) were hermetically sealed in polythene bags before removal from the scene. On the basis of the background history of the garden it was possible to identify particular layers or contexts as being of priority value for further attention by sieving. The net result was that the rear garden of the property was “deconstructed” down to the natural bedrock by appropriate stratigraphic means. This deconstruction gave the police and forensic teams the opportunity to examine individual archaeological contexts of proven chronological association in order to further their enquiry. This activity was very much a team effort; the operation lasted two days, but the sieving and further scrutiny of the layers continued for several weeks thereafter and produced evidence, including the likely murder weapon, which was of great value to the enquiry.

On another occasion a kidnapper had successfully eluded a police trap and had escaped with a substantial sum of money packed into a holdall. When eventually apprehended, he was

charged with both kidnapping and with the murder of a previous victim. However, the ransom was nowhere to be found, and the incident enquiry team set up an investigation for its location. Evidence was drawn in from a number of sources, including eyewitness accounts, criminal profilers, and military fieldcraft experts and others, and a focal area of interest was eventually identified. This focus centred on a bridge adjacent to a main railway line with cultivated fields either side of the railway cutting. An archaeologist was brought in to support the enquiry, essentially to determine whether any disturbances were visible in the railway cutting and to add comment on the overall search focus. It was initially clear that the railway had been cut through bedrock and that burial of even a holdall would have been impossible. However, at the top of one side of the cutting, fenced from a cultivated field, was a strip of scrub woodland running parallel with the railway. It was agreed that this strip should be searched using geophysical survey techniques. In this case GPR was the most feasible method. The target area was some 50m in length and some 3m wide. It contained some fly tipping and a few areas of loose rubble. Later it was found that one of these rubble patches was acting as a marker for the buried holdall. The GPR survey identified a large number of anomalies, each of which was investigated by hand until the holdall was found. This investigation was seen as a major achievement for teamwork and led to the successful conviction of the offender.

Allegations of Anonymous Human Remains Buried in Specific Locations

There are a substantial number of instances in which members of the public feel obliged, after years of soul searching, to confess to having witnessed serious crimes in the distant past. Typically, a person admits to having seen a victim being buried in a particular location, but invariably there is never a missing person or a named offender to place in context. However, the location is always specific, such as in the corner of a garden or by a certain tree in woodland. There is rarely any corroborating evidence, but the police have an obligation to take the information seriously. From an archaeological point of view, the situation is relatively straightforward and involves simple testing or ground-truthing of the location in question. One such case involved the edge of a golf course in a woodland clearing. The informant took officers to a small hollow at the edge of the course and pointed to a low-lying area of vegetation in the middle. The officers and the archaeologist agreed that any investigation should be bounded within an area measuring some 3 x 2m centred on this location. Systematic probing demonstrated consistent hard compacted substrates across the whole area but indicated softer ground in the lowest-lying parts at the centre. This area was subsequently sectioned and shown to be of softer earth probably resulting from water-logging. There was no evidence of any previous anthropogenic activity, and the file was closed.

Incidents such as this one can usually be resolved directly by careful invasive means. Other methods, such as geophysical survey, are rarely necessary, especially if the location can be pinpointed and needs to be excavated anyway. In one case, the release of a notorious paedophile from gaol, marked by intense media interest, caused one elderly lady apparently to recognise him from the newspaper photograph. She had seen him, she claimed, years earlier trampling down loose earth at the edge of woodland. She was adamant that he was the man in question, but she was unable to define the location other than the general area of a field corner. Fieldcraft showed no suspicious vegetation or topographic features. Geophysics was commissioned in order to narrow down the area in question, and a cadaver dog was introduced in order to check any resulting anomalies. Again, boundaries were defined, and the geophysical (resistivity) survey identified two anomalies, neither of which was of appropriate size. Each anomaly was tested by the dog, who responded to neither. One anomaly was in very open landscape, but the other was



Figure 31.3 A small trial excavation took place in order to test an anomaly identified through geophysical survey. A cadaver dog was also used.

more secluded, and this one was sectioned by the archaeologists before being fully eliminated (Figure 31.3).

Geophysics was also used to eliminate the garden of a property in which a woman claimed her father had murdered and buried a prostitute. The alleged incident had occurred almost two decades earlier and the woman had a history of drug abuse. Nevertheless, it was felt that the allegation could not be ignored, and archaeologists were brought in to devise a search strategy. The house in question was a council property with a relatively secluded rear garden measuring some 20 x 10 m and a very small front garden that was open to the road and in full view of other houses. Both gardens were flat and grass covered. It would have been possible to excavate both parts of the garden fully using Operational Support Unit (OSU) officers, but this approach would have been both obtrusive and costly and unlikely to have been justified on the strength of the information received. It was also in a city area that was not particularly police-friendly. Instead, both parts of the garden were gridded out for a resistivity survey, and the work was carried out in a few hours. After data processing, it was seen that there were no significant anomalies in the rear garden but that there was an oblong lower resistance anomaly in the front garden. This was subsequently sectioned by the archaeologists (dressed in the guise of workmen) and found to be a former flowerbed. The file was then closed. In this case, as in all others presented in this chapter, investigation progressed from the noninvasive to the invasive in order to minimize any potential loss of evidence.

Compared with adult victims who are rarely physically transported very far, newborn or premature individuals weigh less and can be more easily carried and disposed of. Consequently, alleged infanticide or neonatal disposals are probably the hardest to search for. Nevertheless, if infanticide or neonatal disposals are buried, the minimum size of the intrusion is likely to be that of a spade width, perhaps some 30 x 30 cm, and likely to be detectable in otherwise undisturbed ground by a careful geophysics or clearance strategy. Many of the cases encountered are several decades old and relate to women who have buried stillborn neonates at a time when there was greater stigma attached to illegitimacy. Often the buried whereabouts are only vague, or landscapes have changed, and often the enquiry is based on issues of closure rather than legal

action. Given the size of the buried intrusion, the smallness of the individual bones and the area to be searched, the investigation can often most usefully be undertaken by a careful but lengthy process of sieving gridded areas of the ground.

In one instance the allegation was that the individual was located in an unused grassy part of a graveyard measuring about 4 x 4 m. This area was surveyed using resistivity at 25 cm intervals, and a small number of anomalies were found, all of appropriate size. The turf was carefully removed in a square around each and the topsoil trowelled back to undisturbed natural deposits. In each case the anomaly had been created by tree or plant roots. After this, the SIO asked for the whole area of 4 x 4 m to be cleared; turf was removed and the topsoil trowelled down to undisturbed substrates. No further disturbances were identified, and the file was closed.

A similar allegation involved the rear garden of a terraced house, but here, in order to avoid suspicion, access could not be made until the morning of the search. However, a covert aerial photograph had identified that the garden was predominantly covered with grass, and as a result a resistivity survey was planned. But it was discovered that the grass and topsoil had been superimposed over concrete, effectively making the technique unviable. Fortunately, a GPR system was also available. GPR is unique in being able to penetrate dense materials, and this case identified a number of anomalies. The entire concrete was lifted and disposed of into a prearranged skip, and the underlying deposits investigated by hand. None of the anomalies or any of the other features contained human remains.

Accidental Discovery of Human Remains

All the preceding examples were investigated as a result of careful planning and briefing, but there are many cases that occur at short notice, usually because human remains have been discovered during building operations or by people enjoying leisure activities. One such instance occurred when articulated skeletal remains were discovered by children playing in woodland. The remains lay on the side of a steep bank and were partially covered in soil and obscured by vegetation. The area was immediately taped off and the SIO kept the site secure until an archaeologist and an anthropologist could be brought in at short notice. The archaeologist was able to determine that the remains had not been intentionally buried but had become covered (buried) through natural accumulation of deposits as a result of material washing down the hill. This determination provided an important distinction, because it demonstrated that a third party had not been involved. Had the remains been moved before this examination, this distinction would have been lost. The anthropologist was able to provide preliminary information regarding sex, age, and stature so that the enquiry could move forward before the postmortem the following day. It transpired that the individual was likely to have been a young male adult who had discharged himself from a local hospital, wandered off, and who had died from natural causes. His identity was later confirmed by DNA.

In a similar scenario, building workers came across part of a human skeleton on wasteland that was being redeveloped. The skull and upper torso were visible against a wall behind some low bushes, but the rest appeared to be buried (Figure 31.4). The area was sealed off until archaeologists could attend. Preliminary examination of the remains and the soil layers showed that the body lay on the surface and that its lower part, far from being buried, had been severed above the pelvis, probably by the earth moving machine that had been clearing the site and landscaping the site perimeter with low banking. A few skeletal elements were observed in the immediate vicinity, notably a foot, but otherwise the skeleton was incomplete.

Fortunately, the upper torso retained a heart pacemaker with a reference number that could be associated with a specific individual. He was an elderly man and a known alcoholic who lived



Figure 31.4 The skeleton of an individual found at the edge of wasteland. Excavation showed that the lower half of the body had been removed by an earth-moving machine.

in a local hostel and who was known to wander off. Reference to the manner of landscaping and machine activity at the site suggested that the missing remains could lie anywhere within a large area. It would have been impractical to excavate and sieve the entire disturbed area of some 80 x 50 m, and the collected remains were returned to the family for burial. Cause of death was never established but was assumed to be from natural causes.

The final case concerns skeletal remains found by a member of the public while walking along a beach. The bones were taken to the local police station and were identified by the police surgeon as being human. The general area of the discovery was secured until an archaeologist was called in to examine the location. His first question was to ascertain whether they belonged to a burial or whether they had been introduced as disarticulated remains in a redeposition of material. His findings demonstrated that the former was the case: they were part of a complete buried skeleton that had been partly exposed by marine erosion at the shore edge (Figure 31.5).

The task then was to ascertain the age of the burial. In similar instances where there had been no associated material such as clothing, jewellery, or modern dental treatment radiometric dating was able to offer some solution, but here there was good stratigraphic evidence to indicate an “archaeological” timescale of deposition. Once cleaned up the exposed grave section was shown to underlie anthropogenic deposits, including the unbroken surface of a footpath that had been in use for over a century. Moreover, reference to local museum collections revealed that the area was part of a known prehistoric burial ground. The remains were formally excavated and dispatched to the museum for further analyses.

Conclusion

The case studies under these four broad themes provide insight into the types of work in which a forensic archaeologist might expect to contribute. Much of the work will be routine and most will be concerned with elimination or with giving advice. Fifteen years ago, involvement at this



Figure 31.5 The excavated remains of an “archaeological” burial. The right arm of the individual had been eroded out of the shoreline and caused the enquiry to take place.

level would have been relatively rare: input would have been restricted to a few individual cases involving a known missing person or occasionally to situations where skeletal remains had been found. Awareness of the discipline has developed significantly since then, partly through teaching and research in the subject, especially at universities, and partly through the effectiveness of operational involvement and the provision of training programmes. These programmes have been delivered not only to law enforcement groups but also to other archaeologists in a two-way process of awareness. There is, nevertheless, still some misunderstanding as to what archaeology and anthropology actually are as disciplines, and how they differ. Unlike in the United States, where archaeology tends to be subsumed and practiced under the discipline of anthropology, in the United Kingdom the roles are very clearly defined—the archaeologist deals with buried material of whatever type and the anthropologist with human skeletal materials, buried or not. Of course, some individuals are skilled in both areas. Nevertheless, in the U.K. the misunderstanding is more than compensated for by an increasing use of archaeological evidence in court and through recognition by the Forensic Regulator. Archaeologists still wince at certain crime reports in the media, in which it is clear that archaeological involvement should have been used but was not, but such reports are becoming fewer. However, the fact that any exist at all is still a cause for concern.

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Forensic Anthropology in Disaster Response

Paul Sledzik and Amy Z. Mundorff

When struck by disaster humans attempt to control the associated effects on their lives. The first response to controlling the immediate chaos gives way to the recovery process: rebuilding infrastructure, homes and businesses, and support services. If a large number of people are killed in the disaster the recovery process becomes more complex. The affected community must deal with the retrieval of the dead, the identification of the remains, and personal and social grief processes made more intense by the sudden death of the victims.

Although not considered first responders in the traditional sense, forensic scientists are invaluable to mass fatality response. They are the specialists in mass fatality management and disaster victim identification (DVI), areas that fall outside the realm of first responders who are trained to rescue survivors, treat the injured, and provide for the living. As part of the medico-legal systems requirement to conduct victim identification, forensic scientists bring both technical capabilities to identify the dead and a unique understanding of the complexities of managing large numbers of deceased individuals. Mass-fatality forensic teams are multidisciplinary and usually include forensic pathologists, forensic anthropologists, forensic odontologists, forensic radiologists, fingerprint specialists, DNA analysts, medico-legal investigators, funeral directors, and forensic managers.

The involvement of forensic anthropology in mass-fatality response encompasses traditional technical roles, operational support, and management responsibilities (Table 32.1). The traditional approaches are extensions of those applied in skeletal casework: the application of archaeological methods in the search and recovery of human remains from disaster sites and the examination of human remains to determine biological characteristics useful for identification. In recent years anthropologists have expanded their involvement to mass fatality management, improving the science and process of victim recovery and identification. Outside of management and the mortuary setting, anthropologists work closely with community groups and family members of the deceased, to help to answer their questions and address their concerns about individual cases or the overall victim identification process. With broad training in biological interpretations of human identification, anatomy, taphonomy, and human biology, and supported by knowledge of the cultural considerations of religion, death, and mourning, anthropologists are uniquely suited to make important contributions to the fields of mass fatality management and disaster victim identification.

Although large-scale disasters may overwhelm local medico-legal agencies, the agencies are still legally responsible for victim identification and determination of cause and manner of death. Soon after the disaster, individual and societal needs to recover the deceased (for funerals and other grief rites) and medico-legal requirements for proper identification are often at odds. Family members of the victims and civic leaders may question certain aspects of the forensic response, particularly

Table 32.1 Forensic anthropological skills in mass-fatality incidents

Disaster Scene

Devise appropriate system for search for and recovery of remains based on size and scope of event.
Locate, recognize, and recover human remains, especially burned and fragmented.
Train search personnel to recognize human remains (based on taphonomic factors).
Provide field assessment of condition of remains.

Incident Morgue

Assist in triage of remains.
Separate commingled remains.
Describe incomplete/fragmentary remains and condition of remains.
Determine sex, age, race, stature, and distinguishing characteristics.
Interpret radiographs for age estimation and unique skeletal features.
Determine minimum number of individuals based on remains recovered.
Assist in identifications using anthropological features.
Assist in sex and age assessment of remains.
Analyze trauma evidence and incident-related injuries.
Conduct quality assurance of remains before release from morgue.
Serve as morgue manager.

Disaster Management

Examine processes used to document remains to ensure all appropriate biological data are collected.
Speak with family members concerning methods of identification.
Assess and solve problems in management of antemortem and postmortem data.
Examine antemortem data collection issues, including availability and accuracy.
Serve as manager of overall victim identification efforts.

what is often a lengthy identification process. When informed about the need for a comprehensive medico-legal investigation and provided details explaining the identification process, family members and the public begin to understand the issues involved. Cultural and religious beliefs also affect methods of identification, and whether attempts at identification are undertaken at all (Kahana 2014). Because family’s expectations about the level of identification vary across the globe, the use of scientific methods to identify disaster victims is not universal.

Overview of Mass-Fatality Response Operations

Disaster victim identification procedures have been divided into five distinct phases: the scene, the mortuary, antemortem data collection, reconciliation, and debrief (Blau & Hill 2009). The response usually sees three separate areas of work develop: along with the disaster site and the disaster morgue, the family assistance center—where families of the deceased gather to receive and provide information.

In the flow of events following a disaster the search for and recovery of human remains often comes after life-saving efforts, ensuring the surroundings are safe (for example, fire suppression) and other first-responder requirements are completed; they can also be conducted concurrently. Forensic personnel work with first responders to document the scene, evidence, personal effects, and the human remains before they are recovered. The tenet used by recovery personnel is to

treat the site as a crime scene and document it accordingly. A comprehensive approach includes using survey equipment such as a total station or global positioning systems (GPS) supported by photographs, diagrams, and other types of manual or digital documentation.

The methods used to process a crime scene are logically applicable to the disaster scene, and some disaster scenes are crime scenes. However, when these methods are applied to a disaster scene, other factors unique to the incident must be taken into consideration. The size and location of the affected area, the number of fatalities, and the condition of the remains—even the time of day the event occurred and current weather conditions during search and recovery efforts—influence the time required for search and recovery. When remains are distributed across a disaster site, appropriate search procedures document the scene, ensure that all areas are searched, and make certain that human remains are recognized and recovered properly. Forensic anthropologists trained in archaeological methods easily adapt their techniques to disaster scenes (Blau 2005; Dirkmaat 2012; Steadman et al. 2014). Large amounts of physical evidence at a terrestrial disaster scene require a rigorous approach to location, documentation, and recovery. Dirkmaat (2012) and others stress the routine use of electronic surveying instrumentation along with other procedures typically employed at archaeological sites. Along with archaeological training, experience participating in search and recovery of skeletal remains from crime scenes allows anthropologists to contribute to management considerations at a disaster scene, such as determining the size and scope of the field operation. Using their knowledge of taphonomy anthropologists can train search and recovery personnel on the unique aspects of scenes where remains are fragmented, burned, and decomposed. The ability to recognize compromised remains allow for the recovery of specimen that might otherwise be overlooked. And on-scene assessments can reveal if questioned materials are human, nonhuman, or nonbiological. Human remains are then numbered on scene and removed to a temporary storage location to await their transfer to the disaster morgue.

The disaster morgue resembles an assembly line where human remains are systematically documented and analyzed (Wagner & Froede 1993; Sledzik & Kauffman 2008). Figure 32.1 portrays a typical disaster morgue operation process and indicates some of the considerations that affect how remains are processed.

Remains are taken directly from the disaster site or from a temporary holding location to the morgue. On arrival at the morgue they are placed in refrigerated storage to await processing, which allows forensic analysts to control the flow of remains into the examination portion of the morgue. Once admitted into the morgue the remains are radiographed or CT-scanned in the container they are received in, usually a body bag or pouch. Imaging allows personnel to look for items embedded in or associated with remains that may be a safety concern (such as sharp metal items or unexploded ordinance). In the case of fragmented or dismembered remains the radiographs also aid in the triage process by allowing anthropologists and pathologists to assess the remains *in situ* (the body bag) before processing (O'Donnell et al. 2011). This ability can be particularly useful when remains are commingled and compromised, because imaging allows the examiner to “visualize” individual skeletal elements otherwise obscured by soft tissue (Viner 2014). Sometimes the process of examination can inadvertently cause precariously articulated remains to become disrupted. Therefore, discerning potential commingling through imaging provides the analyst valuable supplementary information before physical examination (Rutty et al. 2007; Sidler et al. 2007; Blau, Robertson, & Johnstone 2008).

In the morgue the anthropologist's knowledge of skeletal biology and comparative anatomy is critical for the analyzing and interpreting of remains that are fragmented, burned, and decomposed, typical of many types of mass disasters. For example, at the triage station anthropologists sort human remains from nonbiological material (such as building or plane wreckage),

Mass Fatality Morgue Operational Plan

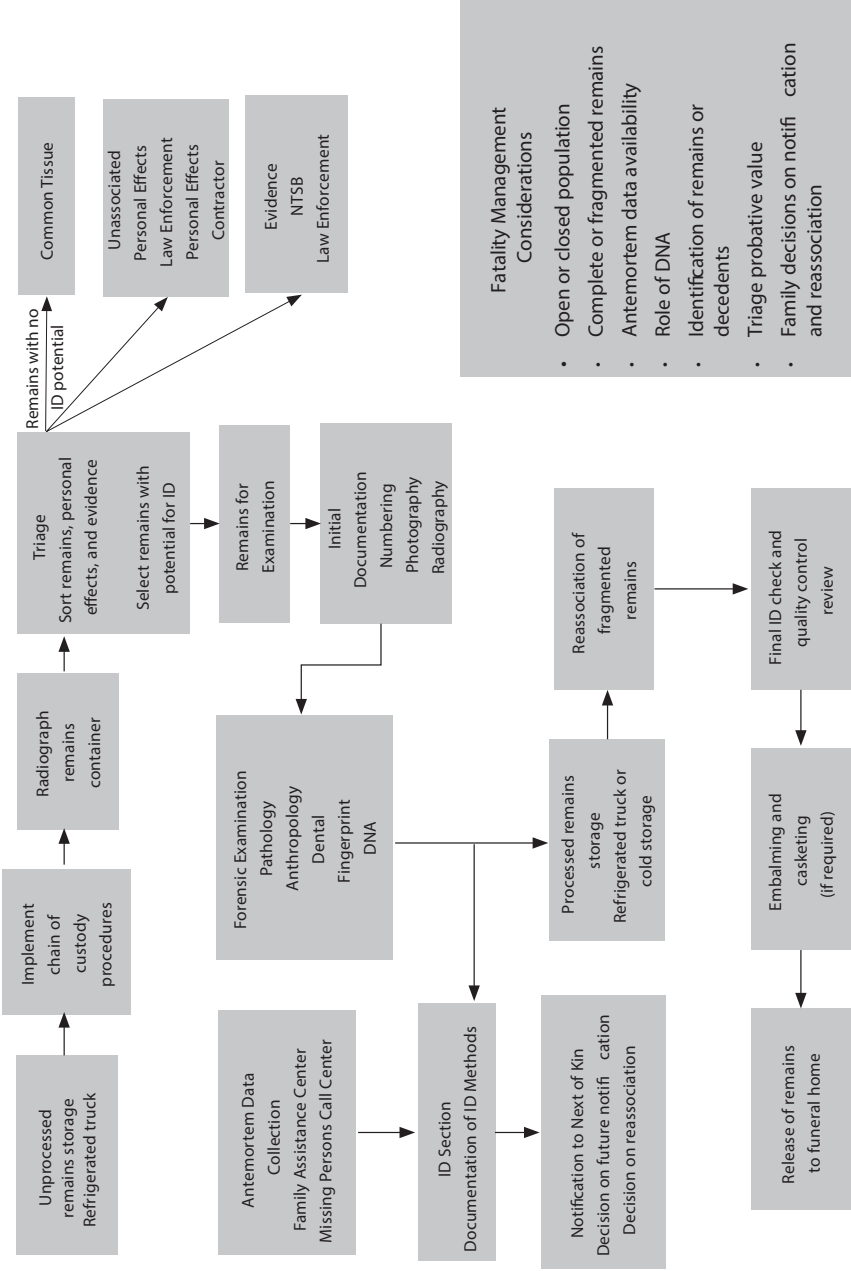


Figure 32.1 Mass fatality morgue operational flowchart

differentiate human from nonhuman (animal) bones, and identify personal effects. In a disaster mortuary the triage station is typically where anthropologists apply a probative index—that is, each fragment is systematically classified according to its identification potential or investigative value. Assessing human remains with a probative index facilitates rapid identifications (Kontanis & Sledzik 2014; Mundorff 2014). This categorization system relates the number of positive and presumptive identifying features to the potential for a DNA, dental, fingerprint, or medical identification. Those remains with the greatest potential for identification (for example, jaw fragments with teeth, hands with ridge skin for fingerprints, bones with prosthetic devices) are prioritized into the morgue stream for analysis. Less probative fragments likely to necessitate expensive and time-consuming DNA testing are processed next. Depending on the identification mandate (for example, 100% victim identification or 100% fragment identification), small pieces of soft tissue and organs are processed last or not at all, because their likelihood for identification is small. These remains are placed in a separate container and may be analyzed further if all victims are not identified. Eventually, these remains will become a group of remains—that is, remains that cannot be identified and therefore represent the group of victims.

Remains that are placed into the morgue flow for analysis are sequentially numbered, photographed, and radiographed a second time (as an individual specimen). Each set of remains, accompanied by its corresponding case file, progresses through various stations for specific forensic analyses. In the case of a complete or nearly complete body each discipline participates in the analysis. For fragmentary remains, the most appropriate disciplines will examine the specimen (for example, a hand would be examined by a pathologist, anthropologist, and fingerprint expert, but not by an odontologist). Data from each examination are recorded in the case file, which is later entered into a database that allows comparison with antemortem data.

While the postmortem data are being collected at the morgue, antemortem information is being obtained from family members and friends of the deceased. This process typically happens at a family assistance center. Law enforcement officers and specialists in forensic identification use standard interview forms when meeting with family members. Requests for information may include contact information for dentists and doctors (to access antemortem records and radiographs), data on the unique biological aspects of the deceased, DNA samples, and information related to personal effects with the deceased.

In most disaster situations involving recently deceased positive identifications are established using scientific methods that focus on biologically based attributes. These methods include friction ridge prints, odontology, radiology, DNA analysis, and medical implants with recorded serial numbers. Distinctive physical characteristics (for example, ears, scars, moles, tattoos) with appropriate antemortem photographic documentations may be used for a positive identification in a small, closed population incident (such as an aircraft accident) where the victim's demographics or characteristics are known. However, identification based on visual means or personal effects must be done with caution, because both methods are known to be inaccurate (Fierro 1993; Weedn 1998; Lain, Griffiths, & Hilton 2003). Using such characteristics for positive identification in an open or undefined population, or if the victims' demographics are homogenous, should be avoided. Unlike other scientific modalities, "individualizing" or "unique" characteristics for identification are not accompanied by probability or error rates (Komar & Lathrop 2006). Instead, distinctive characteristics, personal effects, and clothing allow for a presumptive identification, which can be a preliminary step toward positive identification using some or all of the scientific procedures listed previously.

Regularly scheduled review meetings are held between the medico-legal authority and forensic scientists to examine, critique, and decide on identifications. A forensic specialist from the discipline specific to the identification will document the identification details in a report,

which is presented to the medical examiner or coroner for agreement and death certification. Once remains are positively identified, and before notifying the next of kin to arrange for their release, as a quality assurance check a group of experts reviews the remains and all associated paperwork; this group may include a forensic pathologist, anthropologist, odontologist, and mortuary manager (for instance, MacKinnon & Mundorff 2006; Blau & Briggs 2011). After this final verification the remains are released to the funeral home or other designated party.

Fatality Management Considerations

Each disaster poses unique challenges for *mass fatality management*, a term defining forensic-based decisions influencing how the victims, their families, and the identification efforts are managed. Mass fatality management encompasses the overall recovery and identification efforts and addresses the expectations of both the family members of the dead and society about the identification process. Before victim identification begins, the medico-legal authority and the primary forensic responders must consider several important questions:

- What is the number of fatalities?
- What are the challenges in searching for and recovering the victims?
- Is the victim population open or closed (that is, unknown or known number of fatalities)?
- What is the condition of the remains (for example, complete, fragmented, burned, dismembered)?
- What are the types, availability, and accuracy, of antemortem information?
- Will forensic efforts focus on identifying all victims or all remains?
- What is the role (and the limitations) of DNA in the identification efforts?
- What are the concerns and expectations of society and the next of kin for the identification efforts?

Answers to these questions focus the work of the forensic teams, determine the length of the recovery and identification process, identify necessary resources (both technical and monetary), expose potential limitations, and establish the role of forensic science in the response (Tun et al. 2005; United States Department of Justice 2005, 2006).

Conventional wisdom may suppose that the greater the number of fatalities, the more complex the identification process. In practice, while the number of fatalities is important (particularly when the figure rises into the thousands), the associated taphonomic factors and antemortem data availability have a more profound effect on the identification process. As an example, consider two hypothetical disasters, each resulting in 100 fatalities. Complete bodies with little taphonomic change and readily accessible antemortem records characterize the first disaster. The second disaster causes fragmentation of remains (with nearly 8,000 fragments representing the 100 victims), and little is known about the victims and their available antemortem information. If the same amount of forensic resources is applied to each incident, the second disaster will take longer, cost more, and require more complex fatality management decisions than the first.

Characterizing the group of victims highlights an important mass fatality management concern featured in the questions above. Victim populations are categorized as open or closed based on the information known about them at the time of the disaster. In a closed population some basic data about the number and identity of the victims (usually a name) are easily obtainable. With a victim's name or other type of contact information, authorities can reach next of kin to obtain antemortem information. The most common example is an aircraft

accident wherein a flight manifest (supported by positive identification checks, ticket purchasing procedures, and airport security) becomes the initial source of antemortem information. Under United States law, for example, passenger names and contact information are provided to the authorities within a matter of hours following an accident, and the collection of antemortem information can begin shortly thereafter.

Conversely, an open population defines a victim group in which neither the numbers of victims nor their names are immediately known (for example, the 2002 Bali Bombing; see Buck & Briggs, Chapter 35 this volume; the Asian tsunami; see Black, Chapter 34). To create an accurate victim list, response personnel must sort those who are reported missing from those who are actually missing. A central call center for reporting disaster missing is essential for effective victim identification. Ideally, a single call center receives all missing-persons calls, although depending on the jurisdiction and size of the event, multiple call centers may be necessary. Call center personnel compile a comprehensive catalogue, and from these data investigators establish a list of those actually missing through winnowing duplicate reports, clarifying misspellings, and verifying the status of a missing person (Hennessey 2014). Once a victim is known to be missing the process of obtaining their antemortem data begins.

Often the initial reports of the number of fatalities in an open population disaster differ significantly from the final figures, which may take years to establish. For example, in the September 11, 2001, World Trade Center disaster, initial media reports indicated as many as 20,000 dead or missing. In subsequent days the number of reported missing ranged between 3,958 and 6,453 (Simpson & Stehr 2003). As of November 2005 the total number of missing from the disaster was 2,749, of which 1,594 had been identified (Biesecker et al. 2005). In the Asian tsunami of 2004 the World Health Organization reported 10,000 dead, and within 10 days the number expanded to 153,000 (Fleck 2005). The final death toll was nearly 250,000, with an understanding that the final number will never be known (Thieren 2005; Morgan, Tidball-Binz, & Van Alphen 2006). Following the bombing of several trains and buses in London on July 7, 2005, a centralized casualty call center was established (per previous planning efforts) to handle missing persons calls (Great Britain, Greater London Authority 2006). The center received 42,000 calls within the first hour of operation. The number of missing-persons calls, for an event that killed 38 and injured over 700, underscores the intense public response following a disaster and the need for authorities to implement a coordinated missing-persons system.

The process of positive identification requires comparing the postmortem data with antemortem information, with a focus on unique biological genetic characteristics. Thus two areas of forensic work develop: the morgue (Phase 2) and the collection of antemortem information (Phase 3). Analyzing remains for postmortem information occurs relatively quickly and simply as forensic scientists examine remains in the morgue. However, locating, obtaining, and evaluating antemortem data are often more time consuming and complex (Brannon & Kessler 1999; Blau et al. 2006; De Valck 2006).

Antemortem records in the form of dental and medical documents, radiographs, fingerprints, and DNA reference samples are the most frequently used and reliable methods for identification. However, to be used for identification, these records must be available, obtainable, and accurate. Potential antemortem records may be lost or destroyed during a natural disaster, as was the case with Hurricane Katrina (Donkervoort et al. 2008). If records do exist, they are usually obtainable only if family members can provide the victim's dentist and doctor contact information. Forensic dental literature reports difficulties in next of kin's ability to locate dentist contact information for the deceased (Brannon & Kessler 1999; Petju et al. 2007). Conversely, a victim's socioeconomic status may have prevented them from ever visiting a doctor or dentist. Many people have never been fingerprinted or were printed as part of a process that does not allow

for access to the record. Other factors such as age, socioeconomic status, cultural practices, and religious beliefs of the victims and their next of kin may limit antemortem record availability.

Efforts required to locate and analyze antemortem data have received little attention from forensic scientists, despite the nature of this essential requirement for victim identification. Anthropologists have begun to apply their research skills to this important area, which has the potential to enhance disaster-fatality identification practices (Simmons & Skinner 2006; Tyrrell et al. 2006; Wright et al. 2015).

The accuracy and applicability of antemortem records also limits their usefulness. Wright and associates (2015) point to accuracy, completeness, and legibility problems with antemortem dental records as a hindrance to identifications in Phuket, Thailand following the 2004 tsunami (James 2005; Kieser, Laing, & Herbison 2006; Chaikunrat, Pongpanitanon, & Petju 2011). They also cite other problems with antemortem data such as poor quality electronic transmission of fingerprints that prevented automated matches (Wright et al. 2015).

Taphonomic influences on human remains (see Nawrocki, Chapter 25) also affect mass fatality management. As part of the management team anthropologists can address the myriad ways taphonomic factors might influence different aspects of the identification process. The taphonomic spectrum of a disaster ranges from complete bodies to small, fragmentary remains. Along this spectrum, fire, chemicals, decomposition, and water cause additional damage to remains (Sledzik & Rodriguez 2002). In the case of fragmentary remains one critical management decision is whether to identify all remains or all victims—a decision influenced by the type of disaster (open or closed) and the social/cultural beliefs of the population affected by the disaster. In the case of an open population the decision should focus on identifying all the remains, in order to account for the unknown number of missing victims. Because certain fragmented remains possess the individualizing anatomical structures needed to conduct identification (for example, dental structures or hands with ridge skin), when the fragment is identified there is both proof of death and identification of the victim. While some fragments may assist in the development of a biological profile (for example, Blau & Briggs 2011), many fragments have no unique physical identifier, and DNA becomes the sole method for identification. Consequently, DNA analysis is heavily relied on in this type of scenario to identify the fragments lacking features that would allow for identification by other conventional methods. In a closed-population disaster resulting in heavily disrupted remains, such as an aircraft accident, identifying every victim is often the focus, along with identifying as many additional remains as possible from each victim. Available resources and the limitations of forensic identification methods may prevent all remains from being identified, yet identification of all the victims has been achieved.

History of Forensic Anthropology in Mass Disasters in the United States

Over the past several decades forensic anthropologists have played an increasingly important role when disaster strikes. Complex human identification efforts, such as those seen in investigations following wars, human rights abuses, and disasters, require the broad training and specific skills of forensic anthropologists. The experience of forensic anthropologists in disasters is visible in the scientific literature, viewed largely through the reporting of activities at specific events. A synthesis of these reports underscores the range of involvement of the science in disaster response (see Black; see Buck & Briggs, Chapter 35).

Forensic anthropology's exposure to mass-fatality work is rooted largely in its support of the U.S. military war dead identification efforts during World War II, the Korean War, and the Vietnam War (Holland, Byrd, & Sava 2008). Although anthropologists focused on identifying individual service members killed in battle, their skills were also useful when accidents killed

large numbers of troops (Sledge 2005). Starting with the work of Shapiro, Trotter, Snow, and Stewart during World War II (Wood & Stanley 1989; Ubelaker 2000) and continuing to the efforts of Warren, Kerley (Hinkes 2001), and McKern during the Korean and Vietnam Wars, anthropologists assisted in disaster situations when they arose. In fact, the Vietnam War era job descriptions of anthropologists employed by the military specifically mentioned examining remains from disasters and resolving commingling issues (Warren 1981).

The culmination of this military support work was Stewart's (1970) edited volume *Personal Identification in Mass Disasters*. The volume, comprising papers from a 1968 seminar sponsored by the Support Services of the U.S. Army and the Smithsonian Institution, reflected the military's desire to apply new scientific methods to war dead identification efforts. The volume dealt little with management issues of disaster victim identification but did present new anthropological methods useful in identification. Stewart was initially approached by the military to organize a seminar dealing with war dead identification. However, after discussing the proposal with several forensic colleagues, he decided to expand the scope of the seminar to address both mass-disaster and war dead identification, thus tying the techniques presented in the volume to both applications.

In the 1960s and 1970s the Federal Aviation Administration's Civil Aeromedical Institute (CAMI) employed anthropologists Richard Snyder and Clyde Snow. Although their research focused mainly on biomechanics and anthropometry, they also responded to aviation accidents to examine survivability and interpret traumatic injuries of victims. Their reports for CAMI reveal unique applications of anthropology to aviation accident survivability, including issues such as seat and lap belt injuries and trauma resulting from collision with water (Collins & Wayda 2003). Anthropologists have not continued their work, remarkable for its focus outside victim identification and morgue operations, in any significant way.

In 1976 Michael Charney, director of the Center of Human Identification at Colorado State University and codirector of the disaster morgue in Colorado, responded to the Big Thompson River flood. Because of fragmentation and decomposition, Charney's team of anthropologists assisted in identifying the 139 victims. Because of on his experiences Charney called for a centralized national system to identify disaster fatalities (Charney & Wilbur 1984).

Using the 1986 U.S. military aircraft accident in Gander, Newfoundland, as a starting point Hinkes (1989) examined the role of forensic anthropology in resolving the problems of disaster victim identification. In highlighting the field's technical capabilities she argued for the inclusion of anthropologists in all stages of the response (from recovery through final evaluation). Overall victim identification efforts would benefit, Hinkes claimed, because anthropologists produce biological profiles on remains previously considered unidentifiable.

The conditions encountered after the burning of the Branch Davidian compound in Waco, Texas, in 1993 allowed anthropologists to conduct scene documentation, search and recovery, trauma analysis, and victim identification (Owsley et al. 1995; Ubelaker et al. 1995; Houck et al. 1996). The burned remains required careful excavation of the scene to protect evidence and document the sequence of events. The methods used by the anthropological team underscore the comprehensive technical approach anthropologists bring to disaster response. For example, the team applied demographic analyses to examine the victim population, which ranged greatly in age. Research comparing actual victim age with anthropological age assessments revealed that the methods applied were accurate (Houck et al. 1996).

That same year Sledzik and colleagues became involved in the identification efforts following the flooding of a rural Midwestern cemetery (Sledzik & Hunt 1997; Sledzik & Willcox 2003). Floodwaters from the Missouri River carved away several hundred coffins from the town cemetery in Hardin, Missouri. Thousands of skeletal elements and hundreds of complete embalmed

bodies in various states of preservation required anthropological analysis. The team documented the remains, determined the minimum number of individuals represented by the individual bones, and was able to conduct several identifications.

The limited numbers of human remains recovered, following the 1996 crash of ValuJet 592, were extensively fragmented. Few skull fragments or teeth were recovered, necessitating a radiographic age assessment of the wrist and hands to determine the ages of the juvenile victims (Warren et al. 2000). The radiographic interpretations helped isolate and seriate the hands of these victims, a majority of whom were identified based on their age. Radiographic identification based on unique skeletal features seen in postmortem radiographs has been applied by anthropologists in other disasters and is a common technique for positive identification (Lichtenstein, Fitzpatrick, & Madewell 1988; Kahana et al. 1997; Saul & Saul 2003).

With the creation in the United States of the Disaster Mortuary Operational Response Team (DMORT) in the early 1990s, anthropologists became key personnel in forensic disaster response (Sledzik & Willcox 2003). DMORT is a federally supported team of mortuary personnel and forensic experts, including pathologists, radiologists, odontologists, and anthropologists, who are trained in disaster-victim identification and mass-fatality management. Anthropologists have deployed with DMORT teams to multiple disasters over the years, including the bombing of the Oklahoma City Federal Alfred P. Murrah Building in 1995; the 1997 crashes of Korean Airlines 801 in Guam and Comair Flight 7232 in Michigan; the 1999 Egypt Air Flight 990 crash; the Alaska Air Flight 261 crash in 2000; and the crash of Flight 93 in Shanksville, Pennsylvania, on September 11, 2001 (Sledzik 1996; London et al. 2003; Saul & Saul 2003; Sledzik & Willcox 2003; Filippi 2007; Sledzik & Kauffman 2008). Similarly, the Interpol Disaster Victim Identification teams (DVI) are composed of forensic specialists and law enforcement personnel from member countries. Interpol DVI responds to fatality events in most countries around the world, whereas DMORT responds only within the United States.

The events of September 11, 2001, presented an unprecedented challenge for forensic scientists and marked an important change in the anthropological role in disaster response (Sledzik et al. 2009). Taphonomically, fragmentation and commingling posed anthropological challenges in recovery and analysis. These factors, coupled with the large number of incomplete skeletal remains, necessitated anthropologist's emergence as directors of victim identification teams, quality control managers, morgue managers, coordinators of long-term identification efforts, and even stewards of the unidentified and unclaimed remains in the New York City 9/11 memorial museum (London et al. 2003; Rodriguez 2003; Sledzik et al. 2003; Warren et al. 2003; MacKinnon & Mundorff 2007). Their efforts highlight the capabilities of forensic anthropologists as broadly trained experts in human identification who can manage complex human identification events.

Two unique applications of anthropological involvement in mass-fatality identification took place during the World Trade Center human identification operation (Budimlija et al. 2003; Wiersema et al. 2003; Mundorff et al. 2014). The immense administrative effort of managing the data related to more than 20,000 fragments of human remains, coupled with the tremendous destructive nature of the disaster, resulted in commingling, DNA cross-contamination and procedural errors. Evidence of procedural errors included inaccurate or missed data in the post mortem case file, misnumbering, and incorrect and inaccurate data entry. To resolve these problems a quality control project referred to as "anthropological verification" was created. The process required the reexamination of all unidentified specimens and their associated case file information. After a comprehensive reanalysis of 16,969 cases (from a total of 19,963 cases), the anthropology team identified 75 potential cases of commingling (0.044%). Additional DNA testing revealed 24 cases that were truly commingled leading to both new identifications and new associations between previously

unassociated remains (Mundorff 2012). Following the South East Asian tsunami (a similarly chaotic DVI operation), a “Final Inventory Protocol was also undertaken at the mortuaries to re-examine unidentified victims in an attempt to detect errors, collect additional data, and validate existing information” (Wright et al. 2015: 97).

The second unique anthropological application comprised another quality assurance review. However, the focus of this program was on identified cases. A final anthropological review was designed and implemented by anthropologists to ensure the certainty of identification and reduce the possibility of a misidentification. Each time a new identification report was issued, usually by DNA personnel, a final anthropological review of the identified remains was undertaken to confirm the biological attributes of the remains were congruent with the identification and the information in the victim’s case file. The remains were then compared to other remains identified from the same individual, to look for duplication or other inconsistencies in the set of remains belonging to that individual. Problems were resolved by using document reviews, additional anthropological analysis, and reanalysis of DNA. MacKinnon and Mundorff indicate that the review was important to “resolve any final and outstanding issues of commingling and contamination, and ultimately provided the opportunity to reconfirm the correlation between the case files, the identification modality/ies, and the physical remains, before final repatriation of the victim occurred” (2007: 495).

Anthropologists were also involved in the two other 9/11 disasters: the operations in Shanksville, Pennsylvania, following the crash of flight 93, and during the identification of remains from the Pentagon (which took place at the Dover Air Force Base port mortuary). Their involvement in the Pentagon response was largely in the analysis of remains. In Shanksville anthropologists were involved in both analysis of remains and the overall mass fatality management efforts, including morgue operations. The anthropologists produced a morgue operations protocol, which formed the basis of the DMORT standard operating procedures.

In 2002 the operator of a crematorium in northwest Georgia chose to bury and dispose of remains sent to his business rather than cremate the remains. Hundreds of bodies, in various states of preservation, were located in burial pits, buildings, and vehicles. This scene posed anthropologists with several challenges (Steadman et al. 2008). The complex nature of the site and the condition of the remains required varied approaches to search and recovery. Anthropologists analyzed most of the remains because of advanced decomposition and partial mummification. When family members began to question the authenticity of the cremated remains in their possession, anthropologists again became involved in the analysis.

Anthropologists from the U.S. Army Joint POW/MIA Accounting Command and a private disaster-consulting firm responded to the Asian tsunami of December 2004. The dual role of the anthropologist was again implemented, as technical experts to assess biological features useful for identification and as coordinators in the identification efforts (Martrille et al. 2006; Tyrrell et al. 2006). Following Hurricane Katrina in 2005 anthropologists with DMORT served again in these dual roles (Fulginiti et al. 2006). In 2009 anthropologists working with the Armed Forces Medical Examiner’s System, DMORT, and a private university assumed lead roles in the field and mortuary, contributing to the overall scientific identification process, recovery operation, and management of the victims of the Colgan Air Flight 3407 crash (Steadman et al. 2014).

Providing information to family members of disaster victims has also developed as a relatively new area for anthropologists in North America (Mundorff & Steadman 2003; Sledzik et al. 2006), although forensic anthropology practitioners in South America have a long history of interaction with family members (see Fondebrider, Chapter 6). Family members often express concerns about the condition of remains and the process of identification (Blakeney 2002; Levin 2004). For example, when victim remains are fragmentary or skeletonized, it is not uncommon for family

members—before organizing funeral arrangements—to inquire about the “portion” of remains that have been identified. They may want to know whether certain body parts have been identified, and, if not, they may choose to wait. More often the questions focus on “how much,” or the percentage of the body that has been identified, when family members are deciding whether to wait or move forward. Using a skeletal diagram instead of photographs, anthropologists can easily illustrate presence/absence and explain the condition of the remains. Fragmentary, decomposed or otherwise compromised human remains can be difficult to identify in a photograph and may be disturbing to family members expecting to see recognizable features. Forensic anthropologists doing this work must be able to provide factual information about taphonomic and identification concerns in a compassionate manner.

Managing Concerns of Family Members

Disaster victim identification takes place for two reasons: legal and humanitarian. Victims need to be identified because of legal requirements such as issuance of death certificates, settlement of wills and insurance claims, and remarriage. The legal reasons underlie the humanitarian reasons: the empathy and compassion that compel us to aid those affected by a disaster.

The term *family assistance* defines a set of standard practices supporting the unique needs of family members of those killed or injured in disasters. Family assistance differs from traditional disaster services (which encompasses the delivery of food, water, shelter, medical care, and similar needs). Although family members of the deceased and injured may need this support, they also seek information about the victim or injured person. Family members of deceased victims often have questions about the search, recovery, and identification of remains, the cause of the disaster, and the return of personal effects (Eyre 2002). Family assistance support models create a structure whereby family members can receive accurate and timely answers to their questions.

In the United States a primary focus of family assistance was the passage of the law entitled the Aviation Disaster Family Assistance Act of 1996. The law requires the National Transportation Safety Board to coordinate the resources of the federal government, the airline, the local authorities, and identified organizations to meet the needs of aviation disaster victims and their families (United States National Transportation Safety Board 2000). The support families receive often encompasses travel to and from the accident site, lodging, informational briefings (including information on victim recovery and identification), mental health counseling, site visits, memorial services, and long-term information sharing (Slater & Hall 1997). This model of family assistance has been applied to other transportation accident modes and terrorism bombings in the United States and the United Kingdom.

To inform family members about the topics of search and recovery of remains and the process of victim identification, regular, open meetings may be held, attended by family members, their representatives, and family-group liaisons. The medical examiner or coroner (or their representative) is often involved, to provide daily, weekly or even monthly (depending on the length of the operation) updates on all aspects of the process. In New York City additional human remains were discovered near Ground Zero almost five years after September 11, 2001, initiating a second recovery operation. Since jurisdiction over excavations had been transferred to the Medical Examiner's Office, anthropologists were then responsible for recovery and therefore also assumed responsibility of leading the family meetings, which had continued since September 2001. Families with deceased relatives deserve frank and compassionate discourse from forensic responders. Although families are involved in the identification process by providing antemortem information, they must also make

decisions about death notification, final disposition, and other concerns related to the remains of the deceased. For example, in cases where multiple fragments from one individual may be identified over a lengthy period, families choose how often they wish to be notified of identifications (initially or each time an identification of the victim is made) and when the remains will be provided to them for final disposition.

In nearly all disasters resulting in disrupted remains, not all fragments are identified. The medico-legal authority must inform family members of the presence of group remains and work with the families to decide on a plan for final disposition. If families cannot decide, the medico-legal authority takes action under the jurisdiction's laws to dispose of the remains.

Anthropologists are well suited to understand the complex issues related to the condition of remains, the desire of family members, and the technical limitations of the identification sciences. The cultural, social, and scientific implications of this work are reflected in a series of questions often asked early in a disaster response. The questions are asked of, and by, forensic scientists, family members, and society and examine how remains are identified, the extent to which science should go to identify them, and expectations about what is provided to the family for final disposition. Although these questions are not unique to disaster work (Williams & Crews 2003) they do require careful consideration and public and professional discourse. Among these questions:

- Should the limited resources available to conduct identification be used to identify all fragmentary remains or all victims?
- How large does a specimen need to be for testing?
- Should every specimen be analyzed and tested for DNA?
- What if a specimen is identified by DNA yet is consumed entirely in testing?
- At what point does the identification process end?
- Should remains recovered years after a disaster be processed for identification?
- What should be done with unidentifiable remains?

Forensic scientists endeavor to apply all applicable technology to identify the disaster dead. Often, in the first days following a disaster families expect that identifications will happen quickly and that whole bodies will be returned. The process of making their expectations more consistent with the taphonomic reality of the disaster is difficult but necessary if families are to truly understand the reasons behind the answers to these questions. Answers to these questions are dependent on the particulars of the disaster, desires of the family members (individually and as a disaster-specific group), cultural beliefs about death and final disposition of remains, societal expectations about what science can provide, and the availability of appropriate forensic identification tools and techniques (Pan American Health Organization 2004).

Effects of Disaster Work on Anthropologists

Forensic disaster responders work in a highly stressful, challenging, chaotic environment. The disaster environment poses challenges to all responders, and the stress of handling the dead is unique (Ursano & McCarroll 1990). Although disaster forensic work is physically and psychologically demanding, forensic scientists often overlook the effect of these stressors. Early studies by disaster mental health researchers focused on the psychological effects of body recovery and morgue work on inexperienced, nonforensic personnel. Recently this research has expanded to examine experienced forensic responders, with a particular focus on forensic dentists (McCarroll et al. 1996; Webb, Sweet, & Pretty 2002).

Research examining the physical and psychological impact of mass-fatality work on experienced forensic personnel reveals several interesting points. In general, experienced forensic responders managed the physical and psychological stresses of mortuary work more effectively than did inexperienced responders (for example, Wright 2010). The anticipation of mass-fatality work leads to psychological and physiological stress, although experience reduces the amount of anticipatory stress. Mortuary workers reported an increase in somatic symptoms (such as nausea, chest pains, fainting, and weakness) during and after working in the disaster morgue (McCarroll et al. 2002). The condition of the victim's remains, particularly aspects of visual grotesqueness, odor, and tactile features, is considered a stressor. Working with the remains of children is significantly stressful. Identifying or personalizing with the victims increases emotional attachment to the remains, may reduce objectivity, and may increase vulnerability to psychological distress (Wright 2010). Handling personal effects has also been shown to be difficult for mortuary workers (Ursano & McCarroll 1990).

In a study of the psychological stress encountered by experienced and inexperienced forensic dentists who identified victims following the Branch Davidian event, McCarroll and associates (1996) found that about half reported psychological reactions that included anxiety beginning before the work, difficulty working with the remains of children, and stress dealing with the chaos of the identification process. The stress was significantly related to the amount of exposure to the remains, previous experience in mass-fatality events, age, and the level of coworker and spouse support.

The most effective coping strategies are the use of humor and the opportunity to talk with colleagues involved in the disaster response. Indeed, the onsite and postdisaster camaraderie was an important source of positive feelings about a disaster response (Webb, Sweet, & Pretty 2002). Forensic responders also reported that, despite the stress, assisting in the response was a valuable experience, provided a sense of accomplishment, and increased their appreciation of life.

Conclusion

Although cultural anthropologists have examined the behavioral, organizational, economic, and other cultural responses of humans to disasters (Hoffman & Oliver-Smith 2002) they do not often delve into the treatment of deceased resulting from a disaster. The complex cultural questions arising from dealing with the realities of victims of disasters are often overlooked: search, recovery, identification, management, familial grief, societal grief, memorialization, and recovery. Forensic anthropologists, with their broad training in many of these areas, are ideally suited to take on the study and management of these complex topics.

This new application of the field has begun. Forensic anthropologists employed in medical examiner offices and law enforcement laboratories in the United States are taking on the responsibilities of mass-fatality planner as an additional responsibility beyond their casework. This activity is a logical extension of the daily casework and a trend underscoring the important application of broad anthropological training in human identification. Anthropologists in other parts of the world, such as those working for the Pan American Health Organization (PAHO), the International Committee for the Red Cross (ICRC), country specific INTERPOL DVI teams, and the World Health Organization (WHO), are making significant contributions to the publications focusing on managing victims of disasters (Morgan et al. 2006; Tidball-Binz 2007; Kahana & Hiss 2009; Mundorff et al. 2015).

Similar forensic and management concerns affect forensic anthropologists involved in disaster work and human rights responses. The methods used to solve the problems encountered by each group would benefit from a shared approach. As large-scale, complex human identification efforts, both require broad knowledge of forensic science, an ability to work within an existing

cultural framework, and balancing family member/societal and scientific concerns about the identification efforts (Williams & Crews 2003). These two groups of practitioners recently began interacting in a comprehensive way, sharing lessons learned and advancing methods for large-scale human identification efforts (London, Parker, & Aronson 2013).

More broadly, however, these new applications of the field highlight the need for the discipline of forensic anthropology to be redefined. A new definition should encompass forensic anthropology as a science that deals with a range of anthropological issues, as well as medico-legal questions. Such a definition would include applications of other fields of anthropology and would allow for a broader understanding of human interaction with the environment (physical, social, cultural, and linguistic) and resulting medico-legal interpretations. From the perspective of disaster response, forensic anthropologists will continue to take on responsibilities that go beyond the technical requirements of remains identification and delve into the management of the scientific response, interactions with family members, and the needs of society to understand the complex issues of disaster victim identification.

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Medico-Legal Investigation of Atrocities Committed during the Solomon Islands “Ethnic Tensions”

Melanie Archer and Malcolm J. Dodd

Fifty exhumations and autopsies were conducted in the Solomon Islands between 2003 and 2006 as part of the medico-legal investigation into the “Ethnic Tensions” murders. This investigation was unusual for two main reasons. First, all autopsies were carried out by one Australian forensic pathologist (Dodd) over the course of several visits to the country. Second, most gravesites were accessible to exhumation teams only by air or sea, and this situation created significant logistical challenges. Difficulties were exacerbated by a need for rapid results to use to charge alleged perpetrators—partly because some former militants were a flight risk while at liberty but also because swift criminal indictment demonstrated to the traumatised community that positive results could be achieved. The operations were ultimately successful, with over 50 former militants having been arrested by April 2004 (Wainright 2004).

The Ethnic Tensions (1998–2003) was a brutal conflict that received scant media attention. This civil war centred on Guadalcanal Island (Figure 33.1) and was predominantly between the people of Guadalcanal (Guales) and the neighbouring Island of Malaita. Fractiousness between these people has been recorded since colonial times (Fraenkel 2004), but the recent Ethnic Tensions caused economic and political chaos for the Solomon Islands, because its capital city, Honiara, was engulfed in the turmoil.

The influx of Malaitans onto Guadalcanal following World War II was a major step in the evolution of the recent troubles. A large United States military base was established in Guadalcanal during the South Pacific campaign, and Honiara became the capital. Malaitan settlers were among those exploiting its postwar economic and employment opportunities, and many acquired land, which often contravened Guale customs of matrilineal land inheritance and tribal land ownership. Additionally, many Guales felt that their power base was eroded by Malaitan domination of various institutions. For example, by 1998 Malaitans accounted for approximately 75% of the Royal Solomon Islands Police Force (RSIP). Immigrants also held many jobs in Honiara and occupied many surrounding residences (Dinnen 2002; Fraenkel 2004).

In 1998 tensions between Guales and settlers escalated, and a clandestine Guale militia organisation, the Guadalcanal Revolutionary Army, began evicting migrants (mainly rural Malaitans). The pro-indigenous movement later split into factions, the most notorious of which was Harold Keke’s Guadalcanal Liberation Front (GLF). A Malaitan opposition group, the Malaita Eagle Force (MEF), eventually formed under the leadership of Jimmy “Rasta” Lusibaea.

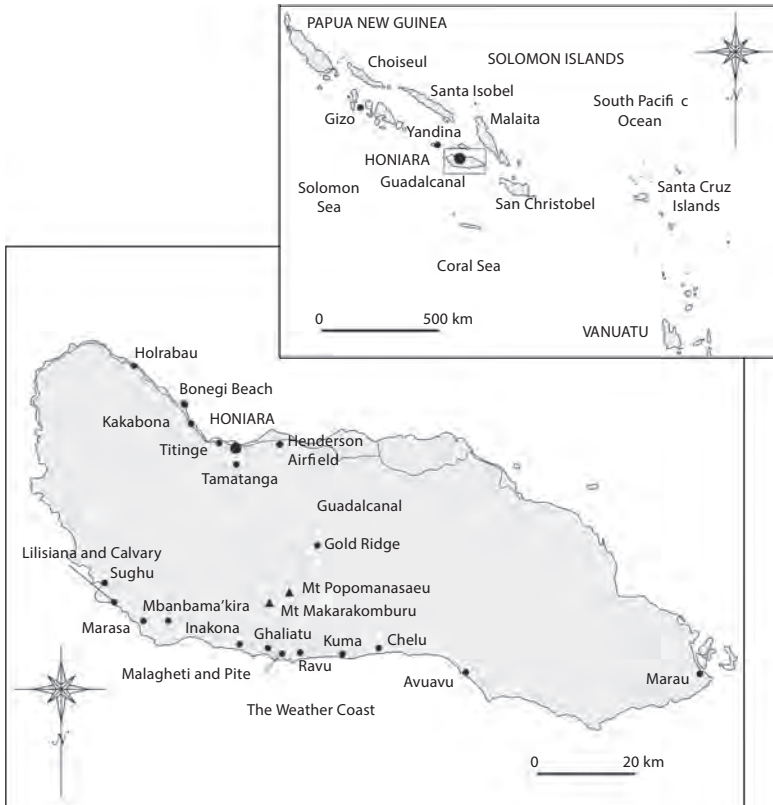


Figure 33.1 Map of the Solomon Islands showing Guadalcanal in detail

Honiara became the MEF's stronghold, whereas pro-indigenous groups held rural areas such as the remote Weather Coast. The Tensions culminated in the MEF-led coup on June 5, 2003, and international intervention was requested by the Solomon Islands Parliament following the Prime Minister's forced resignation (Fraenkel 2004).

Approximately 100 fatalities resulted from the Tensions (Anonymous 2003; Fraenkel 2004), and thousands were internally displaced and terrorised before the first contingent of the Regional Assistance Mission to the Solomon Islands (RAMSI) arrived on July 24, 2003 (Fraenkel 2004). Member countries comprised Australia, New Zealand, Papua New Guinea, Samoa, Fiji, Vanuatu, Kiribati, Cook Islands, Nauru, Tuvalu, and Tonga; these countries initially provided among them 2,225 police, military, and other personnel (Anonymous 2003). The end of the Tensions was swift and bloodless following RAMSI's commencement, but the Operation is still active and now mainly concerned with capacity building and tackling official corruption.

Another of RAMSI's main aims is to prosecute perpetrators of crimes committed during the lawless Tensions period. A proportion of the offences were murders for which RAMSI investigations have yielded detailed witness statements and victim grave locations. Therefore, exhumations and autopsies of 50 victims were undertaken to verify witness statements, provide victim identifications, and determine cause and manner of death. This process began two months after RAMSI arrived, and the initial murder trials in the Honiara High Court (Guadalcanal) have already resulted in life imprisonment for several key militants.

Exhumation Protocol

The remoteness of most exhumation sites necessitated air or sea travel, and few exhumations were conducted close enough to Honiara to utilise road travel. There are no vehicular tracks to the Weather Coast, so a combination of helicopters and Short Take Off and Landing aircraft (Caribous and Twin Otters) was used to transport equipment, personnel, and human remains. A naval ship was also once used to travel from Honiara to the Weather Coast, with helicopter transfer to land. These specialised transport needs presented a challenge, because exhumation teams were competing for air support with personnel from other RAMSI sections. Tight drop-off and pick-up schedules were therefore necessary, and teams often had to extract bodies within six hours. An additional requirement for speed was the risk of unpredictable tropical downpours flooding exhumation sites.

There was a high degree of consultation with the local people before each exhumation, although they were not directly involved with body extraction. Local ministers of religion were also invited to conduct ceremonies at several graves before exhumation. Villagers were predominantly relied on to locate remains, because graves were usually dug by them after militants abandoned the bodies of their victims. Even when murderers buried their victims, this was often done within several hundred meters of villages and in full view of witnesses.

Most exhumations were led by an Australian and New Zealand Police Disaster Victim Identification (DVI) team, and the remainder were led by police investigative and crime scene personnel. An experienced anthropologist/archaeologist was not included with the team for unknown reasons, perhaps partly because of the relative novelty of the discipline in Australasia and a corresponding unawareness of the valuable contribution that anthropologists can make to body recovery. The forensic pathologist fulfilled one major role of the archaeologist by attending gravesites where extensive commingling of remains was expected. Most remains were relatively easy to extract from the surrounding soil without archaeological expertise, which was especially true of those enclosed within wrappings. However, an archaeologist prepared to work under the necessary time constraints could possibly have further increased the pace of some exhumations and probably would have been able to prevent the single case of exhumation fracture that damaged one victim's skull. This unfortunate accident was due to the inexperience of a DVI team member in distinguishing skeletal elements from the surrounding soil and detritus.

Autopsy Protocol

The first three Ethnic Tensions autopsies were performed at Weather Coast gravesites using trestle tables and tents as a makeshift mortuary. Despite the rudimentary nature of the setup basic autopsy technique was applied, including detailed photography. Remaining cases were examined at the Honiara National Referral Hospital mortuary (Guadalcanal).

Remains were classified as “decomposing” if $\geq 60\%$ of soft tissues was present and “skeletonised” if $< 60\%$ of soft tissue was present. All cases had focal areas of skeletonisation and varying degrees of disarticulation; several also had focal areas of mummification or adipocere (the insoluble fatty acids remaining as a residue from pre-existing fats following decomposition). Autopsy technique was therefore somewhat flexible to accommodate these differences. There was no radiographic equipment available, so extra time and care were necessary to locate metallic ballistic evidence.

Bones were placed in buckets of water and cleaned if they were relatively devoid of soft tissues. When skulls were washed, care was taken to avoid loss of teeth and cranial fragments. Bones were then dried, reassembled to anatomical position, and photographed. Traumatized skeletal elements were placed on white paper and injuries clearly annotated with marker pens prior to photography.

Victim Identification

DNA samples were taken from the femoral head and teeth, and these were processed at the Australian Federal Police laboratories. Skeletal indicators of identity were of limited value in distinguishing individuals: all victims except one were male, all were Melanesian, and most were between 20 and 30 years old and of a similar stature. In addition, healed fractures were found in only two cases, and no medical prostheses were recovered. Odontological methods were similarly unhelpful in most cases, since only two victims had evidence of dental treatment. There were no distinctive dental features, such as diastemas, although four cases of periodontal disease were seen that could potentially have caused enough pain that associates of the victim may have been aware of their condition.

No identifying documents or cards were located, which is unsurprising given that the majority of people are rural subsistence farmers. But hairstyles are distinctive in the living population, and, in particular, there are many combinations of dreadlock configuration and length. Dreadlocks were commonly preserved intact on decomposed bodies and were therefore an excellent feature on which to base putative identifications.

Clothing was usually light because of the tropical climate and was often remarkably well preserved. T-shirts usually bore distinctive logos and designs that sometimes allowed establishment of a putative identity. Some groups of victims also wore similar clothing, which grouped them as casualties of particular incidents. For example, seven priests from the Melanesian Brotherhood were murdered (six in one incident), and these men wore a distinctive uniform supplied by a single clothing company. Jewellery and property were also helpful putative identifiers, and either or both were present in 56% of cases.

Decomposition and Burials

All 50 individuals had been buried. The majority (52%) were in beach graves <50m from the beach front. Beach sand at most grave locations is coarse and wet, with a layer of pebbles beginning at approximately 50–100cm deep. Graves were seldom dug below this level—probably because pebbles are difficult to dig through, and grave edges collapse beneath this depth. Thirty-six percent of cases were jungle burials ≥50m from the beach front. Jungle soil is humic, and extensive networks of tree roots hinder digging. There was also heavy bone erosion in the jungle environment, especially in thin areas such as scapulae; this postmortem change was sometimes hard to differentiate from trauma. Only 12% of cases were buried in village cemeteries; one in a coffin and the remainder with or without fabric wrappings. Cemetery graves were sometimes marked by planting coconut trees at the head and foot of the body. Tree roots grew throughout several skeletons, even penetrating the cortex of some bones and holding others in anatomical position.

There was more than one victim in 57% of "killing incidents," defined here as a militia killing (or killings) in the same village or municipal location on the same day. However, 61% of graves were single, which probably arises from the high number of graves reportedly dug by people not involved with the killings and who knew the victims. But the high number of single graves may also be due partly to the comparative ease of digging single graves (especially in loose beach sand), as opposed to pits large enough to accommodate multiple bodies. Most remaining graves were double and triple burials, although there was one mass grave containing eight of ten mercenaries who journeyed to the Weather Coast to capture certain GLF commanders. Commingling of skeletal elements between bodies was seen in 42% of cases, which is the majority of bodies buried in multiple graves.

Many variables are likely to have affected decomposition rate: postmortem interval; antemortem trauma; initial body mass; rainfall, clothing; wrappings/coverings; grave depth;

soil type; soil moisture; number of bodies in the grave; and degree of decomposition before burial and type of overlying vegetation. Evidence of scavenging was seen in 30% of cases; scavenging may also have affected decomposition rates (local scavengers include pigs, dogs, birds, cats, and rodents). The combined effect of variables that affect decomposition produced amazing differences in the state of remains of the same age, burial type, and even within mass graves (Figure 33.2). Therefore, postmortem interval was a poor predictor between about six months and two years of whether a body would be decomposing or skeletonised (see Figure 33.2). Indeed, graves dug within the same month, and within metres of one another, could contain a mixture of decomposing and skeletonised bodies.

Potential ligatures were associated with 44% of remains and were predominantly around the wrists and arms; no potential blindfolds were located. In one case a loop of material encircled the left lower thigh in the region of skeletal gunshot damage and may have been a tourniquet rather than a ligature. Several individuals had multiple unconnected ligatures encircling areas such as the wrists and waist, and two victims were bound together at the ankles. The material from which ligatures were fashioned was variable: rope, vine, cloth, wire, and fishing line were all used.

Injury Patterns

Most victims sustained blunt-force trauma combined with gunshot trauma; however, exclusive blunt or gunshot trauma was also common (Table 33.1). Sharp-force trauma was rarely seen, which may have been because soft-tissue defects had decomposed. But our figures (Table 33.1) may be accurate, because there were correspondingly few witness reports of sharp-force trauma being inflicted.

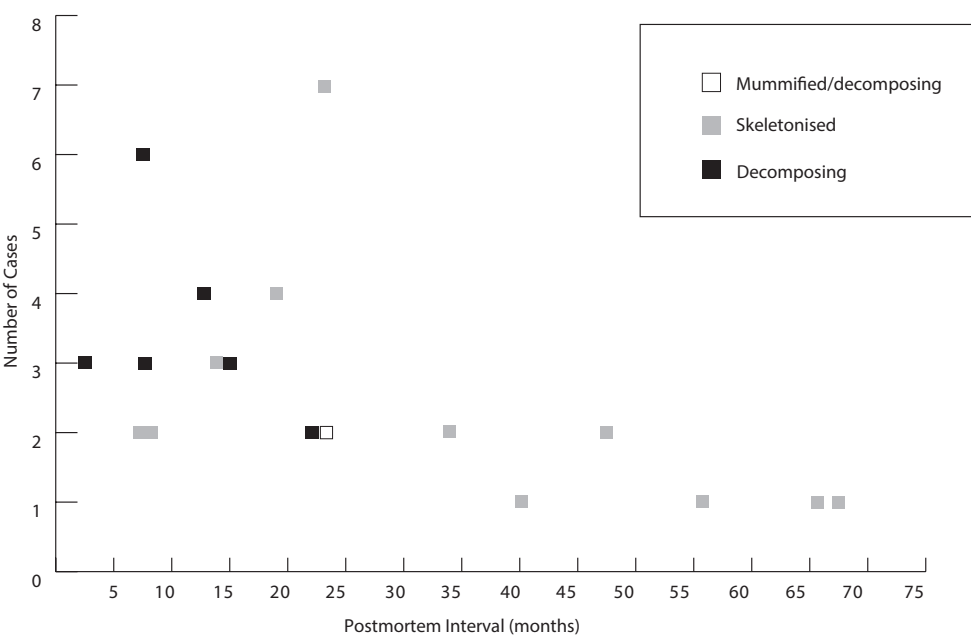


Figure 33.2 Number of cases in each decomposition category for Ethnic Tensions victims medico-legally examined by RAMSI (*n* = 50)

Table 33.1 Patterns of injury sustained by victims of Ethnic Tensions murders medico-legally examined by RAMSI. Numbers of individuals ($n=50$) sustaining each type or combination of trauma are given, along with % of cases in each category.

<i>Gunshot Trauma Only</i>	<i>Blunt Trauma Only</i>	<i>Combined Gunshot and Blunt Trauma</i>	<i>Combined Gunshot, Blunt and Sharp Trauma</i>	<i>Combined Blunt and Sharp Trauma</i>
12 (24%)	13 (26%)	22 (44%)	1 (2%)	2 (4%)

Gunshot Trauma

Thirty-five victims sustained at least one gunshot injury, although, because of decomposition, only the minimum number of gunshot wounds could be determined. In all gunshot cases ballistic trauma would have been sufficient to cause death, and police information indicates that modern military-style weapons were generally used (for example, SLR and SR88 A semiautomatic assault rifles).

Gunshot trauma to the thoracic and abdominal skeleton was usually differentiated with ease by morphology and extent from other forms of trauma. Rib fractures caused by gunshot injury were often of the shatter type, rather than linear, vertical, or oblique. Incomplete circular defects on rib margins caused by projectile transit were additionally present in three cases. Similarly, pelvic gunshot trauma was of the extensive shatter type, rather than the relatively clean curvilinear fractures seen in low-grade blunt-force trauma.

Projectile entry points were concentrated around the head and torso, and few cases of gunshot injury to the limbs were seen. In 46% of gunshot cases the presence of coexistent blunt trauma strongly suggested that beating accompanied the shooting. Witness statements support the proposition that many of these fracture patterns represent a form of menacing or torture before execution by gunshot.

Cranial gunshot cases incurred massive fracture with the shatter patterns typically caused by the passage of high-velocity projectiles. Clear internal and external bevelling was seen in some skulls, and most displayed fracture and dissociation of the cranial plates with the characteristic pattern of symmetrical facial skeletal separation. This pattern is the hallmark of rapidly expanding cranial contents.

The trajectory of fire could be reconstructed in some cases and was most striking for a group of mercenaries allegedly killed by the GLF. Witnesses claim that the men were lined up on the beach with their backs to the ocean and that their executioners stood facing the victims, elevated above them on a sandy shelf. Bullets had passed from the frontal chest to the dorsal lumbar structures in several bodies examined, which could occur only if the shooter was elevated above the standing victim or if the victim was hunched or leaning forward before a standing shooter.

Most high-velocity jacketed military-style projectiles should exit the body, leaving only shattered skeletal elements. But in 15 gunshot cases ballistic evidence was recovered. In 5 cases deposits of friable blue-green material that represented oxidised bullet jacketing were present. These were carefully differentiated from brass studs and degraded green clothing, which can appear similar. Surprisingly, 10 cases also yielded large uncorroded bullet jacket and core fragments, and 3 cases retained largely intact projectiles. Projectile remnants were sometimes deeply embedded in bone but were also located in decomposed soft tissues or soil contained within body bags. A further 2 cases had NATO 7.62 short-cartridge cases contained within debris in the body bag, which highlights the need for meticulous examination of detritus accompanying remains.

There are possible explanations for the high percentage of cases that retained ballistic evidence. First, much of the high-velocity ammunition used by the GLF and IFM was obtained from World War II underground stock piles. Police investigators reported to us that this ammunition was unreliable, with misfires being common: not only can the casing of ammunition corrode as it ages, but the propellant can degrade. Second, some militants also used weapons of World War II vintage that are likely to have become unreliable, and some may also have used homemade weapons (Fraenkel 2004). This combination of factors can reduce muzzle velocity of projectiles and cause instability in trajectory, which would result in a high retention rate within bodies.

Blunt Trauma

Blunt-force trauma was most commonly inflicted in the thoracic region (58%), followed by the head and neck (32%). Definitely lethal blunt-force trauma to the head was identified in only two victims, who had both sustained massive occipital fractures. In the 14 cases where blunt force was thought to be the leading cause of death, analysis of injury patterns strongly suggests a bias toward repeated and aggressive thoracic trauma.

Thoracic trauma involved predominantly the ribs, although complex and often depressed fractures of the manubrium and/or sternum were documented in 14 cases. Sternal fractures are frequently present in victims of high-velocity motor vehicle accidents but rarely result from beatings. At least one rib fracture was present in 70% of remains, probably due mainly to blunt trauma. Two victims suffered clavicular fractures (one bilateral), and six victims suffered scapular fractures (two bilateral). These injuries again probably represent blows with sticks and gun butts, as was frequently recorded in witness statements.

Most blunt-force trauma deaths were probably caused by extreme compressive forces applied to the anterior chest, with or without intercurrent blows to the lateral rib cage. In these cases extensive bilateral rib fractures (often resulting in flail segments) were identified. The most common fracture plane was lateral, followed by posterior and anterior, and this pattern is typical of forceful front to back compressive force. Two potential mechanisms derived from witness reports could be stomping and dropping rocks onto the chests of victims. Death would be caused by a combination of lung collapse following puncture by broken ribs, haemopneumothorax formation (air and blood in the chest cavity), and cardiac contusion and/or laceration.

Analysis of fracture frequency for individual ribs shows virtual sparing of the well-protected 1st and 2nd ribs, and complete sparing of the small and flexible 12th rib (Figure 33.3). Maximal trauma involved ribs 4–9, often in multiple planes, and a bilaterally symmetrical pattern was frequently seen. In some cases focal aggregates of fracture were also seen on the lateral rib cage, often involving three to four sequential ribs, indicating areas of kicking or striking.

Blunt trauma involving the middle one-third of the face (four cases) and mandible (seven cases) further indicated that blows to the face may often have been delivered before the victim's death by crushing the chest. In one case few injuries were identified apart from two rib fractures overlying the spleen. Witnesses report that the victim became very thirsty before he collapsed and died, indicating that death was probably due to splenic rupture and internal blood loss. Ruptured spleen is a particular risk in malaria-ridden countries, where splenomegaly is common. Dodd autopsied a recently deceased murder victim in the Solomon Islands (unrelated to the Ethnic Tensions) who had similar injuries; she was kicked in the ribs, resulting in rupture of her grossly enlarged spleen and internal loss of approximately 2 L of blood.

Pelvic fractures were seen in only two cases, probably because the pelvis is largely protected by overlying fatty tissue and deep musculature. One victim had an uncomplicated pelvic

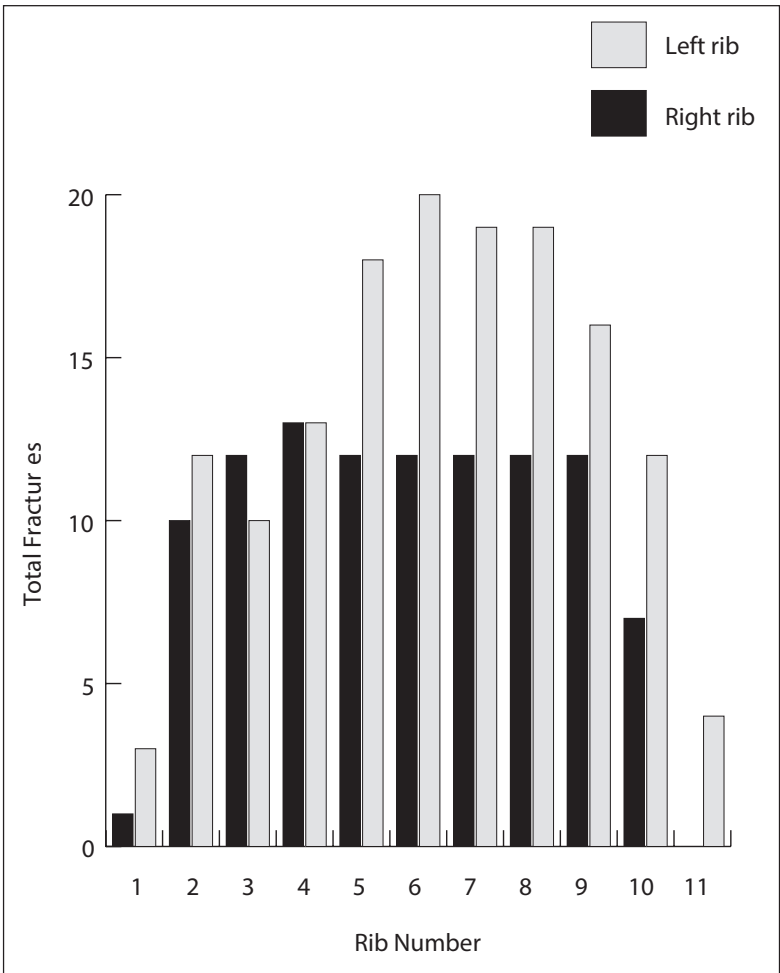


Figure 33.3 Distribution of fractures over the ribcage for cases examined medico-legally by RAMSI. Values are numbers for each rib of victims who sustained at least one fracture to that rib.

fracture, perhaps from a kick or gun butt blow, and this injury was coupled with repeated chest trauma. The second case (see the following case of the Honiara Murder) was attributed to motor vehicle impact.

Blunt trauma to vertebrae, often with bone loss, was frequently seen in combination with repeated thoracic trauma. Seven victims demonstrated spinal trauma involving 13 separate vertebrae between them. Maximal trauma extended from T5–T10, again in keeping with kicking or blows from a gun butt. It is impossible to determine exactly how these injuries were caused, but this segment of the spine is prominent if a defensive foetal posture is adopted.

Blunt trauma to the extremities was seen in four cases and was restricted to the upper arm, forearm, and hand. In each case these injuries were combined with blunt-force trauma to the chest. A higher incidence of defence-type injury to the upper limbs may be expected in cases of repeated blunt-force assault, but the paucity of injuries to the extremities may be explained in two ways. First, there was a high incidence of ligature binding (either of the limbs themselves or

the binding of the victim to an object, such as a tree). Second, many victims may quickly have been immobilised through loss of consciousness.

Sharp-Force Trauma

Sharp-force trauma was identified in three victims only, which is in stark contrast to atrocities in East Timor, where blows by jungle knives and machetes were recorded in 43% of deaths investigated (Pollanen 2003). One victim was allegedly struck with a machete across the upper right back/shoulder area (see the following case of the Marasa Village Incident). This wound involved soft tissue only, and according to witnesses it constituted part of the torture phase before death. Another victim, who was reportedly stabbed, had a solitary shaved and incised defect to a single rib. Examination of his T-shirt showed three independent incised defects to the lower anterior chest/upper abdominal area. Two of these defects did not correspond with skeletal trauma, so were deemed to overlie soft-tissue trauma obscured by decomposition.

Case Studies

In these two case studies, victims' names are coded for privacy. These are not the most horrific incidents investigated but demonstrate some typical pathology and illustrate aspects of investigative methods.

Marasa Village Incident

A Joint Operations Group (JOG) of collaborating militants and police operated on the Weather Coast in 2003 attempting to capture GLF leaders. On June 15, 2003, two boats were sent to Marasa village by the RSIP to reprovision JOG members further inland. Their radio communications were allegedly intercepted by the GLF, who gained information about the landing of the resupply party and ambushed them while they were unloading their boats. An RSIP Special Constable (victim F3) was allegedly shot dead while attempting to start the boat's outboard motor. The remaining JOG forces and resupply party fled, and the body of F3 was taken to Sughu village and buried by locals. The body was wrapped in a tent and buried in a beach grave approximately 175 cm deep.

Two local villagers (F1 and F2) were captured on June 16, 2003, by the GLF. Victim F2 was a former RSIP Special Constable, and F1 was a teenager who had been accused by the GLF of being a government spy. The two victims were allegedly tortured, humiliated, and beaten until their deaths some hours later. Money delivered by the resupply boat to pay JOG members was seized, and some was allegedly torn up and rammed down the throats of F1 and F2 with a stick. RAMSI forensic officers found numerous fragments of material that appeared to be Solomon Islands bank notes under the stones on Marasa Beach in September 2003.

Over 400 villagers were abducted along with F1 and F2 and forced to watch the entire incident, but they were instructed to refrain from showing emotion under threat of death. Most of their village was burned down the day after F1 and F2 died. The hostage villagers were also used to attempt to lure RSIP boat patrols into the area, but the militants did not succeed and eventually abandoned the area. The bodies of F1 and F2 were buried by villagers in a jungle grave approximately 75 cm deep.

The three heavily decomposed victims were autopsied at the exhumation sites approximately three months after death. There were ligatures associated with the wrists of F1 and F2, and both had several nonlethal injuries that corroborated witness statements of prolonged torture. For

example, each sustained blunt-force mandibular fractures, and F2 additionally had a blunt-force nasal bridge fracture and a superficial incised injury to the upper right back, supporting a witness report that he was struck across the shoulder with a machete. F2's oral cavity also had an area of focal swelling and haemorrhage in keeping with the allegation of forceful cramming of paper money fragments into the back of his throat with a stick.

The possibility of mechanical asphyxia following this treatment cannot be excluded, although the cause of death for both victims F1 and F2 was ultimately designated as blunt-force trauma to the chest. Examination of the thoraces of both victims disclosed multiple bilateral fractures, and F2 additionally sustained a sternal fracture. There was accompanying haemorrhage into the upper right anterior, lateral, and posterior intercostal muscles of F1. Death would have resulted from a combination of lung collapse following puncture by broken ribs, haemopneumothorax formation (air and blood in the chest cavity), and cardiac contusion and/or laceration.

Victim F3 was allegedly shot while trying to start the boat's motor, and witnesses reported seeing a plume of blood discharged from the head or neck at the moment of projectile impact. Autopsy revealed a "through and through" defect through his laryngeal cartilage, and the right lateral surface showed a degree of external bevelling. There was also a shatter-like fracture to the medial one-third of the left and right clavicles, and the right 1st rib showed a central shatter-like fracture with complete separation of the lateral and medial halves. A vertically oriented fracture was identified through the manubrium, and there was also bullet jacketing and core associated with the remains.

All injuries to F3 were deemed to have been caused by the path of a single high-velocity projectile through the neck and upper right chest. The projectile is likely to have severed major blood vessels and caused aspiration of blood, asphyxia, and significant internal blood loss. Its trajectory would be in keeping with the stooped and partially rotated position that may be adopted while trying to start an outboard motor.

Honiara Murder

Three RSIP Special Constables were allegedly conveyed to Jimmy Lusibaea's compound on January 26, 2002, because they were believed to have been involved in the killing of several MEF members. Victim W1 escaped but was reportedly rammed by a four-wheel-drive vehicle, after which he continued into long grass, where he was recaptured and shot dead. His body was later recovered from the Lunga River (Honiara), and he was buried within a body bag and a wooden coffin at Titinge cemetery (Honiara City Outskirts). One of the other captive Special Constables was also reportedly killed during this incident, but his body was never found.

W1's remains were exhumed two years after death. The soft tissues had been liquefied by their enclosed environment, and approximately 40 L were retained within the body bag with minimal flesh adherent to the skeleton. Copious ammonia had formed from the liquefied flesh, and fumes were sufficiently strong to require mortuary personnel to take frequent breaks outside. The liquid flesh was sieved, and fragments of bullet jacketing were found. There was also a 6-mm diameter defect through the iliac fossa of the left hemipelvis and a small contralateral conical and ovoid defect representing the point of projectile impact. This pattern indicated that a bullet passed into the pelvis from right to left, impacting and rebounding.

There was evidence of extensive blunt-force trauma as seen after impact with the bumper of an oncoming vehicle. A comminuted fracture accompanied extensive chipping-type bone loss through the body of the left ischium, and the fracture extended over the posterior half of the left acetabulum. There was also a transverse oriented fracture with anterior bone loss of the promontory of the sacrum and a comminuted fracture with extensive bone loss of the left neck of femur.

The cause of death was intra-abdominal/flank high-velocity gunshot wounding in tandem with extreme blunt-force trauma to the left hip (in keeping with motor vehicle impact), and the mechanism of death would have been extensive internal haemorrhage.

Conclusion

The number of Ethnic Tensions victims was relatively small compared with large-scale fatalities in countries with conflict such as Kosovo, Iraq, and East Timor. Witness statements were detailed in most cases and were often given by relatives or associates of the deceased. This information meant that corroboration of witness statements linked to individual victims assumed greater judicial importance than in many large-scale or clandestine killings where such statements are frequently unavailable (for example, Pollanen 2003; Cordner 2005).

There has been considerable success in bringing to justice those responsible for the crimes described here. Many people endured campaigns of terror and intimidation mounted by criminals, and the prosecution of prominent militants has made a significant difference to the community rebuilding process.

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Disaster Anthropology

The 2004 Asian Tsunami

Sue Black

Until relatively recently forensic anthropology was not routinely employed in mass-fatality investigations. Opinion began to change when anthropological expertise came to the fore in the identification of the victims of war crimes and violations of human rights in South America and then in Rwanda (Ferllini 1999), followed in rapid succession by investigations of the atrocities witnessed in East Timor, Sierra Leone, and the former Yugoslavia (Glenny 2000; Komar 2003; Baraybar & Gasior 2004; Steadman & Haglund 2005). Now, as a result of large-scale deaths related to terrorist-related incidents (for example, Bali bombing [see Buck & Briggs, Chapter 35 this volume], 9/11 terrorist attacks, London bombings, and the bombing at Sharm el Sheikh, to name only a few) and natural disasters (for instance, the Asian Tsunami, Hurricane Katrina), the position of forensic anthropology has been more firmly secured within war crimes investigations and global Disaster Victim Identification (DVI) response capabilities (Lain, Griffiths, & Hilton 2003; MacKinnon & Mundorff 2007; Black et al. 2011; Mundorff 2012; Mundorff et al. 2015). Indeed, forensic anthropology continues to be a major component of many national DVI training programs and response capability (Cattaneo 2007; Black et al. 2008; Dirkmaat et al. 2008).

Anthropology has a significant role to play at both a national and an international level in assisting the judicial investigation of homicide, mass disaster incidents, crimes against humanity, war crimes, and genocide (Steadman & Haglund 2005). The context under which many anthropological cases are undertaken has changed during the last decade, owing to a number of factors that have affected not only how forensic anthropologists perform their job but also the types of jobs they are now requested to undertake. Thus it may be argued that viewing the forensic anthropologist as someone who “*deals with the analysis of human skeletal remains resulting from unexplained deaths*” (as defined by Byers 2004; italics added) is somewhat restrictive, given the multidisciplinary nature of the demands of human identification in the 21st century.

This chapter discusses briefly the background of the Asian Tsunami of 2004 and the international disaster victim identification (DVI) response that ensued. The role that different forensic disciplines, including forensic anthropology, played in that disaster scenario is also addressed.

Background

Tsunami is Japanese for “harbour wave.” Japanese fishermen would return to port to find utter devastation in the settlements surrounding their harbor (*tsu*) although they had been oblivious to any impending wave-(*nam*i)-related disaster while they had been at sea.

A tsunami can be defined as a series of waves that is generated by an impulsive disturbance (normally an earthquake, although not exclusively) that displaces a large volume of water. These waves form as a result of the water mass attempting to regain equilibrium, and because water cannot be compressed the energy is dissipated in an outward direction as “shallow-water” waves. The term is somewhat confusing but in fact refers to the ratio between water depth and wavelength. Unlike normal waves, which might have a wavelength of about 91 m (300 ft), a tsunami wave may have a length in excess of 483 k (300 miles).

Waves move at a speed that is equal to the square root of the product of the acceleration of gravity (9.8 m/s^2) and water depth. Because the ratio between water depth and wavelength is very small for a tsunami, it can move at a speed in excess of 805 k (500 miles) per hour, and because of a shoaling effect when the wave reaches the coastline it can grow to over 30 m (100 ft) in height before it breaks land, although the popular concept of a “wall of water” is not always realised. A wave loses energy at a rate inversely proportional to its wavelength, and therefore a tsunami wave can travel at high speeds over prolonged distances for an extended period of time and lose very little of its initial energy before it hits land (Bryant 2001; Lautrup 2005; Tibballs 2005).

Environmental and human devastation occur when the wall of water pushes and floods inland, destroying all in its path through the energy and volume of the water, with most of the damage caused by the large mass of water behind the initial wave front. The sheer weight of the water is sufficient to obliterate most objects in its path, often reducing buildings to their foundations and scouring exposed ground to the bedrock; large objects such as ships can be carried several kilometres inland before the tsunami finally subsides. The destruction continues as the wave then retreats, sucking debris and people back out to sea in the trough in front of the succeeding wave.

Normal waves have a regular periodicity (that is, distance between successive crests) of approximately 10 seconds, but a tsunami wave may have a periodicity of up to an hour. Therefore, there can be a considerable time delay between successive waves of destruction, which can lead to increased fatalities when survivors feel it is safe to go back to their homes to look for other survivors or collect possessions. However, the first wave is not always the most powerful or destructive, and many more lives can then be lost in subsequent waves.

Most tsunamis occur in the Pacific Ocean as a result of the large number of active volcanic island arcs, mountain ranges, and subduction zones (Dudley & Lee 1998). Although the last pan-Pacific tsunami occurred in 1964, many warnings are issued every year for the Pacific Rim (PTWC). This high propensity for tsunamis has led to the development of an elaborate system of early-warning devices by the 26 member states that border the Pacific Rim. However, tsunamis in the Indian Ocean are rare, with the penultimate major event occurring in 1883 as a result of the Krakatoa volcanic eruption. Because of the infrequency of their occurrence there, the Indian Ocean had no early warning capabilities before 2005.

The 2004 Tsunami

At 00:58:53 UTC or Zulu time (07:58:53 local time) on December 26, 2004, an undersea earthquake measuring 9.3 on the Richter scale was recorded with a hypocentre just north of Simeulue Island off the west coast of northern Sumatra (3.316°N, 95.854°E). This has been labelled the “Indian Ocean earthquake” or the “Sumatra-Andaman earthquake,” and it occurred some 30 k (19 miles) below sea level. Approximately 1,207 k (750 miles) of a north-south oriented fault line slipped 15 m (50 ft) along the subduction zone where the India plate passes under the Burma tectonic plate. The rupture proceeded at a speed of over 10,137 kmph (6,300 mph) and lasted over 200 seconds—the longest duration of faulting ever recorded. It took place in

two phases, with the first occurring off the coast of Aceh and the second toward the Nicobar and Andaman islands. Approximately 11 cubic k (7 cubic miles) of water were displaced as the seabed rose by several metres, and a series of tsunami waves radiated out from the entire length of the rupture line. Technically, this was a *tele-tsunami*, because it resulted from a vertical rather than a horizontal displacement of the seabed. The seismic energy release was calculated to be equivalent to 0.25 gigatons of TNT and was sufficient to slightly alter the Earth's rotation—mathematicians have calculated that it may result in a shortening of the day by approximately 2.68 microseconds (Cook-Anderson & Beasley 2005). It was reported that the Andaman and Nicobar islands were displaced to the south west by around 1.2 m (4 ft) and sunk by around 1 m (3 ft) (Science Now 2005).

The North/South orientation of the fault ensured that some landmasses to the north (for example, Bangladesh) remained relatively unaffected as the full brunt of the force was meted out on coastlines to the east and west of the hypocenter as the waves emanated along the full length of the fault-line. Even many of the landmasses that were technically in the shadow of the waves (for instance, the west coast of Sri Lanka) did not remain unaffected, because a tsunami can diffract, producing a “wrap-around” effect.

Variously referred to as the Asian tsunami and the Boxing Day tsunami, it resulted from the second largest ever-recorded seismic event in history, with a periodicity of over 30 minutes between each crest—and the third wave proved to be the most powerful and fatal, arriving a full hour after the first devastation. Eighteen countries were affected around the boundaries of the Indian Ocean—Indonesia, Thailand, India, Sri-Lanka, Malaysia, Myanmar, Bangladesh, Maldives, Reunion Island, Seychelles, Madagascar, Mauritius, Somalia, Tanzania, Kenya, Oman, South Africa, and Australia. Some of the tsunami's energy escaped into the Pacific Ocean and produced small but measurable tsunamis along the west coast of North and South America, and a wave was even registered at Japan's Syowa Base in Antarctica (Japan Coast Guard 2004).

Of the fatalities almost half were in Indonesia (Sumanthipala, Siribaddana, & Perera 2006), with the highest proportion of Europeans killed were tourists in Thailand. The disaster occurred at the height of the Christmas/winter tourist season, and holidaymakers from over 40 countries were involved. Sweden was most heavily affected, with 428 dead and 116 missing. This tsunami was the most devastating in history, claiming the lives of over 250,000 individuals, with a further 40,000 reported missing and millions rendered homeless and displaced. The United Nations Secretary-General at the time, Kofi Annan, stated that this was probably the most expensive natural disaster in history and could take anything up to 10 years to see full reconstruction achieved.

Disaster Victim Identification (DVI) Responses

With regard to the death toll, Indonesia (approx. 220,000), Sri Lanka (approx. 31,000), and India (approx. 16,000) suffered the largest number of fatalities, and over half of the Thailand fatalities (5,395) were foreign tourists (Tun et al. 2005; United Nations Office of the Special Envoy for Tsunami Recovery 2006). Most international DVI teams were not mobilised under the direction of providing humanitarian assistance but were directed by home political direction to facilitate matters of national repatriation. Therefore, over 30 DVI teams from around the world descended on Thailand within days of the event, while the other countries with significantly larger death tolls (Indonesia, India, and Sri Lanka) were largely left to deal with their own dead with little or no international assistance (Perrier et al. 2006). There was a small but temporary international presence in Sri Lanka, but each international team pulled out once all its nationals had been identified (Rutty, Byard, & Tsokos 2005). This situation frequently led to dissatisfaction expressed by the international team members and left indigenous workers no alternative but to

opt for a mass-burial solution with limited attention to identification issues (Perera 2005). In the early days many Interpol DVI teams remained fiercely parochial, focusing their efforts on “finding their own” deceased, which led to some animosity. This approach served to hinder the larger operation, but common sense prevailed largely through good communication and sound diplomacy (Tun et al. 2005).

Not surprisingly, the response to this enormous natural disaster was managed very differently depending on the country (Morgan et al. 2006; Tsokos et al. 2006), and for the most part there was little prior local planning that would assist with the enormity of the operation. This chapter is restricted to the international DVI situation in Thailand, where multinational disaster victim identification teams operated for a complete calendar year.

The Response in Thailand

International teams began to arrive in Thailand around the December 27, 2004, and an agreement was reached with the Thai authorities that the international teams would work in collaboration with the Royal Thai police and the Thai forensic experts. On January 12 the Thai Tsunami Victim Identification (TTVI) centre was established in Phuket. Over 30 international DVI teams worked for nearly a full calendar year to establish the identity of the deceased in Thailand. The teams variably comprised police officers, forensic biologists, fingerprint experts, pathologists, odontologists, anthropologists, radiographers, and mortuary technicians. The British team in the early stages comprised police officers and fingerprint experts and in time would be supplemented with The Centre for International Forensic Assistance (CIFA) odontologists, who would assume the principal identification conduit for the operation.

It was agreed that Interpol protocols and procedures would be adopted utilising the relevant yellow antemortem and pink postmortem forms (Interpol 2015). Antemortem data from families were directed through Consular or Embassy interactions with the Royal Thai Police, and antemortem/postmortem comparisons were undertaken at the Information Management Centre (IMC) in Phuket utilising the Danish Pluss Data computer software.

Initial body recovery in Thailand was a largely uncoordinated event, with the deceased transported to temples on the back of trucks by survivors, local volunteers, NGO personnel, military, reservists, and police. No records were kept of which bodies had been found together or of the location from where the bodies had been recovered. At the temples the bodies were laid out in rows (several hundred at a time), and some temporary shade from the sun was achieved by the erection of makeshift awnings (Figure 34.1). The lack of refrigerated containers in the early stages resulted in a decision being taken by many local authorities to bury the bodies in mass graves in an attempt to lower the temperature and slow decomposition. This action led to inflammatory accusations of attempts to bury bodies without addressing identification issues. An attempt was, however, made to surround many of the bodies with dry ice to halt escalating decomposition. This action proved largely unsuccessful, although a modicum of result was achieved when the bodies were placed in surrounding cells of ice and then the entire area was covered with a tarpaulin (Figure 34.2). However, a considerable number of health and safety casualties resulted from the dry-ice packing process: workers received burns from touching and moving the corpses. Largely to prevent such injuries, workers tried to achieve the same goal using water-based ice, but this led to unacceptable groundwater contamination issues and unsanitary working conditions.

Temporary mortuary sites were initiated in the early days at temples in Khao-Lak, Phuket, and Krabi. Each body was photographed as it arrived at the temple, and the images were made available on computer for families to attempt visual identification. However, the heat, humidity,



Figure 34.1 Remains laid out in lines before the arrival of refrigerated containers. Bloating and discolouration of the corpses is evident (photographer: author; used with permission of CIFA).



Figure 34.2 Remains waiting for analysis were packed with dry ice in an attempt to slow decomposition (photographer: David I. Gross; used with permission of David I. Gross)

and lack of refrigeration meant that most bodies had passed beyond facial recognition within 48 hours of death. In this regard, children were particularly difficult to identify, because the decomposition process rendered facial identification virtually impossible from the outset. The resulting images became too distressing for families to view, and so this practice was halted. When postmortem images were misleading and inappropriate for public view, forensic artists were employed to recreate facial appearance from the soft-tissue remains. The images were cleaned to remove debris, and any clothing was highlighted. The effects of decomposition, bloating, deformation, and discolouration were eliminated, and characteristic facial details were emphasized in an attempt to stimulate recognition (Figure 34.3).



Figure 34.3 Early loss of facial recognition led to attempts to assist via reconstructive art (photographer: Dr. C. Wilkinson; used with permission of Dr. C. Wilkinson)

Although some remains were allegedly identified through either visual means or personal effects, mistakes were inevitably made, and several cases of incorrect identification were picked up later in the process as more refined and reliable methods of identification were employed. It was established in the investigation of the Bali bombing in 2002 (see Buck & Briggs, Chapter 35) that visual identification of the deceased proved to be incorrect in approximately one-third of cases (Lain, Griffiths, & Hilton 2003). Consequently, as Interpol advises, visual identification should not be encouraged, although it does continue in many countries across the world. Within the first week Thai authorities had released over 1,000 bodies to families, and approximately 500 bodies were released by local physicians and police without recourse to forensic assistance (Morgan et al. 2006). Misidentification inevitably leads to an incorrect outcome for two individuals and their families thereby adding to the misery and conflict for families and loved ones.

Many of the early problems in the tsunami identification programme arose through the inability to separate indigenous Thais from Western deceased with any degree of reliability. The heat, humidity, and effect of water resulted in rapid decomposition that primarily affected the external appearance of the body—where the most immediate indicators of ancestry are located, for example, skin colour, hair type, epicanthic folds. This situation led to quite considerable international animosity that was sufficiently vociferous at one stage to actually threaten the continuation of the entire international programme. A unilateral decision was taken by the local authorities to bury all indigenous personnel and concentrate on repatriation of the Western nationals. Such a sorting process is problematic, particularly considering the demographics of a country such as

Australia, where many citizens are of Asian descent. In the tsunami event in Thailand, although many individuals may well have been of Thai descent, victims could not automatically be assigned Thai national status—in some cases, they were classified as “foreigners.” This led to accusations that the primary sorting process based on biological identity was fundamentally flawed and not sufficiently robust, and it was suspected that Western nationals were inadvertently being included in the mass graves. Ultimately, this concern led to all mass graves being exhumed at a later date to allow one additional recording of information before the deceased were finally reinterred.

Clearly, the lack of scientific anthropological input pertaining to indicators of ancestry was contributing to a volatile situation that required resolution, but anthropological advice was never sought and when given was generally not welcome or ignored, because it would have required a realignment of adopted procedures. Misidentification was addressed in some cases at a later date, when DNA analysis would indicate the identity of an interred individual—resulting in that individual being exhumed for a third time. This situation could largely have been prevented if anthropological expertise had been introduced at an early stage in the preliminary deployments.

When the steady flow of corpses arriving at the mortuaries showed no sign of abating, health and safety practical issues had to be addressed. Although there is some acceptance of the fact that an accumulation of a large number of corpses does not necessarily escalate into pandemic high-risk infections (Morgan, Tidball-Binz, & Van Alphen 2006; Pan American Health Organization 2004), issues relating to personal protective equipment, disposal of waste, and long-term storage and processing issues all had to be addressed. Late in March it was decided to consolidate mortuary efforts by building new facilities at the site of the largest temporary mortuary in Wat Yan Yao in the northern Thai Province of Phang Na (Figure 34.4). This was the largest of the temporary mortuary sites and handled over 3,000 cases during the first three months of the operation while housing over 300 workers per day.



Figure 34.4 DVI mortuary facilities (photographer: author; used with permission of CIFA)

Sources of Identification

Each mass-fatality scenario dictates its own requirements and solutions, and the Asian tsunami was largely an issue of identification of the deceased rather than a collection of evidence for prosecutorial purposes (for example, Kosovo war crimes investigations) or for establishing cause of death (for instance, domestic homicides). The main characterising issues for the Asian tsunami were the condition of the remains, the mode of recovery, and the number of victims (Rutty, Byard, & Tsokos 2005; Scanlon 2006). By the time international teams were involved, the issue of body recovery was largely moot. It was decided at an early stage of the proceedings that there would be three primary identifiers: fingerprints, dentition and DNA. Each of these processes was not without problems, laying down challenges and lessons to be learned for future responses (Alonso et al. 2005; Kieser, Laing, & Herbison 2006). The role of identification is clearly portrayed in the TTVI mission statement—to *identify victims of the Thai tsunami and release them for repatriation to their families in accordance with the Thai law, Interpol DVI guidelines, and TTVI protocols.*

The comparison of antemortem and postmortem fingerprints has a relatively short utilization period, because skin slippage resulting from advanced decomposition renders the contact ridge pattern too damaged or faint for recording. Therefore, in Thailand the antemortem recovery of fingerprints was likely to be an identification option for a restricted time period only owing to the rapid rate of decomposition in the early stages. Because there is no genetic basis to fingerprints, recovery for comparison with relatives was not relevant and so antemortem comparators has to be from source fingerprints rather than familial which led to problems for the family liaison officers. The initial prospect for fingerprint identifications was not promising, but surprisingly over 24% of the identifications between January and March 2005 were achieved by this method. This result was largely due to fingerprint records being kept by countries that issued identification cards where this was a recorded biometric.

Comparison of antemortem and postmortem dental information was chosen wisely as the principal means for speedy identifications of the deceased Western tourists. Dental records were sourced from family dentists and the information converted into the antemortem Interpol format. This was then transferred to the IMC in Phuket, where comparisons were made with postmortem forms. Although the *Plass data* system worked well in this regard, the final confirmation of identity required the experience of forensic odontologists to refine the detailed aspects (Figure 34.5). Between January and March 2005 approximately 73% of identifications were achieved through dental comparisons, highlighting the importance of accurate dental recording and record keeping (see Clement this volume; Petjua et al. 2007; Schuller-Gotzburg & Suchanek 2007).

A variety of national and international laboratories were initially contracted to undertake the DNA analysis. Collection of antemortem DNA frequently relied on buccal swab samples from surviving relatives and the generated profiles being compared with profiles retrieved from bone or tooth samples of the deceased. This process, of course, did not achieve separation of siblings or close family relations. Owing to the extensive and increasing levels of decomposition, many laboratories found it difficult to extract a full DNA profile to a level that was acceptable by many Western countries. Eventually the Royal Thai Police entered into an agreement that the DNA profiling would be undertaken by the International Commission on Missing Persons (ICMP) (see Hanson and associates, Chapter 45 this volume), which has an international reputation for extraction of DNA from degraded samples. In the early stages few identifications were made through DNA analysis (less than 3%), but this number continued to rise (Wright et al. 2015).

Between January and March 2005 over 4,000 postmortem examinations were undertaken, and over 2,000 antemortem files had been listed. Within 8 months nearly 70% of identifications



Figure 34.5 Dental analysis proved to be the most successful approach to identification in the early stages (photographer: Dr. J. Robson; used with permission of CIFA)

had been achieved. For comparison, after the World Trade Center terrorist attack on September 11, 2001, identification of 50% of the 3,025 took 18 months (Schwartz et al. 2002), and the 202 deceased of the Bali bombing in the same year took approximately 6 months (Lain, Griffiths, & Hilton 2003).

The Role of the Forensic Anthropologist in Mass Disasters

Where was the forensic anthropology in this largest mass disaster of modern times? Unfortunately, the discipline remained largely underutilized throughout the entire proceedings. Although issues pertaining to ancestry could have been addressed, they were not, and a great opportunity was missed. Most anthropologists served to assist pathologists and odontologists in the general recording of data, and they played virtually no part in the reconciliation of antemortem with postmortem data. Was this a reasonable approach, or an opportunity missed?

A mass-fatality situation requires that the most appropriate disciplines be involved to meet the needs of the situation in hand (see Sledzik & Mundorff, Chapter 32). In the war crimes investigations of the former Yugoslavia (see Djurić, Chapter 36) and Rwanda, the bodies were generally severely decomposed, and the anthropologist's role was in reconstructing biological identity from the remains and assisting the pathologist in the reconstruction of traumatic injuries to establish a cause of death or the trajectory of a missile. Comparison of antemortem and post-mortem data was the primary remit of the tsunami scientific effort in an attempt to identify the deceased and to assign a name to the individual. This identification can best be achieved through markers that can be established via other professional disciplines (for example, fingerprints, dental information and DNA). Each scientific discipline takes on a level of responsibility that is appropriate to the forensic strategy and the purposes of the deployment. Anthropology could have assisted greatly in the determination of ancestry, which could have prevented unnecessary

hostilities, but this problem was largely overcome through diplomatic means. However, anthropology is likely to play a continuing role in Thailand and other countries where there will be a continuous uncovering of human remains over time as redevelopment continues. Many countries do not have forensic anthropological expertise and so there is a need to equip and assist these countries to adapt to changing identification issues in the ongoing humanitarian response to the aftermath of the largest natural disaster in recent history.

In the United Kingdom the Asian tsunami heralded the development of an organised DVI response capability. This response was launched in 2006, and anthropology was involved in both the training and deployment capabilities of the team. CIFA was tasked with coordination of the medical, scientific, and technical component of the team and identified the British Association for Human Identification (BAHID) as the nominated repository for contact with forensic anthropologists in the United Kingdom. This responsibility now lies with the British Association for Forensic Anthropology (BAFA), and deployment of an anthropologist for DVI is restricted to those who are certified by the Royal Anthropological Institute (RAI), the professional body for the discipline in the U.K. Exercises are now common in DVI to ensure currency of knowledge and practice, and these occur at local, national, and international levels (Byard & Winskog 2010). Research into DVI has also accelerated since the Asian tsunami, and so if anything good can indeed come out of such a huge loss of life then it is greater preparedness should it ever happen again on that scale (Meyer, Chansue, & Monticelli 2006; Benedek, Fullerton, & Ursano 2007; Sweet 2010; Thomson & Black 2012; Winskog, Tsokos, & Byard 2012; Crabbe et al. 2013; Mundorff et al. 2015).

Conclusion

The people who survive such mass disasters as the tsunami are also victims, and although Laurence Binyon's poem "The Fallen" serves to commemorate those whose lives were lost in the First World War, it applies equally to those who were lost in the most recent worldwide disaster and serves as a comfort to those who have survived: "They shall not grow old as we who are left grow old. Age shall not weary them, nor the years condemn. At the going down of the sun and in the morning, we will remember them."

Remembrance is a vitally important part of the healing process, and the chosen focus for that act is intimately personal. The Asian Tsunami Wall of Remembrance commemorates the disaster and ensures that the world will not forget those who died on December 26, 2004 (Figure 34.6); it also offers a focus for annual pilgrimage. We can never forget that the results of our labours in forensic identification primarily aid the living.

About the Figures: The Tamaki Makau-Rau Accord on the Display of Human Remains and Sacred Objects

I recognise that the display of human remains is a sensitive issue for a variety of reasons. The disaster of the south Asian tsunami affected hundreds of thousands of individuals and represented a mass disaster on a scale that has never been encountered before. The use of these images attempts to inform not only with regard to the enormity of the mass scale of events that but also to the dedication and care of attention given to each and every case. At the time of writing none of the individuals depicted had been positively identified, and no cultural or community appropriateness could be observed other than the international standards of decency, dignity, and respect. The right of the individual to the retention of his or her identity is recognised. Permissions have been given by the Thai authorities, the DVI teams, and NGO organisations



Figure 34.6 The wall of remembrance in Phuket (photographer: author; used with permission of CIFA)

involved for images to be made available for publication—lest we forget the scale of devastation. The survivors, families, and friends could not be consulted for permission, because they were not known at the time of writing. These images are a powerful record of an unprecedented humanitarian disaster and serve to facilitate scientific and humanitarian learning.

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The Role of the Anthropologist in Disaster Victim Identification

Case Studies from the 2002 and 2004 Terrorist Attacks in Bali, Indonesia

Alanah M. Buck and Christopher A. Briggs

Disaster Victim Identification (DVI) is the term given to the procedures used to positively identify deceased victims of a multiple-casualty event (INTERPOL Disaster Victim Identification Guide 2014). In all mass fatalities the deceased need to be identified to the satisfaction of the local jurisdictional authorities, such as the coroner (in Australia and Great Britain) or the chief medical examiner (in the United States). In a domestic context forensic experts usually work as an extension of the local legal process, and individual identification goes hand in hand with a determination of cause of death. However, in mass disasters the cause of death may already be known or strongly suspected (for example, shrapnel type injury, inhalation of fire fumes), and identification therefore becomes the most difficult and resource-intensive task. Identification is, however, not just a legal requirement but has moral, ethical, and financial ramifications (Blau & Hill 2009). For both legal and compassionate reasons, forensic specialists need to ascertain how many individuals are represented and, as far as possible, match the remains against available records of known persons involved in the disaster.

According to international standards as outlined by the International Criminal Police Organisation (INTERPOL) the DVI process is carried out in five separate phases (Figure 35.1). Traditionally, the examination of human remains in the DVI process has been carried out by the forensic pathologist and the dentist (forensic odontologist). However, with advances in identification technology, such as DNA profiling, the procedures for individual identification have expanded to include a number of specialist areas, among them anthropology, medical science, and archaeology. Since the late 1990s there has been an increasing recognition and deployment of anthropologists as part of the DVI process (Saul & Saul 2003; Mundorff 2012; INTERPOL Disaster Victim Identification Guide 2014; Mundorff et al. 2015). The role of the anthropologist is to support the identification and investigation process by supplying information that would not easily be determined from a routine examination (see Sledzik & Mundorff, Chapter 32, this volume).

The Nature of Mass Fatalities

Mass fatalities can occur in a variety of ways but commonly involve extreme forces affecting the body (Figure 35.2). Natural disasters are often large in scale and “open” in nature, that is, they

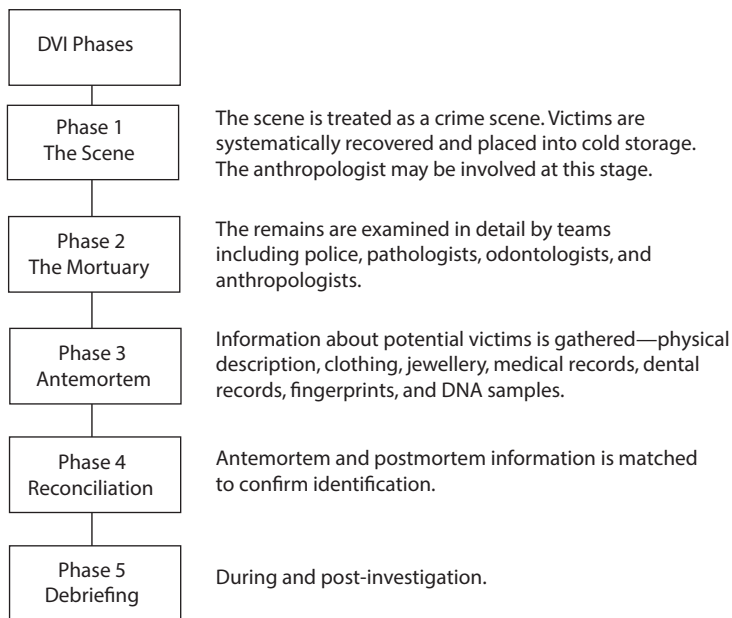


Figure 35.1 Interpol Phases of Disaster Victim Identification

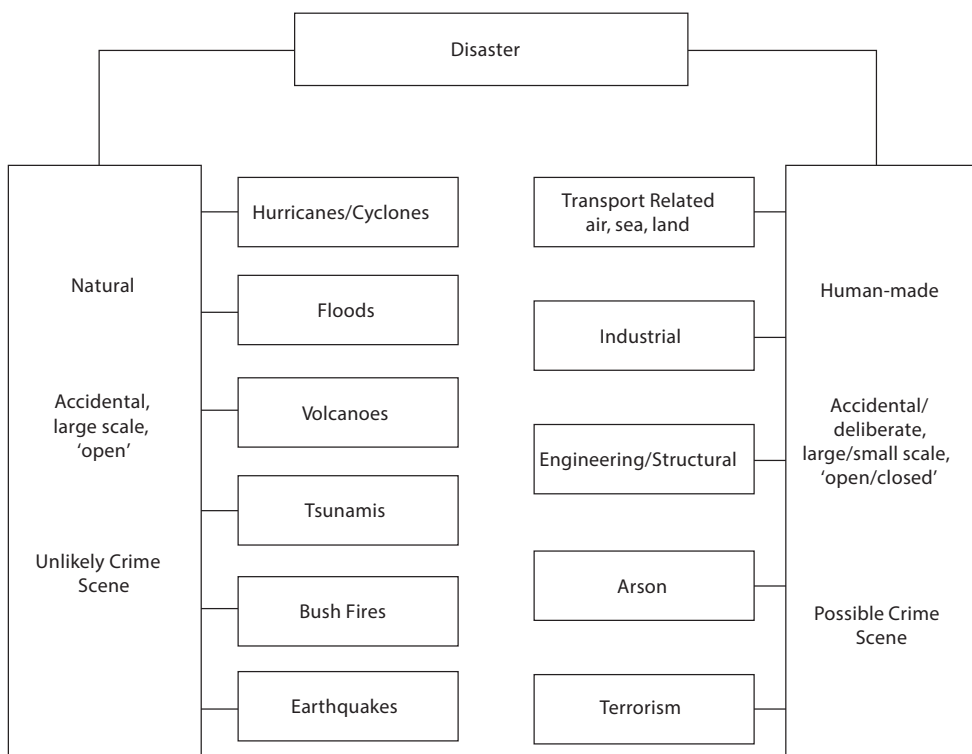


Figure 35.2 Nature of mass disasters

involve large numbers of bodies where there are few clues as to identity. The Boxing Day Tsunami of 2004 (see Black, Chapter 34) and the super typhoon (Haiyan/Yolanda) that devastated the Philippines in 2013 are the most obvious examples of this type of natural disaster. In contrast, a “closed” human-made disaster may also result in a large number of bodies but implies that the exact number of missing individuals is known. Examples of a closed disaster include the Malaysian Airlines MH17 air disaster of 2014, in which 298 people were killed, or smaller events such as the Paris terrorist shootings at the Charlie Hebdo publishing office (2015), where 12 deaths occurred and the victims were readily identifiable. Examples of open human-made disasters include terrorist events such as the train bombings in Madrid in 2004, the bombings of London’s public transport system (2005), and the terrorist attacks in the United States in September 2001. These “open” mass fatality events all highlight the problems associated with human identification when no manifest or list of the suspected victims is available and their ages and ancestral backgrounds are widely varied.

The extreme forces often associated with mass disasters commonly result in a variety of differentially preserved human remains. Incineration, such as that produced in the 2009 bushfires in Victoria, Australia (Blau & Briggs 2011), required careful and painstaking examination of the deceased to provide identification. Natural disasters such as the earthquake in Christchurch, New Zealand, in 2011, where 180 fatalities occurred, can produce a combination of preservation including complete bodies as well as disrupted and incinerated human remains. In situations where recovery of the deceased is delayed, such as the Air France 447 (2009), Malaysian Airlines MH17 (2014), and Air Asia QZ8501 (2015) disasters, decomposition may complicate the victim identification process.

Other factors that influence the nature of the DVI process include:

- *Antemortem records*: The accessibility and completeness of antemortem (AM) records varies throughout the world;
- *Criminal investigation*: When a criminal act has taken place before or during a mass disaster, further, usually complicated, forensic investigation is required; and
- *Multinational involvement*: Incidents that involve individuals in locations other than their country of origin may create delays owing to accessibility to antemortem records.

The Role of the Anthropologist in DVI

By definition a forensic anthropologist should have a background in physical anthropology. The discipline relies on a sound knowledge of human anatomy and, in particular, osteology. As with the pathologist and odontologist, the anthropologist should be experienced in clinical/coronial mortuary work and have the appropriate academic qualifications. Given the increasing use of computed tomography (CT) imaging in forensic sciences centres worldwide a working knowledge of CT interpretation is also desirable. Following are recommendations for the selection of anthropologists required for DVI deployment:

- appropriate tertiary qualifications,
- affiliation with recognised/accredited forensic institution, and
- recent forensic anthropology casework, with particular experience dealing with differentially preserved (for example, badly disrupted, burnt, and/or decomposed) human remains).

Required Skills

A forensic anthropologist’s role at a DVI scene is determined by the nature of the event. However, certain skills are required in most circumstances. The forensic anthropologist must be able to:

- identify small fragments of bone from any region in the body (Mundorff 2008);
- identify left and right elements (often from small fragments);
- identify cross-sections of bone in soft tissue masses;
- assess incinerated (no soft tissue) remains; and
- where possible, assess age, sex, and ancestry in heat-damaged and/or disrupted remains.

Depending on the type of incident, the role of the anthropologist may change over the time of the investigation. In a natural disaster the anthropologist might be introduced at a later stage of examination, as the bodies become more decomposed and are not easily identifiable by other methods. In a human-made disaster, where bodies can be disrupted and scattered, the anthropologist can be involved during Phase 1, in the recovery of bodies from the scene.

Medical Advisory Team (MAT) Member

At a mass disaster, the forensic anthropologist usually works in conjunction with a forensic pathologist and odontologist. Combined, these three professionals form a strong team, covering all areas of assessment of human remains (Buck 2004). The DNA specialist is also involved; however, the forensic anthropologist may also play a role in assessing remains for sample suitability (Mundorff et al. 2008). Examination by the anthropologist and assessment of partially disrupted or incinerated remains can provide information useful for identification relating to

- ancestry,
- sex,
- personal age estimation,
- stature, and/or
- trauma or individualising skeletal anomalies.

The assessment of body parts is ideally undertaken with a pathologist, who evaluates soft-tissue structures. Protocols for the sampling of body parts for DNA profiling should be established before the sampling begins (that is, standard size of sample, policy for exclusion of unsuitable material). These protocols are best determined by a team comprising an anthropologist, a pathologist, and a DNA expert.

The 2002 Bali Bombings

On Saturday, October 12, 2002, just after 11:00 P.M., at a time when foreign tourists as well as locals were out enjoying the night life in Bali's Kuta district, an explosion ripped through Paddy's Irish Bar, a popular destination with holidaymakers, causing massive damage to the building and to the surrounding tourist strip (Figure 35.3). Approximately 10 to 15 seconds later another explosion occurred when a second bomb, concealed in a white Mitsubishi van, was detonated outside the Sari Club (just across the road from Paddy's Bar), another nightspot frequented by Western tourists. Less than a minute later a third bomb was detonated in the suburb of Renon, just 100 m from the United States Consulate.

Indonesian authorities immediately started the task of removing the deceased from the wreckage of the two buildings and commenced disaster victim identification procedures. It was thought the death toll might be in the vicinity of 180–200 individuals and was likely to include people of many nationalities. It was anticipated that up to 50% of the casualties were Australian, with the majority being young people in their 20s and 30s. The Australian



Figure 35.3 Image of nightclub explosion (photograph courtesy of the author)

government response was immediate and, in consultation with the Indonesian government, formed a multi-agency support team, incorporating expertise from state police services, the Australian Security Intelligence Organization (ASIO), and the Department of Foreign Affairs and Trade (DFAT), as well as contributions from the various Australian state forensic institutions that sent forensic pathologists, odontologists, technical support staff, and other specialists (for example, Lain, Griffiths, & Hilton 2003). They were soon joined by forensic experts from Holland, Hong Kong, Japan, Sweden, Taiwan, the United Kingdom, and the United States. Teams were initially rostered on 14-day rotations, although this arrangement was modified as the work proceeded. The work undertaken in Bali was not the first time that Australian forensic specialists had been involved in the investigation and identification of large numbers of deceased in overseas: they assisted in the investigation following the Lockerbie plane crash (1988) and the excavations of war dead from mass graves created during the conflicts of the 1990s in the former Yugoslavia. The work undertaken in Bali was, however, the first time that the Australian Federal Police (AFP) and forensic experts from across the continent had been asked by a foreign sovereign government (Indonesia) to assist in the identification of deceased Australians abroad.

Phase 1: The Scene

The area where the explosions occurred was treated as a crime scene. Victims were systematically recovered and, when possible, placed into cold storage. The scene was photographed and videotaped and the position of human remains recorded. Although this phase of such operations is usually delayed until all survivors are removed, in Bali it was instituted as quickly as possible to negate the rapid rate of decomposition in the hot and humid conditions. Twelve hours after the blasts, both the Sari Club and Paddy's Bar were still ablaze; however, recovery teams had to begin the task of extricating bodies from the ruins. Body parts were not only in the buildings but also widely dispersed within and around the two major bomb sites (for example, on nearby roofs) and scattered over a wide area. Many body parts were not visually recognisable. All immediately accessible bodies and body parts were labelled with a unique identification



Figure 35.4 Body parts in cold storage Sanglah Hospital (photographer courtesy of the author)

tag, bagged, and delivered by Indonesian authorities, including local volunteers, to Denpasar's Sanglah Hospital mortuary (Figure 35.4). Property located at the scene was recorded in situ, collected, and appropriately labelled.

Phase 2: The Mortuary

Owing to a lack of portable refrigeration units, the deceased were placed under awnings in the space connecting the mortuary to the hospital administration wing and covered with ice. On arrival in the mortuary, the remains were logged and placed into storage until space, and personnel were available to begin examination. Bodies were examined in detail, initially by teams of pathologists, odontologists, and anthropologists.

Unlike in a normal autopsy examination of a deceased person, in Bali the emphasis was on clues that might reveal identity rather than on determination of cause of death (which in most cases was already established). The face and the entire body of victims were photographed (clothed and unclothed). Jewellery, personal effects, and clothing were photographed in situ, examined, cleaned, rephotographed, and then secured. When appropriate, the external examination took note of the individual's skin and hair colour, sex, estimated age, height, weight, and body build. The unclothed body was examined for distinctive features such as tattoos, birthmarks, scars (for example, from previous surgical procedures), nicotine staining of fingers, and obvious deformities and malformations. Visual identification is, however, known to carry a significant risk of misidentification (see Watts 2002). Of the 16 bodies that had been visually identified by families immediately following the incident, nine had been incorrectly identified, reinforcing the need for consistent and reproducible procedures (Lain, Griffiths, & Hilton 2003).

Police conducted fingerprint analysis, and molecular biologists waited for DNA samples to be taken. Where possible at least three DNA samples were removed from different body sites: a bone sample, preferably the proximal femur, muscle tissue from unburned regions of the body, and hair and blood were taken, stored in dry ice, and immediately shipped back to the Australian Federal Police (AFP) DNA laboratory located in Canberra, Australia. However, it was not always

feasible to collect DNA samples owing to the calcined or decomposed nature of many of the remains. Following examination, the remains were returned to storage to await further examination in light of accumulating antemortem information. Anthropological examinations were conducted to answer these questions:

- Do the remains represent more than one individual? When there are multiple fragments from different individuals (as was the case in Bali), efforts are made to apportion these to one person, through identification of left and right elements and specific anatomical location (Adams & Byrd 2008).
- Is it possible to deduce from the skeletal remains information about the deceased's ancestry, sex, age, stature, and physique?
- Are there any skeletal traits or features such as healed fractures present to positively identify the individual, or other personal characteristics that might aid the process of identification?

After the initial examination of complete bodies, attention turned to the significantly disrupted, fragmentary, and incinerated remains, and efforts were then made to attribute these separate parts to the appropriate individual. The experiences gained from investigations of the New York Twin Towers terrorist attacks (for example, Budimlija et al. 2003; Mundorff et al. 2009), as well as examinations of skeletonised victims of genocide in the former Yugoslavia (for instance, Rainio et al. 2001), in Latin America (see Steadman & Haglund 2005), and in Rwanda (for example, Kirschner & Hannibal 1994), indicate that skilled forensic anthropologists can play an important role in the identification process. The nature of the Bali incident, with multiple fatalities involving incineration and fragmentation of remains, particularly among those close to the centre of the explosion, indicate a need for expertise in the analysis of bone fragments.

The body parts were recovered from a wide area and over a protracted period of time. Remains were still being recovered up to two weeks after the event, and, as a result, many of the body parts were in an advanced state of decomposition. A procedure for assessment and sampling was determined by the forensic pathologist, anthropologist, and DNA specialists before commencing the examination, and this procedure was maintained throughout the entire process. Every body part was sampled (soft tissue and bone when possible), except when decomposition or incineration was considered too severe. A basic description of the body part was required, which included anatomical location (for example, left mid-shaft of femur). It was at this stage that the anthropologist was able to contribute valuable information.

General observations of the body parts from the Bali incident included these:

- A high degree of fragmentation of individuals close to the blast site was found in both locations;
- The distal limb segments (in particular the legs) were severely incinerated;
- Mid-shafts of most long bones exhibited breakages, and
- A high percentage of major joint complexes (knee, shoulder, hip) was often intact.

These types of findings are consistent with exposure to a high explosive with associated pressure wave and incendiary effects (Dussault, Smith, & Osselton 2014).

Phase 3: Antemortem Data

The antemortem phase of the Bali bombing commenced on Thursday, October 17, 2002 (five days after the incident), with the release of a list of missing persons. In all Australian states police

teams accompanied by counsellors were organized to visit families of those suspected of being among the victims. In Bali police forensic teams visited hotel rooms to identify and recover any antemortem samples. Authorities began interviewing friends and relatives, collecting photographs, details of clothing and jewellery commonly worn by the deceased, and other items such as hair combs and toothbrushes that might be useful in the event of DNA analysis. Surfaces were sampled for finger and even footprints. Names of family doctors and dentists were assembled so that medical and dental histories could be obtained from the victims' places of residence. All individuals potentially involved were initially listed, and then those established to have survived were removed from the list, resulting in the final estimate of 200 victims. Not all of these were immediate victims of the bomb attack. Some, especially those with severe burns who were airlifted to Australia, died of their injuries in the following days and weeks.

Phase 4: Reconciliation

In the reconciliation phase, antemortem and postmortem information are compared in order to attempt to confirm identification. Leaders of specialist sections—fingerprint, dental, medical, anthropological, DNA, and physical (property and photography)—are coordinated to confirm the identity of the deceased. In Bali reconciliation commenced on Friday, October 25, with representatives of the Indonesian military, the AFP, foreign DVI teams, a forensic odontologist, a forensic pathologist, and a medical scientist in attendance. Results of the various sections were compared. If inconsistencies were found, when possible they were reconciled and a formal report prepared. In Bali anthropologists were involved in the reconciliation phase as observers; the stand-alone identifiers were a pathologist, a forensic odontologist, and a DNA expert.

The Bali DVI closed on Friday, February 15, 2003—one year, four months, and three days after the explosions. There were a total of 202 fatalities from 21 countries, of which 199 were positively identified and which included 88 Australians (several body parts remained unidentified). Thirty-nine body parts have been linked to one unidentified body, which may be that of the bomber, and three body parts produced DNA profiles that have not been identified to date.

The 2004 Australian Embassy Bombing

On the September 9, 2004, a bomb exploded outside the Australian Embassy in Jakarta killing 12 people (Figure 35.5). Many of the deceased were Embassy security personnel, along with civilians and a suspected ordinance carrier. A medical advisory team from Australia, including a forensic pathologist, a mortuary manager, and a forensic anthropologist, was deployed to assist the Indonesian authorities with the DVI process and subsequent criminal investigation. A good working relationship had been developed between Australian DVI experts and their Indonesian counterparts during the 2002 Bali disaster incident, which facilitated rapid mobilization of the Australian team and effective communication during the process.

The main tasks of the medical advisory team were to assess and record all body parts, to identify two civilian bodies, and to identify any possible bomb carriers. The forensic anthropologist, in conjunction with the forensic pathologist, identified and recorded all the body parts recovered from the scene. Each body part had been allocated a locational number. Once the identification of the body part had been determined, this part could then be related to the scene, and distribution patterns could be assessed. Over 90 body parts were identified, and an inventory was constructed (Figure 35.6). Body parts were examined and allocated to one of the following categories: bone only, soft tissue, or a combination of both. Specific anatomical



Figure 35.5 Damage to the Australian embassy and surrounding buildings (photographer courtesy of the author)

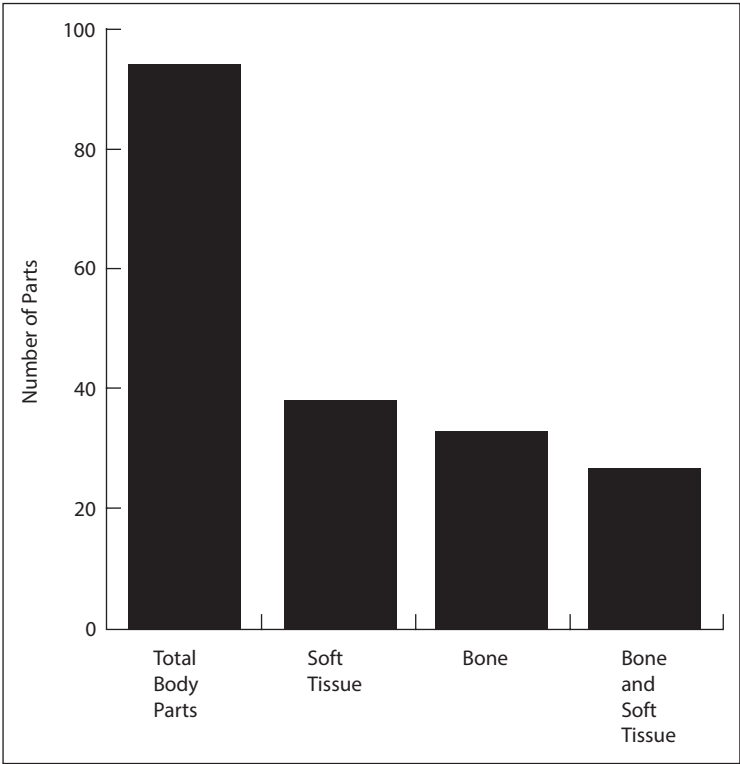


Figure 35.6 Total number of body parts ($n=98$) by anatomical location and further breakdown into broad categories; Australian Embassy Bombing, Jakarta 2004

location was also recorded. This type of inventory is useful for later consultation for estimates of the amount of soft and hard tissue available for sampling. It is also a useful indicator of the degree of fragmentation resulting from the incident.

Most of the bodies were identifiable by routine methods; however, two civilians were close to the blast when it detonated. These bodies were badly disrupted (distal limb segments missing and heads extensively damaged) and displayed a high degree of incineration. Visual identification was not possible, and antemortem records (dental and medical) were not available. Two suggestions were put forward as possible identities for the individuals; however, the age, sex, and ancestry were very similar. Because a preliminary identification was required (identity was subsequently confirmed by DNA), it was necessary to find a biological parameter that would distinguish the individuals. It was decided that the height of the individuals (antemortem estimates obtained by Indonesian authorities) was sufficiently disparate that it could be used to establish a preliminary identification. A stature estimate was calculated by the anthropologist together with Indonesian pathologists from the remaining intact femur. The regression equation was calculated from Southern Chinese male data (Krogman & İşcan 1986), the closest available to an Indonesian sample. The stature estimate identification was later confirmed by DNA testing, thereby highlighting the usefulness of anthropological parameters when antemortem records are difficult or impossible to obtain.

The final task for the medical advisory team was the tentative identification of a possible bomb carrier. This process was carried out by the anthropologist and the pathologist, who, according to experience and observations of postblast injuries from previous cases, systematically examined each body part looking for postblast injuries that were consistent with proximity to the blast site. A process of elimination was used to identify related body parts; for example, a superior articular facet of the atlas was identified that could not have belonged to any of the other victims, because all other neck regions were intact. The size and condition of the atlas fragment were also consistent with it being in close proximity to the explosion. Subsequent DNA tests confirmed the bone belonged to a person of interest to the authorities.

Lessons Learned from the Bali and Australian Embassy Bombing Incidents

The Bali incidents had serious implications for regional governments, forcing both Indonesia and Australia to take the threat of terrorism more seriously (Dupont 2003). At the time, Indonesia (including specifically Bali) was placed at the top of Australia's restricted countries list. Australia also started to take the threat of terrorist attack on home soil seriously and to plan for the possibility of future attacks closer to home. DVI units were established in most Australian states and territories and comprise teams fully trained to respond to disaster and terrorist situations including chemical, biological, and radiological events with the capacity to call in additional expertise if and when required. The value of having a forensic anthropologist on the DVI teams is now widely recognised in Australia. The Australian Disaster Victim Identification Committee (ADVIC) now manages a roster of forensic practitioners available for immediate response, which includes practising forensic anthropologists in each Australian state.

Conclusion

Mass disasters, in particular incidents with a criminal element, have become increasingly prominent in recent times. A wide range of forensic specialists have become involved in both the human identification process and the criminal investigations. Along with the more traditional practitioners—namely, the forensic pathologist and the odontologist—the forensic anthropologist has

also come to play an increasingly important role in incidents involving mass fatalities. Diverse mass fatality incidents such as the 2001 World Trade Centre collapse (Mundorff 2008) the 2004 Madrid bombings (Prieto et al. 2007), the Australian bushfires in Victoria in 2009 (Blau & Briggs, 2011), and the Christmas Island boat disasters in 2010 and 2012 have all benefitted from the skills of the anthropologist both at the scene and in the mortuary setting.

Although the anthropologist's role may vary in conjunction with the type of incident and change during an investigation, as part of the medical advisory team the anthropologist can contribute to both the recovery and analysis aspects of DVI. The anthropologist is able to offer expertise in the assessment of highly fragmented, decomposed, and incinerated human remains; determine the minimum number of individuals; differentiate human from nonhuman remains; and triage biological profiles (age, sex, ancestry) from human remains.

With the increased awareness of the usefulness of forensic anthropologists at mass-fatality incidents comes the necessity to ensure that practitioners have the appropriate training (academic qualifications) and experience to be able to satisfy international requirements. Given the importance of the DVI process and possible associated criminal investigations, the discipline of forensic anthropology in Australia will need to consider the establishment of certification for practitioners accredited to recognised standards for the future, such as those developed by The Royal Anthropological Institute (2013). Practitioner Guidelines for Australian forensic anthropologists were developed as part of the Forensic Anthropology Scientific Working Group of the National Institute of Forensic Science and ratified in 2009 (see Donlon, Chapter 10). With these standards in place, forensic anthropology can continue to bring valuable skills to the DVI process.

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Dealing with Human Remains from Recent Conflict

Mass Grave Excavation and Human Identification in a Sensitive Political Context

Marija Djurić

This chapter's review arose from my personal experiences as a forensic anthropologist working on exhumations of mass graves resulting from conflicts in the territory of the former Yugoslavia. It focuses on practical issues of forensic work in the post-conflict environment, the influence of international criminal proceedings on investigations at a national scale, and the analysis of obstacles to the more successful use of forensic science with regard to different political contexts.

The chapter is divided into several parts: the first section describes the context in which the mass graves were created; the second part discusses the engagement of local and international experts; the third part identifies tensions within the forensic team; and the fourth section illustrates the way in which the political environment and the availability of facilities can influence the outcomes of professional forensic work. This last part contains three case reports displaying the successes, failures, difficulties, responsibilities, and concerns that have followed our professional forensic work during 15 years of continuous changes in the political, economic, and scientific environment.

Background: How Forensic Archaeology and Anthropology Came into Focus

Before the last decade of the 20th century forensic aspects of anthropology and archaeology had been marginalised in the entire former Yugoslavia, since experts in the fields were university based, without any connection to the police and the court. However, following the recent wars, frequent mass grave exhumations in the region began to include some local anthropologists and archaeologists (often as a part of international forensic teams), allowing them to gain experience in forensic methods, and demonstrated that this type of expertise plays a significant role in investigation and prosecution processes.

The downfall of Yugoslavia started in the beginning of the 1990s in an atmosphere of weak political authority at the federal level and arising nationalism among constituent ethnic groups. In total six republics had been constituted in previous Yugoslavia's communistic regime, not

on the basis of ethnic but geopolitical criteria. Some of those republics started to declare and conduct secessions, and enforced growing ethnic tensions escalated into violence. The Federal Army (multi-ethnic at the time) was unsuccessful in its attempts at keeping the country together, and military conflicts occurred across the country, lasting from 1991 to 1999. After a short conflict in Slovenia, which first declared independence in 1991, massive conflicts started in Croatia, where a large Serbian minority opposed secession; the fighting ended in 1995 after operations Storm and Flash.

The hardest war and the most complex situation occurred in Bosnia and Herzegovina, whose population is composed of three dominant entities: Serbs, Croats, and Bosnians (Slavic Muslims). Different sides in this conflict have been supported by Serbia, Croatia, the Federal Army, and the international community. The war in Bosnia and Herzegovina finally ended with the signing of the Dayton Agreement in 1995. Kosovo and Metohia were formerly a province of the Republic of Serbia, with the majority of population represented by ethnic Albanians. Growing tension between ethnic Albanians' pursuit of greater autonomy and state-organised oppression resulted in 1996 in a series of terrorist attacks and counterattacks between the Kosovo Liberation Army (KLA, established by Albanians) and the Serbian military and paramilitary forces. The 77-days of NATO bombardment of Serbia (including Kosovo) in 1999 was the last major destructive conflict in the region and resulted in the final break-up of the former Yugoslavia.

During the series of wars over 140,000 people died (International Center for Transitional Justice 2009). Over 30,000 individuals were reported missing (Table 36.1), and numerous forensic teams worked on the discovery and exhumation of the mass graves created during these conflicts.

Involvement of the Local Forensic Team: Increased Ethical Dilemmas?

Contrary to the practice in some other parts of the former Yugoslavia (particularly Bosnia and Kosovo), where international organizations such as the International Commission on Missing Persons (ICMP), International Criminal Tribunal for the former Yugoslavia (ICTY), and European Law and Justice Mission (EULEX) have formed forensic teams and performed practically all the work related to mass grave exhumations and the analyses of human remains with insignificant participation of local experts, all mass graves in Serbia have been explored and the

Table 36.1 Data on missing persons during the conflicts in former Yugoslavia*

	<i>Croatia</i> <i>(1991–1995)</i>	<i>Bosnia and</i> <i>Herzegovina</i> <i>(1992–1995)</i>	<i>Kosovo and</i> <i>Metohia</i> <i>(1998–2000)</i>	<i>Total</i>
Reported number of missing persons	6,430	22,427	6,027	34,884
Found alive	1,591	650	1,372	3,613
Found dead, identified, and returned to family	2,591	14,323	2,729	19,643
Persons whose fate is still unknown	1,780	6,514	1,404	9,698
Cases closed for administrative reasons	43	74	215	332
Persons who are known to be dead but whose remains have not been found	425	866	307	1,598

* Data obtained from the Commission on Missing Persons of the Government of the Republic of Serbia, based on the reports of the International Committee of the Red Cross

human remains recovered and investigated by local forensic teams (after 2000 including international monitoring).

Local team participation is in itself a challenge for several reasons. It is generally accepted practice that experts involved in the forensic exhumation of mass graves should not belong to any ethnic group, political party, or other interest group involved in the armed conflicts that have led to the formation of those graves being investigated (Skinner, Alempijevic, & Djurić-Srejac 2003). Because of ethical concerns and requirements concerning the objectivity, impartiality, and independence of forensic professionals it is considered as more appropriate to engage international “neutral” experts.

The ethical dilemmas that might affect the local forensic practitioners are related to whether they see their work as predominantly contributing to human rights (in particular to identification of the missing) or the advancement of criminal justice. This issue is recognised in a wider context in the analyses of forensic scientists engaged in international investigations (Klinkner 2012) and in the study of forensic pathologists involved in ICTY missions, where authors have made a distinction between those who believe that such an international tribunal can achieve justice for the victims and their families and those who are critical about the goals of the international criminal justice process/system (Lorin de la Grandmaison et al. 2006).

Additionally, local experts might be stressed by the fact that individuals of their own nationality have committed war crimes and/or that the war victims belong to their ethnic group; they may have knowledge of uninvestigated mass graves with victims belonging to their nation or be aware of incorrect interpretations of war events by the international community, their own country, or the opposite side in the conflict. But personal psychological preparation for forensic work has progressed over the years and experience, particularly in a good exhumation team, has positive effects on emotional reactions to fieldwork. Interaction with international monitors, if their role is not to be just passive observers but to actively contribute to exhumation process, could be especially beneficial for local experts, particularly for inexperienced workers, helping them to better understand their sphere of competence and the international legal framework and to bring together their personal ethical attitudes with the primary aims of the mission.

Clearly, local experts are held back by many circumstances that can make them feel uncomfortable or even affect their professional attitude—but are international experts neutral? An example of personal bias that received considerable public attention is the case of Helena Ranta, a Finnish forensic expert who led a team under the mandate of the European Union (EU-FET) investigating a mass grave in Račak (Kosovo) in 1999.

Just a week before the NATO bombing of Serbia began, Ranta communicated her “personal opinion” in a press conference about the incident in Račak, suggesting that Serbian forces committed a massacre against Albanian civilians there. In sharp contrast, her team actually reported that “the manner of death remained undetermined by EU-FET, because the scene investigation and the chain of custody for the bodies from the site of incident to the autopsy were impossible to verify by the team” (Rainio, Lalu, & Penttilä 2001). Several years later Ms. Ranta (often criticised for her provisional interpretation of the Račak incident) claimed that she had actually been under pressure from William Walker (head of the Organization for Security and Co-operation in Europe for Kosovo) to modify even the contents of her written report in order to incriminate the Serbian side, which she allegedly refused to do (*B92 News* 2008; Riedlmayer 2008). To gain support for NATO military intervention in 1999 Walker had insisted on interpreting the event in Račak as a crime against humanity committed by the Serbs.

Of course, it is possible that international experts come to some foreign locations to undertake forensic work with prejudices that were previously acquired under the influence of media, public opinions, or other sources in their own country. Therefore, despite the expectation that

qualified professionals in the forensic field should be neutral and objective, a more practical approach to providing professional standards and ethical requirements is for the forensic team to concentrate on the application of established and approved protocols and standards, as well as scientific methods and the principle behind the techniques used in mass-grave exhumation and identification of victims. To date, forensic experts have emphasised the need to establish standards in order to provide “consistency both within and among forensic teams at an international level” (Cordner & McKelvie 2002; see also Stover & Shigekane 2002; Skinner & Sterenberg 2005). Several international organizations have produced publications aimed at establishing standard protocols and procedures with the goal of increasing cohesion among experts including the United Nations (1989); Inforce Protocols (Cox et al. 2008); the International Committee of the Red Cross (2004, 2009), and the unpublished (but very useful in the Balkan region) Standard Operating Procedure for Sampling Bone and Tooth Specimens from Human Remains for DNA Testing at the ICMP.

Causes of Possible Tension: Time Pressure, Inadequate Funding, and/or Insufficient Cooperation between Prosecutors, Investigators, Forensic Scientists, and Monitors

Mass-grave exhumation is generally a complex process, but when it happens shortly after an armed conflict, additional pressure is placed on the forensic experts owing to tense political situations. Moreover, once the mass-grave location has been confirmed after preliminary investigations and the prosecutor has decided that the grave will be exhumed, the people in the surrounding social environment become extremely impatient regarding the start of the fieldwork and remain so for the duration of the excavations, up to the identification of victims and repatriation. However, before excavations begin a number of complex activities should be completed: signing agreements between the relevant governmental institutions and different organisations (some of them on the international level, such as ICMP); preparing the logistics required for the mission; securing funding selecting forensic staff and preparing a complete plan of the mission. At the beginning of the fieldwork, the public often feels that the task is urgent but the mission is late. As a result, the forensic team works under significant time pressure, created by the impatience of the families of the missing persons and stimulated by the media and different political factors. To avoid such tensions, the specialists involved in this complex job should respect the competence of each profession involved (Skinner & Sterenberg 2005; Klinkner 2012). Unlike the prosecutor and the judge in charge—whose focus is on collecting as much evidence as possible for the court—and the representatives of families—humanitarian organizations and press who mostly try to speed up identification of victims,—the field forensic team tries to avoid compromises and to maintain professional standards. Because of overlaps and differences among forensic experts’ experience and training, confusion and tension sometimes exist within the forensic team itself (Skinner & Sterenberg 2005).

Some questions from various participants in the forensic team that are frequently heard on the excavation site illustrate differences in approach, academic background, and fields of expertise:

- Do we really need the total station and all these archaeological measurements?
- Is it necessary to scrape and clean every layer of soil and each profile as well?
- Is it important to take X-rays of healed bone fractures?
- Do we need such a detailed dental analysis?
- Should we glue each bone?

- Should all soft tissue be removed from the skeleton after autopsy?
- Is it necessary to take a DNA sample from each dislocated bone?
- Isn't it redundant to perform a chemical analysis of soil in the primary location of bodies found in secondary grave?
- Is it necessary to wash the personal clothes of victims?
- Can a forensic pathologist report the cause of death in cases where human remains are skeletonised?

The last question especially draws the attention of forensic experts in the region, because forensic pathologists from Belgrade have been criticised for not recording the cause and manner of death in cases from mass graves, even when injuries on the bones of the skull clearly indicated gunshot wounds. In many instances pathologists have emphasised the need to be extremely cautious in drawing conclusions about the cause of death in cases where soft tissue is absent or decomposed. Furthermore, pathologists explain that even clear projectile damage to the bones of the skull does not necessarily indicate the exact cause of death. If there is no soft tissue, it is difficult to establish a vital reaction that would indicate that an injury caused by a projectile was inflicted ante- and not postmortem. Moreover, even if a skull injury was caused by gunshot, that does not necessarily mean that such an injury was fatal. Therefore, in such cases pathologists describe their professional opinion in a forensic report to be submitted to the competent judge—for example: “The perceived injury of the left pelvic bone is *probably* the result of a projectile fired from a hand gun. The projectile channel of the wound described here could affect organs and blood vessels, injuries to which may have been the immediate cause of death in this particular case.” However, on the Serbian Death Certificate (the document used to settle legal matters related to the registration of a person's death), cause of death cannot be listed as “probable”—in the case of absent soft tissue the pathologists records cause of death as “unknown.”

How the Political Environment and Available Facilities Influence Professional Forensic Work: Three Case Studies

Case 1: Glodjane—Work during Wartime

In the first half of September 1998 Serbian police discovered the remains of nearly 40 individuals in the area of the village of Glodjane (South Kosovo and Metohia). The investigators surmised that the victims were Serbs, Roma, and Albanians who had not cooperated with the KLA. The bodies were found on the ground surface and in the canal leading to Radonjic Lake (Figure 36.1). The District Court in Peć later requested three forensic pathologists from the Institute of Forensic Medicine, University of Belgrade, to perform the autopsies, but since the remains were in advanced stages of decomposition and partially skeletonised, an anthropologist was, for the first time, included in the forensic team (Djurić 2004). The atmosphere in Serbia was at the boiling point at that time, because the war in the province of Kosovo and Metohia had just started. A series of armed attacks were performed by the KLA on Serbs, Roma, policemen, and ethnic Albanians considered to be loyal to Serbian authorities. The Yugoslav government responded with broad action of the security forces with the aim to destroy the KLA's centres and to crush civilian support to the KLA. The growing violence in the province caused numerous casualties and civilians started fleeing the region.

Despite good communication with the District Court judge and his personal support in preparing the logistics for the investigation of the mass grave near Glodjane, the professional work undertaken during the ongoing armed combat in a very insecure environment and with



Figure 36.1 Bodies found on the ground surface and in the water canal

limited resources was very difficult. International monitors were not present. International journalists showed little interest in the case, taking just a few photographs and, in conversation with the forensic team, were mostly interested to hear whether traces of torture had been found on the bodies. Because of this situation the forensic team recommended to the Ministry of Foreign Affairs of Yugoslavia that international observers should be provided for all future mass-grave excavations, more of which, under the circumstances, were expected.

While autopsies including anthropological analyses were routine jobs for the forensic team, the identification of the victims was problematic. Although DNA-based identification was already an introduced method at the time of the investigation of this case, there was neither a laboratory in Serbia designed for this purpose nor had a blood DNA data bank of relatives of missing persons been created. In addition, a list of the missing persons had not been provided. The forensic team collected bone samples for possible future DNA analysis, but initial identifications were undertaken using traditional methods: comparison of antemortem biological markers of identity of missing persons with the postmortem data. Dental records were not available, and collecting antemortem data from families proved to be difficult, because the forensic team was working in a war zone and with time restrictions. Therefore, local authorities suggested making a local radio announcement inviting relatives with missing family members to visit the place where the forensic team was working, in order to provide data for the identification. Before being interviewed by the forensic workers, family members were invited to view clothing and/or evidence found in association with the human remains (Figure 36.2). Twelve of the 39 deceased individuals were identified, but many years later it turned out that some of these identifications were wrong. Besides the fact that “presumptive identifications” based on classical anthropological markers of identity are problematic (Djurić et al. 2007), our experience from the Glodjane case has demonstrated that interviews with relatives of missing persons were not reliable in many ways. Particularly, the antemortem data about stature and dental status of the missing had not been precise or had been simply wrong (Djurić 2004). In addition, the forensic team had the impression that, in the dangerous political environment at that time, some Albanian families loyal to Serbian authorities had failed to come or to make positive identification of victims, probably because of the fear that the family would be condemned as “traitorous” by their compatriots supporting the KLA. Also, some relatives had been convinced that their family members had disappeared and

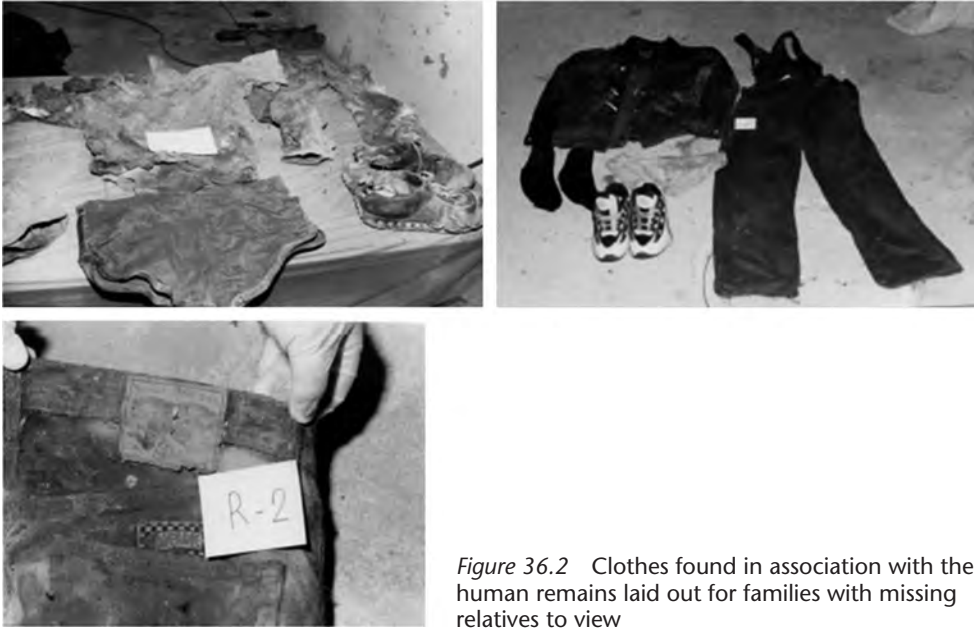


Figure 36.2 Clothes found in association with the human remains laid out for families with missing relatives to view

died precisely on this site but still tried to confirm their recognition of recovered evidence and clothing even though they lacked a basis for this.

Case 2: Batajnica—Local and International Enthusiasm

Up to 2001 many mass graves had been discovered in the territory of the former Yugoslavia but not in Serbia—which was expected, since there had been no war in this republic (with the exception of the Serbian province of Kosovo and Metohia). The end of the wars in 1999, the final disintegration of Yugoslavia, the fall of the former regime, and the new democratic government provided the prospect of a peaceful perspective without political tensions to the residents of Serbia. However, the public were completely shocked by the news that a refrigerated truck containing 50 corpses had been pulled from the Danube River in eastern Serbia and information collected by Serbian police about potential mass graves at Batajnica (in the neighbourhood of Belgrade) that indicated that the graves might contain the mortal remains of ethnic Albanians killed in the recent Kosovo conflict. Although in general the creation of clandestine mass graves during the wars was a known fact, the transport of dead bodies from Kosovo to the suburbs of Belgrade for the purpose of secondary inhumation was astonishing for the majority of local people and a fact difficult to accept. The District Court of Belgrade had appointed a large forensic team composed of forensic pathologists and anthropologists from the Faculty of Medicine, University of Belgrade, and archaeologists from the National Museum in Belgrade in order to organise and conduct exhumations. Over the course of two years a series of five mass graves were explored within one area (a training complex of the Special Anti-terrorist Unit) with a minimum of 705 human bodies recovered (Djurić & Starović 2011).

The new Serbian government had demonstrated the appropriate political will to investigate the issue of mass graves in Serbia, and consequently there was a firm intention that all participants were to perform this mission in the best way possible. The process was monitored by

numerous international and local nongovernmental organizations (ICTY, Humanitarian Law Center–HLC, OSCE, and, sporadically, ICRC), but ICMP was in a special position, because an agreement regarding mass-grave excavation had been reached between the District Court and the ICMP, which allowed forensic archaeologists and anthropologists from ICMP to assist local forensic teams in the actual excavations (International Commission on Missing Persons 2004).

ICMP is primarily a humanitarian organization focused on scientifically identifying the dead. They established DNA laboratories in Bosnia and Herzegovina for the analyses of antemortem blood samples provided by relatives of missing persons and postmortem bone samples collected from skeletal remains recovered from the mass graves. To date the remains of nearly 15,000 individuals from mass graves in Bosnia and Herzegovina have been identified using DNA-assisted methods (International Commission on Missing Persons 2014).

The local forensic team, having experienced situations where monitoring was not undertaken and having worked under high political pressure, was now well positioned to undertake this work. Archaeologists were employed during the exhumation process (except for the grave labelled as BA02), and they recorded details related to the manner of disposal of the bodies, including evidence of the use of a mechanical digger and burning; they also collected important evidence such as personal documents and possessions, including jewellery and money (Djurić & Starović 2011). The excavations were supported by ICMP archaeologists, who introduced the use of electronic distance measuring (EDM) total station, which in Serbia was a novel technique for recoding information during the excavations of the graves from forensic context. Anthropologists undertook detailed postmortem analyses collecting numerous data for identification, including the X-rays of all restored and endodontically treated teeth. However, antemortem data collected by the United Nations Interim Administration Mission in Kosovo (UNMIK) were sparse and incomplete, notably due to the absence of dental records: most people living in villages did not have dental records. The main identification process became the DNA profiling and matching undertaken by ICMP.

Case 3: Rudnica—Is There a Power Struggle 15 Years after the Conflict?

The unresolved fate of more than 1,700 missing persons (ethnic Albanians and Serbs) from the Kosovo conflict remains a challenge in the dialogue between the authorities in Belgrade and Priština and an issue of humanitarian concern. Serbia is continuing in its efforts to find possible mass graves within its territory, and the government's Commission on Missing Persons has the responsibility to coordinate with different organisations in collecting new information about suspected gravesites. The process is supported by the ICRC, whose main role is to exchange information between different governmental organizations in the region, to implement international humanitarian law, and to ensure that families of the missing receive proper and accurate information. Working in Kosovo, EULEX forensic experts, together with the Department of Forensic Medicine in Priština (EULEX-DFM), are trying to improve local forensic capacities, to collect information, and to investigate locations of potential grave sites. Several years ago EULEX urged Serbian authorities to check a potential site at Rudnica, in southwest Serbia, a location pointed out by some witnesses and satellite footage made by NATO. The victims are believed to have been killed in 1999 during the Kosovo conflict.

After several unsuccessful attempts to find the mass grave in 2004, 2007, 2010, and 2011, eventually the first skeletal remains were found in December 2013. The Belgrade Supreme Court–War Crimes Unit gave the order to start the excavations and engaged a forensic team from Belgrade composed of anthropologists, archaeologists, forensic pathologists, and police. The overall organization of the site, including the financial and technical issues, was within

the jurisdiction of the Commission on Missing Persons of the Republic of Serbia. The mission has been monitored by EULEX, a forensic delegation from Priština, and the ICRC, while the ICMP took responsibility to make DNA-based identification.

From an archaeological point of view the site was complex and challenging. The area where skeletons were found had, until the late 1980s, been a quarry. The area had subsequently been modified several times: water from the neighbouring Ibar river had penetrated into the central depression of the former quarry, making an 18m deep artificial lake; then the lake had been utilised for the disposal of tailings created as industrial waste after crumbling ore flotation in a nearby mine, making the lake swampy and much shallower. It was believed that in 1999 ethnic Albanians killed during the Kosovo conflict were thrown into the water and possibly partly covered with soil; finally, in 2000 a road construction company (the new owner of this property) used heavy machinery to level and flatten a large part of the southern zone of the quarry in order to create parking for its working machines and trucks and to build its administrative building.

There was no obvious grave-pit outline, and so the archaeologists started with stratigraphic methods in the zone where the first skeletal remains were found. The excavations demonstrated a complex stratigraphy with seven different deposits of sediments, not properly deployed as the result of the disposal of human remains using heavy machines (Figure 36.3). A total of 45 bodies (complete or almost complete) and 88 dislocated body parts were recovered. In addition, 25 dislocated groups of bones were found on the surface, all with associated evidence. The remains were commingled, disturbed and mostly skeletonised. Unfounded rumours had been circulating that the site had contained many more bodies, so the families of the victims (and some



Figure 36.3 Example of a section with complex stratigraphy with seven different deposits of sediments, largely disturbed as the result of disposal of human remains using heavy machines

organizations and media) showed distrust that the mass grave had been explored completely. For this reason, additional extensive digging and investigation of the entire area were required.

In addition to dealing with the complexity of the site itself, the forensic team invested extensive effort in answering the questions of different interest groups. For instance, the public considered it important to know whether the company's administrative building was intentionally built on the site where the bodies had been previously buried. As a result of this concern the building was demolished, and its solid concrete foundation was removed. This action was followed by the excavation of a series of six deep control trenches (Figure 36.4). To compare the actual morphology of the area with the satellite footage made by NATO in 1999, extensive excavations were carried out to reveal the original bank of the lake and adjacent bottom. No human remains were found, and it was demonstrated that this zone was not part of the mass grave.

The crime scene was recorded in detail using photo documentation and the standard archaeological practice of labelling stratigraphic layers. An EDM total station was used to accurately survey all of the site's features and contents, including the position of body parts and associated evidence. Internationally approved principles and procedures were followed during the excavation. However, archaeologists from EULEX responsible for the total station data have not yet produced maps illustrating the spatial relationships between different types of evidence. Probably the change of EULEX archaeological staff soon after the completion of the excavations in Rudnica interfered with continuity and therefore completion of their work.



Figure 36.4 Series of deep control trenches excavated to check whether a house located on the site was intentionally built on the place where the bodies had been buried

Following the first DNA-based identifications (which were obtained before the completion of the excavations), it became immediately clear which event was associated with this mass grave, which group of missing persons the remains represented, and where the primary inhumation site was from which the remains originated. These findings created the impression that it was not necessary to strictly adhere to archaeological protocol to the very end in terms of producing maps detailing the relationship between body parts and evidence.

The anthropological work was routine, but the presence of numerous firearm injuries required additional time and collaboration with forensic pathologists (Figure 36.5). The EULEX team had monitored the mission, but contrary to the actions of the archaeologists who had actively participated in the exhumation—and the crime scene investigator who had been conducting the photo documentation—their anthropologist decided to work alone. The anthropologist produced separate analyses for each particular case, even though analyses had already been completed by the forensic team. However, the anthropologist did not present any public report about the results of the analyses.

The last part of the fieldwork involved morphological and contextual analyses of dislocated bones in an attempt to reassociate skeletal elements as well as the collection of the rest of the DNA samples. The forensic team worked for two final weeks under time constraints with pressure from the judge as well as financial restrictions. Such working conditions are challenging for the leader of the forensic team and require additional efforts to keep relationships cordial and to allow room for the forensic professionals to work efficiently.



Figure 36.5 Fragmented skeletal material and multiple injuries require additional time for anthropological and pathological analysis

Conclusion

Personal experience excavating mass graves created in recent conflicts highlights the importance of profound preparatory work required to manage the various social and political factors involved in each mass grave discovery, the complexity of the mass grave context itself, and the different kinds of expertise necessary to conduct the exhumation and identification process. Many forensic experts have emphasised the particular roles of different forensic disciplines, understanding which are necessary to meet the challenges of mass grave excavation (Skinner 1987; Connor & Scott 2001; Haglund 2001; Owsley 2001; Buck 2003; Steadman & Haglund 2005; Wright, Hanson, & Sterenberg 2005; Congram 2010; Tuller 2012; Blau 2015). The problems of authority, the responsibility of forensic scientists, and the complex role of the crime scene manager have also been recognised in the literature (Skinner & Sterenberg 2005). Pragmatically, the following preparatory activities could help to avoid some of the obstacles that forensic teams frequently face. These activities should be the responsibility of the forensic team leader:

- Discuss with the authorities in charge the capabilities and limitations of each forensic discipline involved in the mission and clearly specify the aims of the fieldwork.
- Ensure that each expert in the field has access to the background of the case (including the witness testimonies, photos, and so forth).
- Specify the role and activities of monitors and other organizations involved in the fieldwork.
- Prepare the protocols for excavation, anthropological and medico-legal analyses, DNA sampling, storage of human remains and evidence, and documentation and chain of custody.
- Discuss with the team members all aspects of the protocol to ensure good cooperation between experts from different backgrounds.
- Discuss with the authorities issues related to financial and time limitations.

Even if all these requirements are fulfilled before excavation, a lot of *ad hoc* decisions and compromises should be expected during the mission.

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Forensic Investigations in Guatemala

The Continuing Search for Truth, Justice, and the Missing Two Decades after the Peace Accords

Caroline Barker, Ambika Flavel, and Claudia Rivera Fernández

The existence of clandestine and hidden cemeteries, as well as the anxiety suffered by many Guatemalans as a result of not knowing what happened to their relatives, remains an open wound in the country. . . . To heal these particular wounds requires the exhumation of secret graves, as well as the definitive identification of the whereabouts of the disappeared.

(CEH 1999 paragraph 54 p. 28 English version)

In Guatemala, civilian victims of arbitrary executions, killed during the civil war that ended in 1996, were disposed of in clandestine graves throughout the country. In the early 1990s survivor groups contacted experienced forensic anthropologists from North and Latin America to request their assistance; these graves needed to be located and the human remains identified. The first Guatemalan forensic anthropology team (Equipo de Antropología Forense de Guatemala—EAFG) was created in 1992 (and in 1997 became the Fundación de Antropología Forense de Guatemala—FAFG) in order to develop local capacity to find and identify the missing.¹ This humanitarian task came to the forefront after the United Nations–brokered peace agreement was signed by the Guatemalan National Revolutionary Unity (URNG) and the Government of the Republic of Guatemala in Oslo in 1996. In response, additional forensic teams, including the Human Rights Office of the Archbishopric of Guatemala (ODHAG) (founded in 1997) and the Center for Forensic Anthropology and Applied Science (CAFCA) (founded in 1999), were formed. Today these nongovernmental organizations (NGO) are largely run and staffed by Guatemalan nationals. Guatemala's forensic teams contribute to four principle aims: returning remains to relatives; historical documentation; legal proceedings; and deterring continued violations (Kirschner & Hannibal 1994), and their history and development is comprehensively documented in Stover and Shigekane (2002).

The recovery and identification of the remains of missing persons have humanitarian, legal, and economic outcomes; among other things, next of kin can know the fate of their loved ones, burial preferences can be honoured, goods and property can be inherited, and spouses can remarry.

Guatemala's Internal Armed Conflict

Guatemala, like many countries in Latin America, has had a tumultuous past. A lack of social cohesion between the different ancestral and socioeconomic groups and periods of political and civil unrest have prevailed since its independence from Spain in 1821, the most recent period being the 36-year internal armed conflict that ended in 1996. The conflict was not a simple two-sided discord between two opposing factions; there were a number of state and non-state actors involved. The foreign policies of the United States (USA) at that time facilitated the actions of the state-sponsored counterinsurgency regime, while concurrently turning a blind eye to the human rights violations being committed (CEH 1999).

The complexities of the conflict are covered in depth in the 1999 report of the Commission for Historical Clarification (CEH), established to fulfil a ruling of the Oslo Accord to determine the truth about the conflict (CEH 1999). During the conflict an estimated 200,000 people were killed or disappeared, which had a devastating effect on the population (Chamarbagwala & Morán 2011). The CEH determined that 669 massacres had been perpetrated and concluded that the majority of the atrocities and human rights violations had been committed against those who were ethnically Maya (83%), attributing 93% of all the human rights violations and violence to agents of the State.

Non-state actors were also found by the CEH to be responsible for human rights violations, but the scale of these atrocities (3% of all CEH recorded human rights violations) was considerably less than that of the State. The CEH defined the *State* as those public servants and state agencies that were complicit in the human rights violations. Those recognizable state forces that witnesses and survivors testify to having perpetrated crimes against noncombatants are the State's National Army, Military Commissioners, Civil Patrols (PACs) and Death Squads, and other members of the State security forces (CEH 1999). These state-sanctioned forces acted collectively and independently throughout the conflict.

Armed confrontation occurred between the State and the armed insurgency forces of the Guerrilla, of which there were four principal left-wing groups, each with its own military command structures: the Guerrilla Army of the Poor (EGP); the Revolutionary Organization of the People (ORPA); the Rebel Armed Forces (FAR); and the Guatemalan Labor Party (PGT). These groups eventually combined in 1982 to form the Guatemalan National Revolutionary Unity (URNG), which became the political wing of the various guerrilla organizations.

The peak of the violence occurred from 1978 to 1983, during the presidential regimes of Generals Lucas García (1978–1982) and Ríos Montt (1982–1983). Lucas García's counterinsurgency campaign was characterized as bloody and chaotic and viewed by many in the military as counter-productive, fuelling the rural poor's opposition to the State and sympathy with the insurgents (Open Society Justice Initiative 2013). Thus in March 1982 General José Efraín Ríos Montt seized power in a military coup, overturning the constitution and taking *de facto* control of the three branches of government: executive, legislative, and judicial. Ríos Montt had complete control of all the state institutions responsible for maintaining law and order and representation of the people, making him and his government (including the military) accountable to no one.

In April 1982 Ríos Montt launched his National Plan for Security and Development (PNSD), detailing the national objectives of the Military Junta to eliminate the "internal enemy" (who could be anyone involved in activities the State disapproved of; Flavel & Barker 2009) and remove its civilian support base in those areas identified as combat zones. The PNSD identified the main areas of conflict "red zones," including the departments of El Quiché, Huehuetenango, and Chimaltenango—areas largely populated by the indigenous Maya. The military operational

plans, known as Victoria 82 and Firmeza 83, set out the guidelines and methods designed to achieve the PNSD's strategic goals. Implementation of these plans saw the military adopt a scorched-earth policy, with the killing, torturing, raping, and displacement of thousands of unarmed mainly indigenous Maya. Survivors of the violence were relocated to "model villages" as part of the State's economic and social development program and ambition to "change the mentality"² of the Maya people and make them more Ladino.

Plan Sofia was the military's operational plan specifically for the Ixil area of the country.³ The records make specific reference to the killing of indigenous noncombatants (Open Society Justice Initiative 2013). It is also clear that military orders were carried out with the consent and knowledge of then President and Commander in Chief of the Military, General Ríos Montt, and other high-level military officials (National Security Archive 2009). Evidence of the crimes committed and command responsibility and intent to commit such acts form the basis of the January 2012 indictment for genocide and crimes against humanity against the former general (see the case study at the end of the chapter).

The human rights violations and abuses committed by all parties to the conflict were carried out with impunity, owing in part to the ineffective judicial system in place at that time. This deficiency of an available system of legal recourse gave rise to, and enabled, a regime of state social control through the use of military intelligence, military force, and internationally sanctioned counterinsurgency techniques. While recent attempts have been made to rectify these inadequacies and address the issue of impunity, Guatemala still struggles to realize justice for the victims.

The CEH report provides the facts and figures of the violations and the witness and survivor testimony name the missing in a process that endeavoured to make the truth available. However, the *prima facie* physical evidence is the human remains of men, women, and children interred in clandestine graves across the Guatemalan landscape, which has been used to demonstrate the link between the military's counterinsurgency plans and orders and the brutal consequences of their implementation (see the case history).

Guatemala's Legal Framework

Articles 1 and 2 of the Political Constitution of the Guatemalan Republic (Guatemala 1993) define the State's responsibility to protect its citizens and guarantee fundamental rights and freedoms; the constitution also grants the Supreme Court of Justice (which include three chambers covering criminal, civil, and constitutional matters) the authority and competency to judge any violations of these rights or other procedures established by the law.

Article 1, Protection for the individual: The State of Guatemala is organized to protect the individual and the family; its principal aim is the achievement of the common good.

Article 2, Duty of the State: the duty of the State is to guarantee the people of the Republic life, liberty, justice, security, and personal development.

Since the mid-1990s the performance of the courts has resembled an adversarial system, where the role of the court is to act as an impartial arbiter between the prosecution and defense (Torres 2007). The burden of proof rests with the prosecution who needs to prove "guilt beyond a reasonable doubt" and a judge (or panel of judges) decides on the accused's guilt or innocence.

In 2009 a Supreme Court decree (No.21-2009) paved the way for Guatemala's courts for High Risk Crime, the *Tribunales de Mayor Riesgo*. Adjudication by these special courts is in relation to

specific crimes, such as genocide, torture, crimes against humanity, and those related to organized crime. The existence of these courts is in response to the protection and security issues faced by judges, prosecutors, defenders, and witnesses in high-profile cases and, entrenched corruption within the judiciary, police and military (The Center for Justice and Accountability 2014). Extra financial and technical resources as well as security are given to judges to help them to concentrate on hearing these “high-risk” cases. Impunity for serious crimes in cases implicating state involvement (past or present) or people in position of power was, and remains, commonplace.

The Judicial System and Forensic Anthropology Investigations

In 2003 the three NGOs then working in the field of forensic anthropology (FAFG, CAFCA, and ODHAG) recognized the need to harmonize working methods and clearly outline the Guatemalan laws applicable to the exhumation process and the identification of the missing. Together with prosecutors and forensic pathologists from the Public Ministry (*Ministerio Público*, MP) they wrote the Manual for the Procedures of Forensic Anthropology Investigations in Guatemala (FAFG, CAFCA, & ODHAG 2004). This manual is based, in part, on the internationally recognized Minnesota Protocol⁴ (UN 1991) and adapted to the Guatemalan context. In 2005, under MP general instruction No.12-2005, the manual was accepted as the national protocol for such investigations.

On behalf of the State,⁵ the Department of Public Prosecutions (DPP) of the MP is charged with the responsibility of investigating complaints, determining whether there is sufficient evidence to show that a criminal offence has been committed, and charging the accused. The DPP is obligated to investigate any substantial accusation against a person or group. In cases of suspected illegal burial, any person may file a complaint to the police, MP, or the court.⁶ A petition to the DPP to investigate⁷ can be made by the victims, relatives of victims, and human rights or legal organizations.⁸

During the conflict many of those killed were either buried in inaccessible places, or in shallow graves where they were executed. As a consequence, only relatives, neighbours, and (on occasion) the perpetrators know their exact location. For example, in 2012 the remains of 426 individuals, the victims of enforced disappearance, were discovered at the military base of CREOMPAZ. These individuals had been secretly abducted, imprisoned, and killed by state forces at different times during the conflict, and the whereabouts of their subsequent burial were known only by those involved in the crimes. Relatives of the missing and disappeared understandably want the remains of their loved ones found and returned.⁹ To achieve this goal the relevant permissions from the DPP¹⁰ and the assistance of forensic experts skilled in antemortem (AM) data collection, field techniques to locate and excavate clandestine graves, and laboratory methods to analyse skeletal or decomposing human remains are required.¹¹

From the preliminary investigation stage, the DPP will usually call on the forensic expertise of such organizations as the FAFG and CAFCA. Agencies of the State, such as the National Civilian Police (PNC), are also obligated to offer the courts and prosecutor any assistance required to carry out their investigations.¹² However, in Guatemala the police do not routinely investigate these or many other types of serious crimes; the authority to investigate is entrusted to the investigating judge or prosecutor (Articles 1 and 2 of the LOMP 1994), and thus it is the prosecutor or an investigating judge who generally directs the activities.

The appointment of a forensic expert¹³ (*perito*) to the investigation is a legally binding arrangement obligating the expert to submit to the court an expert's report¹⁴ (*peritaje*), which will be disclosed and accepted or rejected during the pre-trial hearing (*fase intermedia*)¹⁵ and may be used as evidence of grounds for a trial.

Consequently, an expert may be subpoenaed¹⁶ by the court to give oral testimony on his or her evidence and subjected to cross-examination. The expert can be questioned as to

competency (qualifications and experience), the chain of custody of the physical evidence, and his or her report contribution—such as the methods employed during the investigation, the findings, and the interpretation of the evidence (see Henneberg, Chapter 43 this volume).

The forensic findings by Guatemala's experts have been used in a number of high-profile trials; the FAFG was first called in 1999 to give evidence in the trial of former military commissioner Cándido Noriega and has recently provided evidence in the genocide trial of Ríos Montt and the co-accused (see the case history at the end of the chapter). Notably, in 2011 and 2012 the *Tribunales de Mayor Riesgo* secured historic convictions of military officers indicted for their involvement in the Dos Erres¹⁷ and Plan De Sánchez¹⁸ massacres in 1982 (The Center for Justice and Accountability 2014).

Delays in bringing to trial many of those accused of grave violations of human rights during the conflict have, in part, been due to the legacy of Guatemala's amnesty laws. Guatemala's general amnesty law of 1986¹⁹ gave amnesty to those responsible for, or accused of, political and related common crimes between March 23, 1982, and January 14, 1986. This act, in effect, covered any crimes committed during the presidential terms of office of Ríos Montt and his successor, Meía Victores.

After the signing of the peace accords in 1996 Congress issued decree 145-96 of the National Reconciliation Law, awarding a partial amnesty for certain crimes but excluding prosecution for crimes the State is obligated to prosecute under international norms,²⁰ such as genocide and enforced disappearances (Human Rights in Practice 2012). Congress also repealed all amnesty laws dating to before 1996²¹; however, former President and Commander in Chief Ríos Montt contests this ruling, believing he is entitled to the continued benefits of the 1986 amnesty.

The International Legal Framework

If it can be proven to the international community that all domestic judicial remedies have failed to investigate the status of those unaccounted for, international instruments can be activated. Relevant to the victims of Guatemala's conflict are the 1949 Geneva Conventions²² and additional Protocol II²³ (ICRC 2015a), which apply in all situations of noninternational armed conflict, and the customary international law instruments of the International Convention of Civil and Political Rights (ICCPR)²⁴ and the Inter American Convention on Human Rights (IACHR).²⁵

The Forensic and Psychosocial Impact of the Exhumation

The exhumation of clandestine graves is often a community event, with traditional Maya and Christian ceremonies carried out in accordance with the spiritual beliefs of the people. This collective gathering also provides an opportunity for psychosocial organizations such as the Community Studies and Psychosocial Action Team (ECAP), established in 1997 to provide support, advice, and access to trained psychologists.

The exhumation process also provides an opportunity to witnesses and survivors to give their statements to social anthropologists through informal, semistructured interviews. Their version of events is recorded, along with the collation of the biological details of the missing person (age, sex, stature, ancestry, and individuating criteria). The AM data provides the basis for any contextual²⁶ and presumptive identification²⁷ of the remains with a missing person and is often the first occasion when the missing are legally acknowledged as deceased.

Also at this time biological reference samples from living family members and the details of their biological relationship to the missing person are taken to enable DNA-assisted identifications. In Guatemala DNA-assisted identifications of the missing are made using kinship analysis,



Figure 37.1 Mayan priest and members of the community conduct a traditional ceremony at a clandestine gravesite to ask the spirits of the dead for permission to disturb the soil and recover the remains.

established through the statistical evaluation of the DNA profile of the missing person with the DNA profiles and pedigree of the biologically related family members. This complex scientific process is explained to the people (collectively or individually) in lay terms to secure their written and informed consent to use their biological data for this purpose.

Comparison of Witness Testimony and Physical Evidence

Reconciling the memories of families, witnesses, and survivors with the physical evidence is not an easy process. Inconsistencies often exist between the expected numbers of victims based on witness testimony, AM data of named missing persons, and the physical evidence. Inconsistencies are due, in part, to the problems of collecting information from witnesses over 30 years after the event, and the rural ethnic Maya still feel oppressed, fearing reprisals should they speak out. Nevertheless, for the exhumations performed by the FAFG (2015) between 1992 and 2013 ($n = 1595$), there is an average success rate of 63% (range 0%–100%, median 70%) for the location and recovery of human remains based on the number of reported victims. In general, the fewer individuals interred, the higher the correlation among the physical evidence, witness testimonies, and AM data of the missing. This correlation can be attributed to a tendency for people to overestimate casualty numbers in cases of mass trauma and to the difficulty in keeping track of internally displaced persons (IDPs). Needless to say, when information about a case is inaccessible, or witnesses do not wish to talk, the complexity of discovering the location of clandestine graves increases, often resulting in graves not being located.

The Forensic Exhumations

The figures published by the CEH are consistent with those demonstrated by the physical evidence. For example, the FAFG carried out exhumations in 22 departments of Guatemala, with human remains located and recovered in 20 (FAFG 2015). The five municipalities most

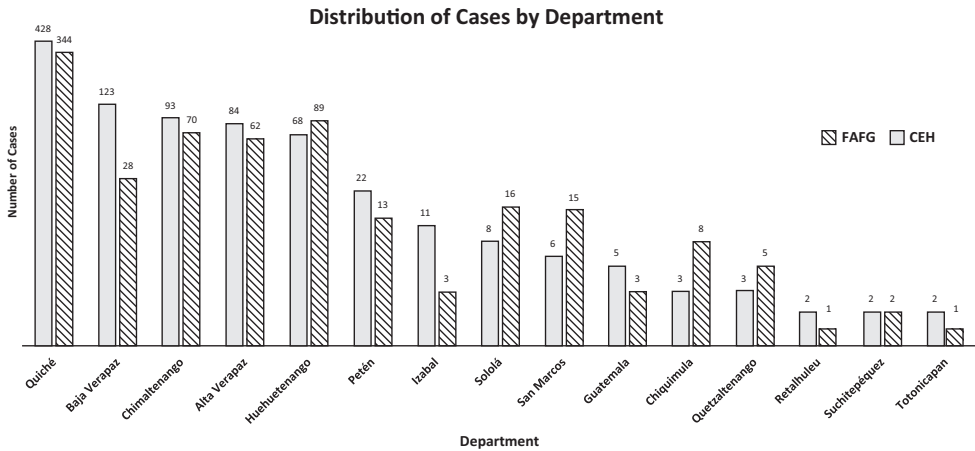


Figure 37.2 Comparison of the distribution by department of cases reported (CEH 1999) and cases where remains have been exhumed (FAFG 2015)

commonly visited by exhumation teams (Figure 37.2) correspond to the geographical and proportional distribution of the massacres recorded by the CEH (1999: 22 para 27), who state that “during the most violent and bloody period of the entire armed confrontation, 1978–1985, military operations were concentrated in Quiché, Huehuetenango, Chimaltenango, Alta Verapaz and Baja Verapaz, the south coast, and the capital, the victims being principally Maya and to a lesser extent Ladino.” The vast majority of cases exhumed by the FAFG relate to crimes committed between 1980 and 1984, with the greatest number (144) of cases belonging to crimes committed in 1983, at the peak of the violence (FAFG 2015).

The Forensic Anthropological Analyses

Biological Profile

The use of population-specific standards to determine the biological profile of skeletonized remains increases the accuracy of conclusions, especially in cases when multiple analysts are assessing the biological profile of minority populations over a long period of time (Barker et al. 2008).

Work undertaken on the Guatemalan population, either modern or archaeological, has been related to stature estimations (Genoves 1967; Haviland 1967; Danforth 1994; Wright & Vásquez 2003) or sex identification (Ríos Frutos 2002, 2003, 2005). Published material relating to forensic anthropology in Latin America, as İşcan and Solla Olivera (2000) state, has increased over time but continues to fall short of covering the diversity of the populations within Latin America (Spradley et al. 2008), and there is a demand for relevant literature to be available in the Spanish language.

There are distinct morphological differences between male and female adult skeletal remains in the Maya population, and, although not empirically tested, they have become standard indicators of biological sex accepted as accurate by the Guatemalan forensic anthropological community. Estimation of biological age is, perhaps, less confidently determined than sex. It is likely that, although the estimated age ranges may not reflect the actual ages of the individual, the chronological seriation of groups of remains is correct—that is, younger to older—and consequently the

overall shape of the demographic profile is accurate. Factors such as chronic malnutrition or stress (which may include physiological factors such as disease or diet or living under the pressures of a conflict) experienced by individuals during the growth and maturation period affect the timing of dental and skeletal development (Scheuer & Black 2000). However, although the development and maturation of skeletal features may be delayed, the sequence of those changes remains the same. A caveat, with regard to the indigenous rural Maya, is that a precise age at death of many of the deceased may not be known. The accuracy of the AM data is affected by deficiencies in witness recall 30 years after the killings—and many of the witnesses were very young and traumatized, and official documentation, such as birth certificates, is often absent.

Irrespective of these limitations, the demographic profile of the individuals analysed by the FAFG from 1992 to 2014 (FAFG 2015) correlate with the conclusions of the CEH. The profiles demonstrated that women were the victims of violence (Figure 37.3), representing a minimum of 12% of the total number of victims. Although adult females make up a considerable proportion of the victims, adult males represent the highest number (minimum of 50%) of skeletal remains recovered. Of the 38% of remains for which sex could not be identified, the majority is non-adult (19% of all remains). Furthermore, age distribution indicates that no age group was spared, with adults (aged 26+ years) representing 45% of those recovered; young adults (18–25 years) representing 22%; adolescents (13–17 years) 8%; children (4–12 years) 10%; and infants (0–3 years) 5%, and foetal remains account for 3% of the total, indicating that pregnant women were not spared.

Perimortem Trauma

The CEH does not publish figures relating to cause and manner of death, reporting only that “state terror was applied to make it clear that those who attempted to assert their rights, and even their relatives, ran the risk of death by the most hideous means” (CEH 1999: 26 para 48). Be that as it may, expert testimony given in high-profile trials (see the case history) and previous research (Flavel & Barker 2009) has demonstrated that a large proportion of those buried in clandestine graves exhibited perimortem trauma consistent with gunshot, blunt-force, and sharp-force trauma wounds (Figure 37.4).

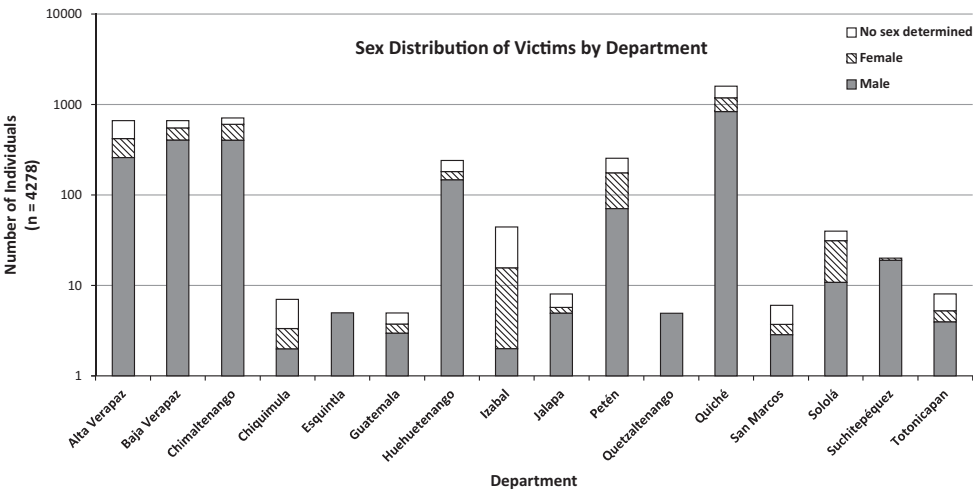


Figure 37.3 Sex distribution by department (≥ 5 individuals recovered) of remains exhumed by the FAFG from 1992 to 2014 (FAFG 2015)

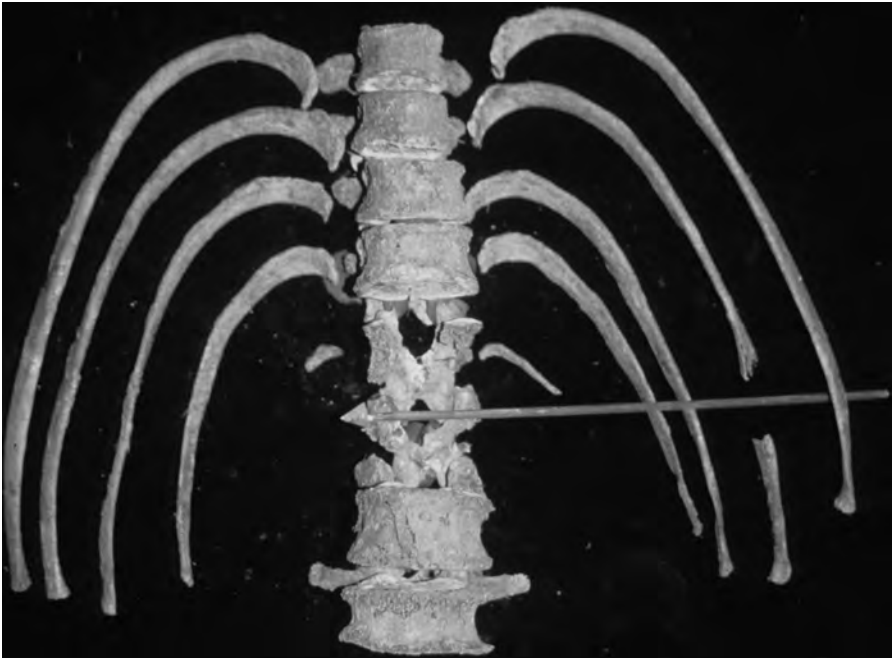


Figure 37.4 Examples of perimortem injuries sustained by victims to the conflict: adult Maya female with a gunshot wound affecting the ribs and vertebrae and adult Maya male with a machete injury to the left parietal of the cranium.

Identification

Personal identification involves comparing and attempting to reconcile AM data of the missing person with postmortem (PM) data established from the analysis of the remains. The International Committee of the Red Cross (ICRC 2003) acknowledges that comparing AM data (collected during interviews with relatives or acquaintances of the deceased) with PM data is an acceptable method of ascertaining a presumptive identification. It stands to reason that the more reliable and complete both data sets are, the greater the likelihood that remains can be presumptively identified. The reality is that this process is negatively affected by a general lack of availability of AM medical records in Guatemala. Also, the increasing time since burial of remains, often buried in shallow graves, adversely affects the PM preservation of both the remains and the artefacts (clothing, personal effects, and other associated evidence).

Fleshed bodies of victims were often visually identifiable at the time of their interment and known to those who buried them. These “closed contexts” enable the contextual identifications of the deceased, because the grave contains a sufficiently unique assemblage of human remains, clothing,²⁸ personal effects, and artefacts that are intimately known by a witness or witnesses, usually the person(s) who dug the grave.

Where the consistency between the findings of the forensic investigation and the witness evidence is viewed by the identification team (which includes anthropologists) as sufficiently robust to make a presumptive or contextual identification, this evidence is packaged to demonstrate that the probability of the deceased being someone else is extremely unlikely. A presiding judge or prosecutor will be the final arbiter and make the decision whether to legally acknowledge the identification. To date, using such methods the FAFG has identified just over 2,500 individuals.

Until relatively recently only presumptive and contextual identifications of the victims could be made. However, such identification is a difficult task and one that relies on the memory of witnesses or relatives to identify the dead through the recognition of clothing or personal effects. Consequently, approximately 63% of all remains exhumed in Guatemala are never identified (FAFG 2015).

Globally, DNA-assisted identifications are becoming increasingly widespread in forensic anthropological work, yielding results that are significant when combined with the physical evidence. For example, DNA-assisted methods were used to name 144 missing soldiers from WWI (Loe et al. 2014) and over 19,000 missing persons from around the world (International Commission on Missing Persons 2015). Initial progress on this front has been made through the establishment of the Latin American Initiative for the Identification of the Disappeared (LIID), an Argentinian initiative that also incorporates Guatemalan and Peruvian exhumation teams (Doretto & Pettit 2008).

Not satisfied with the identification rate in the region, the LIID enlisted the assistance of the Bode Technology Group, Inc. (Bode), in order to take advantage of DNA technology to increase the identification rate in Latin America (Weitz et al. 2009). The LIID received grant money from the U.S. Congress to initiate the project in 2007, involving the establishment of genetic laboratories and training of personnel in each respective country (Adams & Byrd 2014; Boles, Snow, & Stover 1995). A fully functional DNA laboratory, the first in Central America, was established in Guatemala during 2008 (García et al. 2009). Since then the Guatemalan program has received further financial support from the Forensic Assistance Project (FAP) and the Regional Forensic Assistance Network (RFAN), the main objective being to improve in-house capacity for comparing DNA from victims of human rights violations and reference samples as an identification tool. In 2013 the FAFG held a national sample collection campaign that allowed relatives of missing persons the opportunity to provide comparative samples to aid the identification of exhumed remains; thousands of samples were collected in this manner. To date

nearly 300 individuals have been identified using DNA-led methods (Giron 2013), and there is a strong possibility that (with continuing funding) an increasing proportion of unidentified remains, both retrospective and yet to be exhumed, can be identified in the future.

Reburial

In closed-context cases (where the group who died in an event is known) the unidentified remains are returned to the community for reburial alongside those that have been named. The remains are often reburied collectively, albeit in individual coffins, in accordance with the wishes and the cultural beliefs of the community. Facilities and resources do not exist to store the remains indefinitely, and long-term retention of remains would be culturally unacceptable to many. However, with the advent of DNA testing capability and programs to encourage more relatives of the missing to come forward and give DNA reference samples, reburial of the unidentified is becoming less common.

Despite the obvious challenges associated with identifying the missing it is worth remembering that the humanitarian component of this work is often fulfilled in the eyes of the survivors' and victims' families. Because these people live in small, tight-knit communities, their grief and experience are shared and form part of the community's collective history, with the missing grieved for by all its members. Legal identification of the dead is often not the primary concern; the observation of burial practices and recognition of the missing as found are felt to be more important.

Case Study: The Pursuit of Truth with Justice in the Trial of José Efraín Ríos Montt

We the Judges must state that . . . acknowledging the Crime of genocide affects all Guatemalans, because in addition to causing damage to the victims in particular, and to their families, it has also damaged the social fabric of the Guatemalan people. . . . acknowledging the truth helps to heal the wounds of the past . . . the pursuit of justice is a right of the victims, which also contributes to the strengthening of the rule of law in our country.

(Judges summing up in the trial of Ríos Montt, Open Society Justice Initiative 2013: 49)

Acknowledging and Atoning for Past Crimes

The marriage of truth with justice is often cited (for example, CEH 1999; Sanford 2001; Open Society Justice Initiative 2013; Henderson, Nolin, & Peccerelli 2014) and the pursuit of both, particularly in postconflict environments, viewed as central to the development of a functioning rule of law and to peace and reconciliation processes. The truth about the atrocities committed during Guatemala's internal armed conflict has been widely reported (CEH 1999; Sanford 2001; Stover & Shigekane 2002; Flavel & Barker 2009; Chamarbagwala & Morán 2011; Henderson, Nolin, & Peccerelli 2014). Further, the human and national experiences of the genocide and human rights violations are comprehensively covered in the documentary and testimonial evidence and forensic investigations collected and undertaken by organizations such as the CEH, REHMI, CIDH, FAFG, CAFCA, and ODHAG. Justice, however, has proven to be somewhat elusive. Nearly 20 years after the signing of the Oslo Peace Accords less than 30 people have been convicted for conflict-related crimes in Guatemala (Open Society Justice Initiative 2013). Those convictions are of mainly low-level military, police, and paramilitary personnel (International Crisis Group 2013).

Making Judicial History: The State Indicts a Former Head of State

History was in the making, when in January 2012 the former military general and *de facto* president José Efraín Ríos Montt (1982–1983) was indicted for genocide²⁹ and crimes against humanity³⁰ committed during his 17 months in power. This was the first occasion that a former head of state was to be prosecuted for genocide by a court of his or her own country (ICJ 2013; International Justice Monitor 2014).

The 2012 indictment of Ríos Montt and his codefendant, former chief of military intelligence José Mauricio Rodríguez Sánchez, related to 15 massacres that resulted in the deaths of 1,771 indigenous Ixil people, the forcible displacement of 29,000, at least 9 cases of sexual violence, and various cases of torture (Open Society Justice Initiative 2014). This indictment occurred over a decade after the original petition to the DPP, brought by the coplaintiffs and civil representatives of the victims, requesting the authorities to investigate and prosecute those responsible for the worst abuses during the conflict. The case was to be heard in Guatemala's Court for High Risk Crime. Finally all the evidence would be heard in an open, transparent judicial process. Was this the beginning of the end of impunity in Guatemala?

The Trial

Pretrial hearings began in January 2013 with the oral trial of Ríos Montt and his codefendant commencing in March 2013. To secure convictions for genocide and crimes against humanity, the prosecution placed a premium on evidence demonstrating the elements of command responsibility³¹ and intent³² to commit these crimes.

The Prosecution presented testimony from more than 100 survivors of massacres, displacements, torture, and rape and from experts in the areas of the military (hierarchy and chain of command), forensics, statistics, sociology, psychology, and history (Open Society Justice Initiative 2013). The defense presented nine witnesses, including military chain of command experts (Open Society Justice Initiative 2013). However, rather than presenting direct testimony to refute the charges, the defense relied on a commonly used tactic in such cases to stall and undermine the process, filing numerous *amparos*³³ petitioning for remedies to perceived violations of constitutional law or legal procedures (ICJ 2013).

The Forensic Evidence

Social anthropologists and forensic archaeologists and anthropologists from the FAFG and CAFCA were called to give expert testimony on the material that had been previously accepted into proof.³⁴ Their evidence covered several cases they, or their NGO, had been directly involved in, relating to several hundred victims killed or disappeared by state actors between 1982 and 1983.

During the examination in chief, general explanations were given on the processes and methods employed during the exhumations and analysis of the remains, including personal identification of remains based on genetic and osteological data and chain of custody procedures (International Justice Monitor 2013a, b). In addition, individual experts testified about their specific findings in particular investigations (International Justice Monitor 2013a, b), including the number of individuals recovered in a particular case, the demographic profile of the deceased (men, women, children of all ages, and infants and newborns), the range and type of perimortem injuries sustained (projectile, blunt-, and sharp-force trauma), and the consistency of these patterns of injury to defense wounds (for example, cut marks to bones of the hands) and execution-style killings. Particularly compelling testimony detailed the exhumation of the

skeletal remains of three women in advanced stages of pregnancy in Sajsivan, Quiché, leading the expert to conclude that these women were defenseless victims of war. Also, according to the style of clothing, earrings, and other personal effects recovered on remains and in the grave, an FAFG expert testified that the remains recovered in 1998 from Chel, Chajul, and el Quiche were Maya Ixil (International Justice Monitor 2013c).

The FAFG presented their analysis of perimortem trauma patterns based on 420 individuals from 227 graves related to 114 cases, of which 31% (130/420) of all individuals were subadults less than 12 years of age (Open Society Justice Initiative 2013). The results were used to demonstrate that the victims were civilian noncombatants, primarily because of the inconsistency of the trauma sustained to the remains with patterns of combat injuries from other conflicts—giving credence to the FAFG's assertion that the injury pattern observed was consistent with execution-style killings. Of the 338 wounds to 157 individuals, 162 were gunshot wounds and the remainder blunt- and sharp-force trauma; 75% of the trauma affected the bones of the head and thorax, and 83% of all wounds were classified as fatal (International Justice Monitor 2013b)—figures much greater than those observed in combat casualty statistics. For example, Champion and associates' (2003) study of several modern conflicts (for example, the World, Gulf, and Korean Wars) found that penetrating head and thorax injuries (fatal and nonfatal) affected 51% of soldiers (killed in action, wounded in action, died of wounds), and the average combat fatality rate was 20%.

The defense cross-examined the forensic experts on their credentials, and during closing arguments levelled particular criticism at the forensic evidence, stating that such evidence was unreliable because it was incapable of identifying the person responsible for any death or the exact date of the deaths (Open Society Justice Initiative 2013). This tactical and wilfully simplistic approach of viewing the physical evidence in isolation ignored its corroborative characteristic—for example, recovered artefacts (coins, documents) indicating the time period in which the crimes had occurred that were consistent with the recollection of survivors.

A Short-Lived History: Ten Days from Verdict and Judgment to Annulment

In a packed courtroom on May 10, 2013, history was briefly made. Handing down its verdict the Court found the accused José Efraín Ríos Montt guilty of genocide and crimes against humanity and sentenced him to 80 years in prison; his co-accused Rodríguez Sánchez was acquitted of all charges. With this landmark ruling Guatemala's domestic courts were the first in history to successfully convict a former head of state for the crime of genocide (International Crisis Group 2013).

The 718 pages of written judgment, issued on the May 17, 2013 (Organismo Judicial 2013), brought together all the evidence as a coherent narrative. The witness testimony, military operational plans and reports, and the forensic and statistical evidence showed that a disproportionate number of the indigenous Maya Ixil, compared to non-indigenous population, had been targeted and killed.

The judgment detailed the facts that the prosecution had proved to be consistent with the crimes of genocide and crimes against humanity set out in the indictment. It elaborated on the elements consistent with Ríos Montt's command responsibility and intent to commit the crimes. Principally, as *de facto* head of the branches of government and commander in chief of the military, Ríos Montt was responsible for the National Plan for Security and Development (PNSD) and was aware of and sanctioned the military's counterinsurgency operation plans, Victoria 82, Firmeza 83, and Sofia. Moreover, he failed to prevent or punish acts by his subordinates that constituted genocide and crimes against humanity.

The State's plans and counterinsurgency operations effectively institutionalized the elimination of the Maya Ixil population—primarily because 100% of the population was classified as

the “internal enemy,” and civilian noncombatants of all ages were viewed as collaborators and sympathizers and the social support base for the insurgency. The killings, abductions, forcible transfer of children, and destruction of land and property were part of a planned, coordinated, and widespread response intent on destroying the Maya Ixil as an ethnic group. Cultural expressions such as wearing traditional clothing and using the Ixil language became a threat to life and liberty. Women were seen as a legitimate military objective: they were the victims of rape and sexual assault by members of the military as part of a systematic and widespread campaign to destroy the social fabric of the Ixil people, causing serious bodily and mental harm. The relocation of the Ixil people to Ríos Montt’s “model villages” was part of a concerted effort to reeducate and dilute the Ixil culture. Further, the forced conscription of Ixil members into the PACs had destroyed communities and created mistrust and fear.

In the judgment the forensic anthropological and archaeological evidence was affirmed as providing the physical proof confirming the testimony of the surviving victims. Furthermore, the statistical evidence demonstrated that the army had killed 5.5% of the indigenous population in the Ixil area between April 1982 and July 1983 (Open Society Justice Initiative 2013).

Lamentably, justice and the making of history were to be short-lived. Ten days after the verdict the ruling was effectively annulled on procedural grounds (partial mistrial) by the constitutional court,³⁵ in a bewildering three to two decision by the panel of judges and a seemingly perverse misuse of the *amparo* process. A scheduled retrial in January 2015 came across new procedural obstacles and objections, resulting in the recusal of one of the new trial judges. The case against the defendants was in limbo at the time of this publication, and Ríos Montt continues to try to evade justice by citing his right to amnesty, based on the repealed general amnesty law of 1986.

Right to Reparations

An important aspect in the pursuit of justice and reconciliation is the right to adequate reparation. The right to reparations is a norm recognized in the international and human rights instruments of the Universal Declaration of Human Rights (UDHR 1948) Article 8, ICCPR Articles 2(3), 9(5) and covered domestically under Article 124 of the Penal Code of Guatemala (CPP 1992) and the Peace Accords recommendations (CEH 1999). Despite the failure of the attempt to endow the victims with access to justice, the process has given prominence to the victims’ concept of suitable reparations. The court approved 12 of the 25 reparations requested by the civil parties representing the victims (International Justice Monitor 2014). Of particular note is that none of the requests were for money; all were directed at the State.

The requested reparations were motivated toward state-sponsored education, memorialization, and remembrance measures to ensure that history did not repeat itself, the genocide could no longer be denied, and the coexistence of the rich cultural diversity and multilingual nature of Guatemala was respected and preserved. Examples include requests made for public apologies from the Guatemalan government, the creation of a National Day Against Genocide, the setting up of memorials and a cultural centre to honour the victims and preserve the historical memory, and education measures to disseminate the trial judgment and train the military, police, and other state agencies on human rights and International Humanitarian Law (IHL) and to set up schools in the communities affected by the genocide (Open Society Justice Initiative 2013; International Justice Monitor 2014).

It would seem that those who have suffered and continue to suffer the most view actions intent on promoting respect and dignity for the victims and confronting the past as critical elements of truth, justice, and accountability.

Acknowledgments

This chapter is dedicated to all victims, past and present, and to those who dedicate their lives working to establish the truth and achieve justice. Many thanks to Mirko Fernandez for advice relating to international human rights and humanitarian law.

Notes

- 1 “Missing person is a person whose whereabouts are unknown to his/her relatives and/or who, on the basis of reliable information, has been reported missing in accordance with the national legislation in connection with an international or non-international armed conflict, a situation of internal violence or disturbances, natural catastrophes or any other situation that may require the intervention of a competent State authority” (ICRC 2009: Art.2a).
- 2 “The population’s mentality is the principal objective,” Plan Victoria 82[3] (National Security Archive 2013).
- 3 The Ixil people are from the three municipalities of Nebaj, Chajul, and Cotzal in the department of El Quiché.
- 4 The Minnesota Protocol has been referenced in inter-American and UN human rights jurisprudence and is legally recognized as minimum international standards.
- 5 Art. 251 of the Constitution
- 6 Art. 297 CPP
- 7 Art. 117 CPP
- 8 The Center for Human Rights Action (CALDH) and the Justice and Reconciliation Association (AJR) civil representatives in the petition against General Efraín Ríos Montt (see the case history at the end of the chapter).
- 9 A temporary Executive Commission (order No. 264-2006) was set up in 2006 to deal with tracing of involuntary disappearances during the conflict and coordinate the efforts of state and non-state actors. Arts. 201 and 203 of the CPP cover the crimes of enforced disappearance and illegal detention. International obligations to account for the missing are covered under Customary IHL chapter 36, rule 117 (ICRC 2015b).
- 10 Art. 311 CPP
- 11 Arts. 108, 110, 225 CPP
- 12 Art. 12 CPP & LOMP Art. 10
- 13 Art. 227 CPP
- 14 Art. 234 CPP
- 15 Before the judge the prosecution presents their evidence, and the defense has the opportunity to contest the inclusion of elements of the investigation based on points of law. At the end of this stage the judge gives a written ruling on whether the defendant(s) will proceed to the trial stage.
- 16 A subpoena is formal document that orders a named individual to appear before a duly authorized body at a fixed time to give testimony.
- 17 In August 2011 four soldiers were sentenced to a total of 6,060 years each for their roles in the murders and crimes against humanity. Argentine and FAFG experts provided testimony, including about DNA results during the trial.
- 18 In March 2012 five PAC members were sentenced to a total of 7,710 years for their roles in the murders and crimes against humanity. The FAFG provided expert testimony during the trial on 88 sets of remains they recovered.
- 19 Congress Decree 8-86, January 1986
- 20 Customary IHL chapter 44 rule 158 (ICRC 2015b)
- 21 Decree 133-97
- 22 Signed by Guatemala 1952
- 23 Signed by Guatemala signed in 1977 and ratified in 1987
- 24 Ratified by Guatemala in 1992
- 25 Ratified by Guatemala 1978
- 26 Contextual identification of a group or individual set of remains details contextual consistencies between the remains, artefacts, and burial context, the AM data, and witness testimony.
- 27 Presumptive identification of an individual is based on the consistencies of biological profile and individuating criteria of a set of remains and AM data of a named missing person.

- 28 Clothing of Maya people, especially of indigenous women, is distinctive, and there is a high degree of individuation in colours and patterns and recognizable as belonging to a particular individual. Also see Hendrickson (1995).
- 29 Covered under the Convention on the Prevention and Punishment of the Crime of Genocide: *Resolution 260 (III) A of the United Nations General Assembly, 9 December 1948 ratified by Guatemala in 1950* and Article 376 CPP of Guatemala.
- 30 Crimes against humanity are not codified in a specific treaty but cover the acts of persecution against any identifiable group or collective on political, racial, national, ethnic, cultural, religious, gender, or other grounds that are universally recognized as impermissible under international law, when committed as part of a widespread or systematic attack directed against any civilian population, with knowledge of the attack (Human Rights in Practice 2012).
- 31 Commanders and other superiors are criminally responsible for war crimes committed by their subordinates if they knew, or had reason to know, that the subordinates were about to commit or were committing such crimes and did not take all necessary and reasonable measures in their power to prevent their commission, or if such crimes had been committed to punish the persons responsible: Customary IHL, chapter 43, Rule 153 (ICRC 2015b).
- 32 The determination to perform a particular act or to act in a particular manner for a specific reason; an aim or design; a resolution to use a certain means to reach an end (<http://www.Legal-dictionary.thefreedictionary.com/intent>, accessed March 6, 2015).
- 33 The constitutional court deals with *amparos*, a legal instrument providing protection for constitutional rights and remedying violations of constitutional laws or procedures. The *amparo* process in Guatemala is often abused and used as a mechanism to obstruct justice and delay due process (International Crisis Group 2013).
- 34 Arts. 234, 235 CPP
- 35 For further details see International Crisis Group (2013); International Justice Monitor (2013a, b); Open Society Justice Initiative (2013).

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Continuing Challenges for Forensic Archaeology and Anthropology in Iraq

Derek Congram, Jon Sterenberg, and Oran Finegan

ي العجلة الندامة و في التاني السالم

In haste there is regret, but in patience and care there is peace and safety.

الصبر طيب

The first edition of this chapter (Congram & Sterenberg 2009) was by non-Iraqis and took an etic approach. We were among the couple of dozen forensic archaeologists and anthropologists who were doing much of the forensic work related to grave surveys, excavations, and anthropological analysis in Iraq in the first years following the invasion by Coalition Forces in 2003. In an effort to mitigate the shortcomings of the perspective of outsiders, we are joined by another author [O.F.] who, although also a foreign national, has spent much time in Iraq in his role as a forensic advisor working for the International Committee of the Red Cross (ICRC).

There are some things that have not changed since the first edition of this chapter. Because of the scale of missing persons presumably buried in anonymous graves throughout Iraq from various 20th- and 21st-century events, it is not surprising that the majority of victims remain unexhumed in these graves. As highlighted in the previous version of this chapter these events and crimes include killings of Iraqis by the occupying British of the 1920s and 1930s, political conspirators against Saddam Hussein in 1979, Iranian prisoners of war in the 1980s, Iraqi Kurds in the 1980s and 1990s, hundreds of Shia in Dujail following an attempted assassination attempt of Saddam Hussein, Kuwaiti prisoners of war in the 1990s, Iraqi civilians and military by UN-sanctioned forces in 1991, Iraqi Shia following the 1991 Gulf War as well as in Najaf in 1999, and the more than 100,000 noncombatants who have died as a result of fighting following the Coalition invasion and change of governments since 2003.

The former Human Rights Minister of Iraq stated that the Ba'ath Party regime "turned Iraq into a 'massgrave-istan' by the scale of their crimes" (Burns 2004). The number of individuals still missing as a result of the Iran-Iraq war is in the tens of thousands. In only five years since 2003, tens of thousands more have gone missing within Iraq (Serafin 2008; Williams & Al-Salhy 2009). The scale of missing persons is difficult to comprehend, yet understanding and resolving the

issue of the missing are responsibilities held by the Iraqi state under international law. Further, Iraq ratified the Convention for the Protection of all Persons against Enforced Disappearances on November 23, 2010.

Iraq has one of the oldest medico-legal institutes in the region, having been founded in 1939, although limited forensic work was being done previous to the establishment of the institute. A law on forensic medicine was passed in 1987, although it has been superseded by a new law, signed in 2013, establishing the Medico Legal Directorate (MLD). Although continuing violence has hindered development in some regions, until recently others (such as the Kurdish north and Basra and Najaf in the south) were accessible to international support. Development has been further affected by the emigration of many highly trained practitioners over the past decade.

Sources of Information

One particular advantage of an updated and distinct version of this chapter is that there is now a larger body of published work to draw from. There are, of course, continuing press reports, which owing to a lack of detail do not contribute much to a discussion on forensic work in Iraq. Slightly more detail can be gleaned from specialized publications, such as *National Geographic* (Simons 2006) and *Archaeology* magazine (Pringle 2009), but the information that can be obtained from these sources often lacks critical analysis. Much of what is now available in academic journals is discussion about the criminal legal system within which forensic work has been presented. More pertinent, however, is debate published about the ethics of archaeologists/anthropologists who were engaged with (or perhaps more appropriately, “working for”) coalition militaries and foreign governments. To be clear, these archaeologists and anthropologists were also working for a new Iraqi government. This association included support for a new judiciary and special court, which tried and in several cases convicted and executed several members of the former regime, including former President Saddam Hussein.¹ Although there are a few publications now available that relate directly to forensic archaeology and anthropology in the country, only one (published in a volume that, by its title, will be found by few forensic practitioners) reports any meaningful quantitative data on the work performed so far (Trimble & Malin-Boyce 2011). Oral presentations by anthropologists and other forensic investigation team members were given at the 2008 annual meeting of the Society for Historical Archaeology, but these have neither been published nor made public (see Congram 2015).

Human Rights Watch has produced several reports related to disappeared persons, mass graves, and forensic investigations in Iraq (for example, Human Rights Watch 2003, 2004, 2006). Similarly, Amnesty International produces regular reports on human rights in the country, including incidents of enforced disappearance and mass killings (for instance, Amnesty International 2014).

Unsurprisingly, there are contradictory reports. Following the 1991 Gulf War, U.S. Lieutenant General Charles Horner, responding to questions about the number of Iraqi deaths, stated: “I think eyewitness accounts on the battlefield support probably less than 10,000 casualties. . . . We didn’t find any mass graves. We didn’t find any large numbers of people dead from attacks” (in Heidenrich 1993). However, an intrepid journalist was quite able to find mass graves of Iraqis killed in bombings by UN forces, buried and very inadequately marked (in violation of the Geneva Conventions) by U.S. soldiers (Fisk 2005: 845–53). This contradiction is one of many whereby it is necessary to negotiate probable fact by critically assessing the few sources available, typically government or military and press reports.

The Recent Past

Before and including part of 2003, the ICRC² was working with the medico-legal authorities in Iraq to help refurbish its facilities. In 2003 the ICRC temporarily reduced the number of its international staff in Iraq following the bombing of its offices in Baghdad and the death of a number of its staff. However, they continued to provide support and training to forensic staff in Iraq. Soon after the 2003 invasion, various organizations including the U.K.-based Inforce, the seemingly now-defunct Archaeologists for Human Rights, the International Commission for Missing Persons (ICMP), and the U.S. Department of Justice's Regime Crimes Liaison Office (RCLO) (all in coordination with the Coalition Provisional Authority), went to work in Iraq with enthusiasm. Baraybar, Brasey, and Zadel (2006) used the example of Kosovo to warn against poorly planned and coordinated exhumations and autopsies, as well as noting the need for a centralized approach to investigations. In the years following the 2003 invasion a certain lack of coordination among international organizations in Iraq was due to many factors including poor preparation for the preservation of mass graves as evidence of past crimes, the vastness of the country, changes of political control, and ongoing fighting in different parts of the country. As with other contexts, however, there was also an element of different organizations with "humanitarian" agendas purporting to be the sole institutions capable of providing aid and/or of knowing how to do it "correctly."

In July 2004 an agreement was signed between the RCLO and the newly formed Iraqi High Tribunal to investigate graves and victims of the Ba'ath Party regime. This agreement resulted in two mass-grave sites being excavated in September 2004. There was a mandate to excavate a further nine additional sites in 2005–2006. However, the forensic team excavated only six sites (Trimble & Malin-Boyce 2011: 518, 519). Table 38.1 shows examples of recent mass-grave discoveries and related forensic work.

Of the work that has been done to date, there are clearly some who have benefited. In 2005 Massoud Barzani, the President of the Kurdish region of Iraq, wrote in the *Washington Post* about what he considered to be three recent milestones in the country. Two of these related to recent forensic work:

- 1 The repatriation of Kurds, victims of the Anfal campaign that had been exhumed from a mass grave in Southern Iraq by the RCLO team; and
- 2 The trial of Saddam Hussein (Barzani 2005).

Since 2003 the search for victims in unmarked graves has been directed by the Iraqi Ministry of Human Rights (MoHR) and the Medico Legal Department (MLD). The MoHR has two departments involved in grave excavations: one for the Iran-Iraq war and a Mass Graves Department that investigates victims from the Ba'ath Party regime. All examination of human remains recovered takes place within the MLD facilities.

In 2006 the Iraqi government passed a law on the protection of mass graves:

The law is passed in an effort to facilitate the mission of searching for mass graves that resulted from crimes committed by the past regime; and in an effort to facilitate opening of mass graves in compliance with legal regulations and humanitarian values; and in an effort to protect mass graves from disturbing [*sic*], as well as haphazard excavation and digging; and in an effort to identify victims buried in the graves and preserve criminal evidence to be forwarded to the Court to facilitate the establishment of responsibility of criminals for the crimes of genocide, illegal burial, as well as other crimes committed against the victims.

(Article 19)

Table 38.1 Examples of recent mass grave discoveries in Iraq and related activity

Discovery of al-Mahawil mass graves, near Hilla. These allegedly contained at least 3,000 bodies, but disorganized excavation makes an accurate accounting impossible (Human Rights Watch 2003; Stover, Haglund, & Samuels 2003).

The first mass-grave excavations (Ninawa 0002 and Ninawa 0009) by RCLO forensic team near al-Hatra and Mosul (Stover, Megally, & Mufti 2005; Burns 2006; Trimble & Malin-Boyce 2011). Ninawa 0002 was incompletely excavated (120 bodies were removed), because RCLO mortuary facilities were not equipped to handle remains with soft tissue. Sixty-four bodies were exhumed from Ninawa 0009, most of which were blindfolded, ligatured, or both. Autopsies and analyses of material culture were conducted following and concurrent with exhumations (Trimble & Malin-Boyce 2011).

In April the RCLO team excavated one of 10 mass graves found at the same location in the Ash Sham desert in Muthanna Province, near the city of Samawa, exhuming bodies of 114 adults and subadults, some with blindfolds and ligatures. Autopsies and material culture analysis were completed in July (Pringle 2009; Trimble & Malin-Boyce 2011).

In May RCLO conducted excavations in Karbala Province at a site where four features with human remains were excavated, three of which had been disturbed and contained commingled remains. The remains of a minimum of 41 individuals were analysed (Trimble & Malin-Boyce 2011). This same year the Ministry of Human Rights registered 200 mass graves (Burns 2006). Further excavations at a site disturbed by natural forces continued at least 28 bodies (Davis 1998). On November 28 forensic anthropologist Clyde Snow and forensic archaeologist Douglas Scott testified about mass graves, skeletal and material evidence that they examined in the town of Koreme in 1992, from killings in 1998 (Kelly 2007). Two days later archaeologist Michael Trimble testified about RCLO excavations and analyses (Pringle 2009). In December, four days after denial of his appeal, Saddam Hussein was hanged as punishment for crimes committed in Dujail in 1982. During this year the United Nations conducted their first comprehensive accounting of civilian deaths due to violence since the invasion. The number of Iraqis violently killed exceeded 34,000, an average of 94 per day (Tavernise 2007).

On November 3 mass graves were discovered around Baghdad where U.S. forces were fighting with al-Qaeda and other groups. They were reported to be related to deaths from sectarian fighting following the 2003 invasion (BBC 2007).

In February a mass grave with 50 bodies was discovered near Samarra. Another was found in March with about 100 bodies. An Iraqi army officer reported that: "We can't identify them. . . . There are just bones in there. At the moment we have left the remains in the grave itself" (BBC 2008).

It is reported that, between 2003 and 2009, 10,000 Iraqis were listed as missing, which the government estimates is a small percentage of the actual number of missing. "Dr. Munjid Salah al-Deen, the manager of Baghdad's central morgue, said his staff was working to identify 28,000 bodies from 2006 to 2008 alone." Mass graves continue to be discovered around the country every few weeks (Williams & Al-Salhy 2009).

In November Iraq became the 20th country to ratify the International Convention for the Protection of all Persons against Enforced Disappearances.

In April a mass grave with more than 800 bodies was discovered in Anbar province. Bodies are believed to be from the Iran-Iraq war, although they include women, children, and men in civilian clothing (BBC 2011; McEvers 2011)

Human Rights Watch reports that on June 10 at the edge of a ravine ISIS executed over 600 mostly Shia prisoners from Badoush prison in Mosul in June. On June 11 ISIS claimed to have executed 1,700 Shia troops in Tikrit and posted videos (Human Rights Watch 2014).

Article 2 of this law called for the establishment of a central database at the government's Mass Grave Department, within the Ministry of Human Rights. The law defines a mass grave as:

land or location containing the mortal remains of more than one victim, who were buried or permanently [*sic*] hidden with no respect to legal regulations and humanitarian values that must be taken into account during interment, and who were buried in a way to hide the evidence of the crime of genocide committed by an individual, a group or an institution.

These definitions presuppose two things:

- 1 That crimes involving illegal burial were committed by the past regime (that is, that of the Ba'ath Party); and
- 2 That mass graves were created to hide the crime of genocide.

In many instances these two things are true; however, they ignore the fact that illegal mass burials and wide-scale enforced disappearance both pre- and postdate the Ba'ath Party governments. Focusing the legislation on one specific era politically prioritizes one group of missing persons above others.

Training

Training in forensic investigation methods has been ongoing on a limited scale. The ability to organize for experts to work with their Iraqi counterparts has been complicated by the ongoing conflict and the feasibility of providing secure training areas for internationals who are prepared to travel and work within Iraq. This complexity was particularly notable during the period of 2004–2008. The vast amounts of money required to provide adequate insurance for anyone working in the region has meant that much training has taken place outside Iraq. The exception to this situation is the work of the ICRC, which does not contract private security and is the only organization to provide regular on-site training, mentoring, and support in Baghdad. As early as 2003 the CPA directed some training of Iraqi nationals within Iraq, and, although the training was limited in scope, it did identify areas including effective site assessment, archaeological techniques and recovery, forensic anthropology, and analysis of remains that could be expanded in future programs. The issue of whether different training programs were aimed at a level consistent with international practice or whether they should be geared toward what the Iraq experts themselves required had been given much thought. Unfortunately even at the present time these important issues have not been fully resolved.

Funding, including travel costs for initial training sessions, was provided through the assistance of the United Nations Assistance Mission in Iraq and the ICRC and was conducted in the relative safety of neighboring states. The largest hurdle to the early training was the issue of travel visas with very strict guidelines being implemented at all times. To date various non-governmental, government, and other interested groups have staged training sessions outside Iraq. Organizations include ICMP, the Victorian Institute of Forensic Medicine (VIFM) in Australia, the ICRC, and the Argentine Forensic Anthropology Team (EAAF).

ICMP directed training in Iraq and Bosnia Herzegovina every year between 2004 and 2007. They report having trained more than 550 Iraqi professionals in methods “including basic DNA extraction, sequencing and amplification methodologies, and introduce[d] the concept of high-throughput testing” (ICMP online). A Memorandum of Understanding was signed between

ICMP and the MoHR in 2008 that enables ICMP to keep a limited presence within Kurdistan as well as provide further assistance to Iraqi Departments as funding became available or requests are made. Regarding DNA identification, ICMP has processed bone samples at their own laboratories outside Iraq, rather than develop DNA facilities at either of three DNA laboratories in Iraq.

In 2011 ICRC, through the presence of one of its forensic experts based in Baghdad, increased support in Iraq as part of a long-term engagement with the MLD. The ICRC continues to support their Mass Grave Department through the provision of equipment and the mentoring of staff and targeted training, supported by external experts, on the subjects of skeletal and DNA analysis. Since 2011 the ICRC has worked with the MLD on a strategy to develop its capacity in managing its laboratories and developing the skills of its staff through training and on-site mentoring. Developing links between Iraq and other countries that do similar work (for example, Cyprus and their Committee on Missing Persons) has been seen as an important first step in exposing Iraqi scientists to projects that are well established and seen as a model of best practice. The aim is to share experience and learn from others.

In 2012 the VIFM delivered training to a group of approximately 40 Iraqi nationals (Figure 38.1). Representatives from the MoHR, Government of Iraq Victims of Terror, and several Iraqi departments involved with the location, recovery, identification, and repatriation of remains attended the training. Staff from the VIFM, Victoria Police Forensic Services Department, and external experts (including from the ICRC) gave presentations on a variety of subjects. The training focused primarily on the situation of survivors and relatives of missing persons, with particular emphasis on the HR Ministry's Documentation Centre and mass graves. Designed within the existing international human rights law framework concerning victims, training included sessions on establishing an institutional framework for dealing with such cases.



Figure 38.1 Mock exhumations undertaken by MoHR staff in Melbourne, Australia September 28, 2012 (image courtesy of Dr. Soren Blau, VIFM)

The objective was to facilitate the expedition of case processing and address management issues, including the determination of compensation for victim families.

Discussions with MoHR staff and author J.S. in 2012 and 2013 highlighted several issues, the most pertinent of these being the number of graves investigated. The exact number of excavations and recoveries is very difficult to establish, but at least 44 graves were excavated between 2008 and 2011, and a total of approximately 3,000 sets of remains was recovered.³ According to MoHR staff approximately 5,000 bodies were exhumed between 2008 and 2010.⁴ A further 84 graves (including an unknown number of sites with Iran-Iraq war dead) were scheduled to be excavated as soon as resources were available by a combined Iraq/Iran team.⁵ The MoHR has since established links and cooperated with other government institutions that maintain a database on graves dating to the era of the former regime as well as more recent victims of terrorism. They also collect antemortem information from the families of missing persons and have established contact with martyrs groups (for example, Al Shuhadaa [*Martyrs*] Institution) and the Forensic Department. The MoHR is also responsible for fencing around suspected mass graves to protect them from tampering and the erection of memorials and signs to honour the dead. An annual celebration on May 16 was proposed to coincide with the National Day of Mass Graves Martyrs. The celebration stresses the activities undertaken by the seven branches of the Mass Graves Division.

While many Iraqi experts have left the country because of security concerns, a group of committed scientists remain. The MLD is the primary medico-legal entity in the country, and its main institute is in Baghdad. All human remains recovered are transferred to a Mass Graves Department for analysis. The department has separate laboratories for the analysis of skeletal remains and for DNA. This is one of three DNA laboratories in the MLD system.

Over the last few years the MLD has made important structural and material advances (for instance, purpose-built tables, storage facilities). Further training and support are needed, but they cannot be achieved through ad hoc training programs; rather a long-term strategic engagement with mentoring of staff alongside targeted training is necessary. Both here and in similar contexts elsewhere, ad hoc short courses in forensic anthropology and archaeology are of limited benefit; such approaches lead to the impression that a complex fieldlike forensic anthropology can be mastered in a matter of weeks. Many sites in Iraq are extremely complicated and require qualified and experienced professionals to recover and analyse human remains recovered. Regardless of the method of identification used, failure to employ skilled professionals will result in error and misidentification. Engagement with authorities to reinforce the fact that there are no simple answers or quick fixes is essential; otherwise, the process is undermined and results are compromised.

Since 2003 the ICRC has been working with the MLD and more recently with their Mass Grave Department to provide material support (for example, refrigerated storage, computers), mentor staff, and give targeted training on skeletal and DNA analysis. Since 2011 the ICRC has worked to develop a strategy to gradually develop local capacity in laboratory management and skill development through training and on site mentoring. As mentioned, one aspect of this work includes targeted training courses by external forensic subject matter experts.

Although this section provides a broad overview of training, for any training to be successful follow-up sessions are necessary. Following up on training ensures that personnel are up to date with current standards and techniques and assists participants with maintaining specialized equipment. Training in the use of expensive pieces of equipment takes time and requires mentoring if they are to be used successfully. Failing this, often expensive equipment may end up languishing at the back of a shipping container. However, return trips may be difficult to manage both for Iraqi nationals wanting to undertake casework abroad and for non-Iraqi experts to work safely within Iraq.

In 2003 Corder and Coupland noted that security was the biggest obstacle to finding, identifying, and repatriating the tens of thousands of missing Iraqis. Fifteen years later, changing security situations in different regions continue to interrupt progress. For the foreseeable future security will continue to be a major concern for both parties. Site security is legislated, but it is unknown how well it can be enforced in the current conflicts situation.⁶ Another essential element of training is the support of the development of infrastructure and the fostering of links with Iraqi academics who have relevant expertise. Without the tools to operationalize training at home, Iraqis will forever be dependent on foreign support, and such dependence should never be the goal of assistance. What is needed is a long-term plan of development that includes working with local educational institutions.

Current State of Affairs

Today there is little doubt about the daunting challenge that exists in Iraq concerning the recovery, analysis, and identification of victims from the many past and ongoing events in the country. The provision of foreign aid often includes a tendency to “reinvent the wheel,” setting up new structures and training new staff, instead of taking the time to explore current facilities and capacities within a specific context. Also, the common mistake is often made of starting large-scale projects to recover and identify human remains without the necessary levels of planning, and without a full understanding of the long-term scale of such projects. International experts need to better sensitize concerned actors, whether they be the authorities or other organizations, to the complex nature of such work, its long-term nature, the need for suitably qualified scientists, and the lack of a guarantee of success. This approach would have an important impact on those in a position of power, who often misunderstand the scale of what they are undertaking, and would allow for more realistic planning. In Iraq some people with decision-making responsibilities are beginning to accurately understand the challenge ahead and to recognize the complexity of the tasks. There is also growing recognition in Iraq of the need for a more planned and structured approach to training and capacity building.

Currently, important progress is being made with the MLD in Baghdad. Efforts are being made to develop their Mass Graves Department, through SOPs, training programs, and overall management of the department. Limited exposure, not to international teams but to international scientific forums, fellow scientists, and similar projects, has been a problem. As of writing (2015) it is likely that violence will continue to affect large areas of the country. This situation is likely to hinder development of forensic capacity and result in more scientists leaving the country. It is hoped that the highly committed group of young scientists currently in Iraq can continue to develop forensic capacity to ensure that any human remains discovered can be professionally recovered, analyzed, and identified in line with scientific best practice. As in many contexts, balancing this hope against the need for quick results will be a challenge.

Looking to the Future

Stover and associates (2008) emphasize that because of the massive scale of people missing and murdered in Iraq that occurred under the rule of the Ba’ath Party regime, a truth commission would be appropriate. This need exists partly because criminal prosecutions in large-scale investigations can ever process only a very small proportion of those deemed responsible for crimes.

The work and influence of the ICRC in promoting the need for dignified and respectful handling of the dead and resolution of the fate of the Missing⁷ have coincided with the global professionalization of forensic archaeology and anthropology. Professional development is exemplified by working documents by the Scientific Working Group for Anthropology in the United

States (SWGANTH, www.swganth.org), standards and guidance for forensic archaeologists (Power & Sibun 2013), and accreditation systems in Latin America (Directorio Latinoamericano de Antropología Forense online), the United Kingdom (Royal Anthropological Institute online), Europe (Forensic Anthropology Society of Europe online), and in the United States (American Board of Forensic Anthropology online).

There has also been a dramatic increase in the production of forensic archaeology and anthropology publications. It includes textbooks (for example, this volume; Dirkmaat 2012; Christensen, Passalacqua, & Bartelink 2014; Moran In press), reference books (such as, Pokines & Symes 2014; Groen, Márquez-Grant, & Janaway 2015), collections of case studies from around the world (Kimmerle & Baraybar Forthcoming), and journal volumes dedicated to the subjects (for example, *Annals of Anthropological Practice* Vol. 38, Issue 1).

These developments support the global reach of forensic archaeology and anthropology. Coinciding with them is the increasing awareness that in conflict and peacetime these disciplines are necessary for the resolution of cases of missing persons and unidentified remains for medico-legal and humanitarian reasons. Possibly no other country in the world is in greater need of this expertise than Iraq. It is a testament to practitioners, organizations such as the ICRC, and the commitment of the Iraqi people that, despite the violence and the lack of security that continue in the country, forensic archaeology and anthropology are recognized and developing.

Social Action and Ethical Issues

Steele (2008) highlighted several problematic issues regarding forensic mass-grave excavations in Iraq, including lack of openness of procedures (for example, peer review of work, prohibitions on publication), managing political influence on investigations, and the inability of contracted forensic scientists to influence shortcomings. Some of these problems have been and can be mitigated (Congram 2015). Steele also points out the challenge of exhumations fuelling ongoing ethnic conflict, which is one of many of the sometimes conflicting goals of transitional justice (Leebaw 2008).

A very important, albeit brief, debate on (forensic) archaeology and anthropology in Iraq was published in a 2009 issue of *Heritage Management*. As was the case in the chapter reporting data from Iraq mass-grave excavations mentioned earlier (Trimble & Malin-Boyce 2011), it is unfortunate that the exchange did not appear in a forum more frequently accessed by forensic scientists. Zooarchaeologist Umberto Albarella instigated the debate, outlining why he believes that archaeologists and anthropologists should not work for or with militaries that are actively involved in a conflict. His argument is cogent and reasonable, although not without some problems. He incorrectly links the work of forensic scientists to the execution of Saddam Hussein (Hussein was executed before he could be judged on his culpability for the crimes of the Anfal Campaign, on which Clyde Snow, Doug Scott, and Michael Trimble gave evidence). Nevertheless, the link is still valid, because others were executed for Anfal crimes revealed in part by evidence collected from the excavations of graves and anthropological analyses by foreign forensic scientists. Trying to point to an apparent inequity regarding where forensic archaeologists will and will not work, Albarella laments the neglect of forensic assistance (or, as he phrases it, “risking their lives”) in more geopolitically marginalized contexts such as Columbia and Spain. Albarella incorrectly assumes that the forensic archaeologists and anthropologists who worked in Iraq do not also work with family groups and nongovernmental organizations in these countries. It is true, of course, that there is some disparity that results from the interests of global powers. However, there are also many examples of the agentic power of forensic scientists (including the authors of this chapter) influencing these powers—states and militaries—from within as well as working apart from them to actively create humanitarian and forensic equity

(see Congram, Flavel, & Maeyama 2014; Congram 2015). Albarella correctly states that there are no simple answers to the ethical questions raised about working in conflict contexts, but in his mischaracterization of forensic specialists in Iraq we have to say that, similarly, there are no simple characterizations of forensic archaeologists and anthropologists.

Albarella's principal point is that there is a need for an open and mature debate about the ethical implications of archaeologists and anthropologists working with parties involved in conflict, and on this matter he is right so far as the academic community is concerned. Unfortunately, the reply that follows his call for debate does more to exacerbate differences and diminish understanding than to promote productive discussion. Speaking to the charges of Albarella are Michael Trimble and Susan Malin-Boyce, both of whom work for the U.S. Army Corps of Engineers and who managed RCLO grave excavations and autopsies in Iraq from 2004 to 2006. In their response they are defensive and, as pointed out by Albarella in his retort to their reply, fail to address most of his arguments. Recent publications have taken a much more open and productive approach to some of these issues (see Gonzalez-Ruibal & Moshenska 2014), and we hope that the discussion continues to develop in this manner.

In the first edition this chapter outlined a couple of the many cultural and religious factors that might affect forensic work. In this edition we emphasize the necessity of drawing on local population input for the assessment of feasibility and methods in forensic work in Iraq. Iraq's boundaries were defined by imperial powers following WWI, and little consideration was given to making them coincide with groupings of fairly distinct peoples. The cultural diversity in the country is tremendous. Although a central, national approach to forensic investigations may be the simplest and most effective in administrative terms, the form of investigations ought to vary from one region to the next, taking into consideration victim community concerns and guidance.

Conclusions

This “outsiders account” of forensic archaeology and anthropology in Iraq is based on our experiences in the country since 2003 and interaction with Iraqis both in and out of the country. In a way, this work may be seen as analogous to that of Baghdad envoy Ibn Fadlān's ethnography of Viking life, which took place over a thousand years ago (and which includes a dramatic description of a mass, ship-based cremation) (Ibn Fadlān 2012). We have aimed for accuracy but know that our perspective, experience, and knowledge are incomplete.

We hope (and we believe) that the complexity of the development of forensic archaeology and anthropology in Iraq has been accurately portrayed. Nevertheless, we hope that in the future a more stable Iraq will allow for the development of the disciplines, which in turn will enable Iraqis to speak for themselves about how they have progressed in the task of search, identification, and repatriation of the missing in their country. Iraq has been and continues to be a very violent country, where foreign and indigenous participation in forensic investigation of the dead is limited. For the foreseeable future the best that we, as fellow forensic scientists, can do is partner with Iraqi civil and public organizations to augment local capacity through the development of frameworks, standard operating procedures, and institutions to investigate mass graves and missing persons as the security situation permits.

Notes

- 1 A video of Hussein's hanging, showing an executioner posse taunting Hussein just before the noose tightens, is widely available on the Internet. In no way do the authors advocate this as exemplary justice, but we mention it as a reminder to forensic practitioners of what can result from investigations in which they participate.

- 2 The ICRC has been present in Iraq for over 30 years, since the outbreak of the Iran–Iraq war in 1980.
- 3 Humanitarian Directorate Mass Grave Division (MoHR) 2011, unpublished document
- 4 Ibid.
- 5 Ibid.
- 6 MoHR staff have allegedly been the subject of targeted killings (email correspondence with author J. S.).
- 7 www.icrc.org/en/mandate-and-mission

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Fromelles

Forensic Archaeology and Anthropology in Identification

Margaret Cox, Louise Loe, and Peter Jones

Context

Motivation for the Fromelles project came from Australian civilians, concerned that 1,294 Australian soldiers from the Battle of Fromelles (July 19–20, 1916) remained missing (as well as missing British soldiers—hereafter the Missing). Research led to the identification of a burial site south of Pheasant Wood, Fromelles, near Lille, northeastern France (Steel 2010).

The Fromelles project was undertaken on behalf of the Australian and British governments, through their respective defence departments, via the Fromelles Management Board. All stages of work have been compliant with relevant national and international guidelines, regulation, and legislation. Glasgow University Archaeological Research Division (GUARD) was commissioned to undertake topographic, geophysical, ground penetrating radar, and metal detecting surveys in 2007 (Pollard, Barton, & Banks 2007) and an evaluation in 2008 (Pollard et al. 2008). These indicated the presence of eight anomalies of approximately 10 x 2 m, with 225 to 400 burials in six graves: two were empty. The subsequent excavation and anthropological analysis of the mortal remains of 250 buried soldiers (hereafter “the Buried”) of the Australian Imperial Force (5th Division) and the British Army (61st Division) were undertaken from 2009 to 2010 by Oxford Archaeology (Brady 2010; Loe 2010; Loe et al. 2014).

Aims and Objectives

Aims of this project were to (1) excavate the Buried and associated artefacts, (2) identify as many individuals as possible by name, and if not, to the army for which they fought, and (3) reinter them in individual marked graves in a new cemetery constructed nearby. Planning and delivery commenced in 2007, the excavation and anthropological analysis in 2009, and DNA profiles were compiled from the Buried from mid-2009 until early 2010. DNA analysis of samples donated by possible informative genetic relatives (hereafter “the Donors”) was undertaken from 2009 and is ongoing. Y-STR and mitochondrial DNA (mtDNA) profiles were recovered from the 250 Buried, with the best yields from dentition.

In an attempt to identify as many of the 250 individuals as possible a bespoke identification process collating and analysing all available archaeological, anthropological, genealogical, historical, and artefactual data sets began in 2010 and concluded in 2014 as a joint governmental

project. Each government is subsequently taking responsibility for responding positively to any putative familial DNA donors.

This chapter focuses on key aspects of this project in the context of an historic identification project.

Forensic Archaeology

Fromelles is the first large-scale excavation and analysis of WWI soldiers ever undertaken by archaeologists and anthropologists. The methodology employed was based on a fusion of traditional archaeological techniques combined with modern forensic practice (Brady 2010; Loe 2010; Loe et al. 2014).

The archaeological and anthropological operation began in May 2009, following an intense period of planning with the Commonwealth War Graves Commission (CWGC) and local suppliers to establish a secure compound in a field adjacent to the graves. This preparation included setting up a temporary mortuary, offices, storage space, staff welfare facilities, and a media room in a logical way that facilitated continuity and chain of custody. Site security was paramount; consequently, the site had a perimeter fence with a security controlled entrance and exit regime, full-time security guards, and cameras (Figure 39.1). To create a dry and stable area for the compound in the wet field, an area was levelled, drained, and tarmacked. Essential on-site facilities required the installation of services (running water, communications, electricity, and waste pipes) and relevant licenses to deal with hazardous waste and to operate a digital X-ray machine in accordance with health and safety standards. The health and safety plan addressed all anticipated hazards, including the potential for live ordnance and fleshed bodies.

An international team of highly experienced specialists and consultants was employed including traditional archaeologists, osteoarchaeologists, and surveyors; forensic archaeologists and anthropologists; hospital mortuary managers; a scene of crime officer; unexploded ordnance officer; forensic radiographers, finds specialists, and conservators; and a forensic photographer. A senior forensic advisor, a forensic pathologist, and an odontologist were appointed, and all activities were subject to independent external monitoring.

Excavation was undertaken under the cover of tents and a marquee by two teams of six, each working on two graves in parallel and employing established forensic protocols (Wright, Hanson, & Sterenberg 2005; Cox et al. 2008). Methods were to a standard that was high enough “to allow scientifically verifiable and independent analysis, reinterpretation and auditing of any records and conclusions” (Cheetham et al. 2008: 216). More specifically, they allowed confident associations between the Buried and artefacts that could be verified and confirmed at later stages of the project. This process was achieved by single (and multiple) context recording of deposits and features, two and three-dimensional survey of all contexts (for example, Figure 39.2), recording the identified stratigraphic sequence of each grave and the use of standardised recording forms and logs.

The evidence log, which recorded all numbers assigned to bodies and artefacts (with relationships noted) from a running sequence, was central to the excavation and was managed as an integral part of the evidential chain of custody process. This approach ensured that numbers stayed with each body and artefact from the time they were exposed in the mass graves to their time of reburial in individual CWGC graves. It guaranteed absolute integrity of individual bodies, their DNA samples, and associated artefacts despite physical separation during the investigation processes.

Overall, the bodies, which were virtually all skeletonised, were very complete and in good condition. Associations between skeletal elements and artefacts were maintained with very little postdepositional movement having occurred (other than in areas subject to previous evaluation). To maximise recovery, fingertip-searching the soil and metal detecting were employed.

(a)

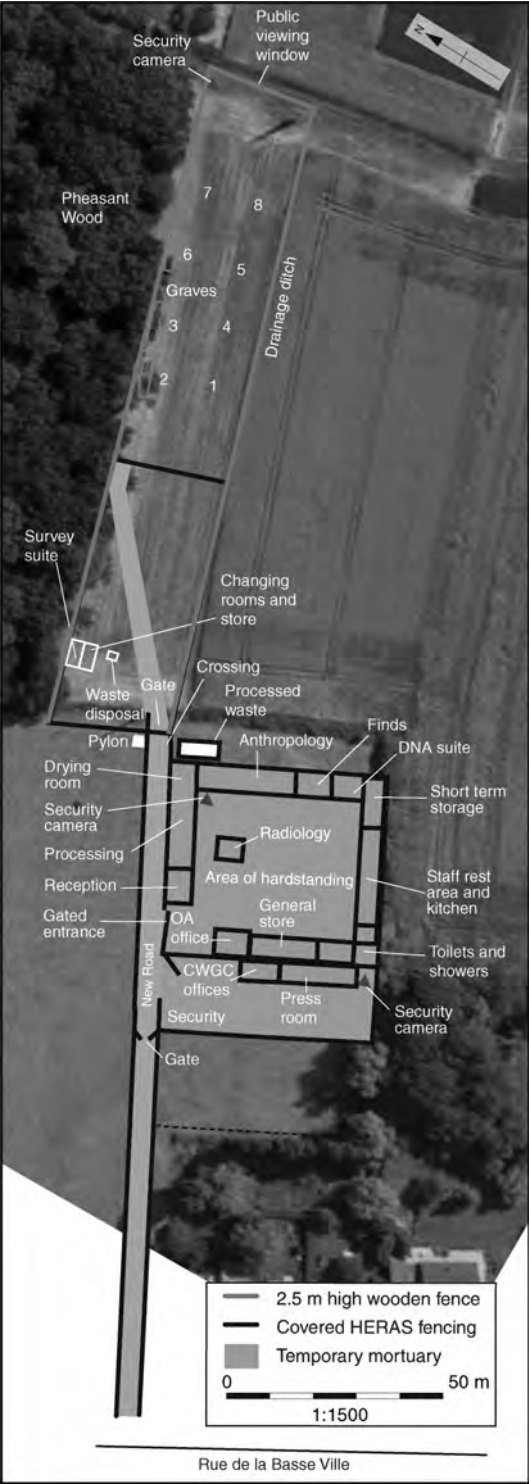


Figure 39.1 (a) Compound layout and grave locations (continued)

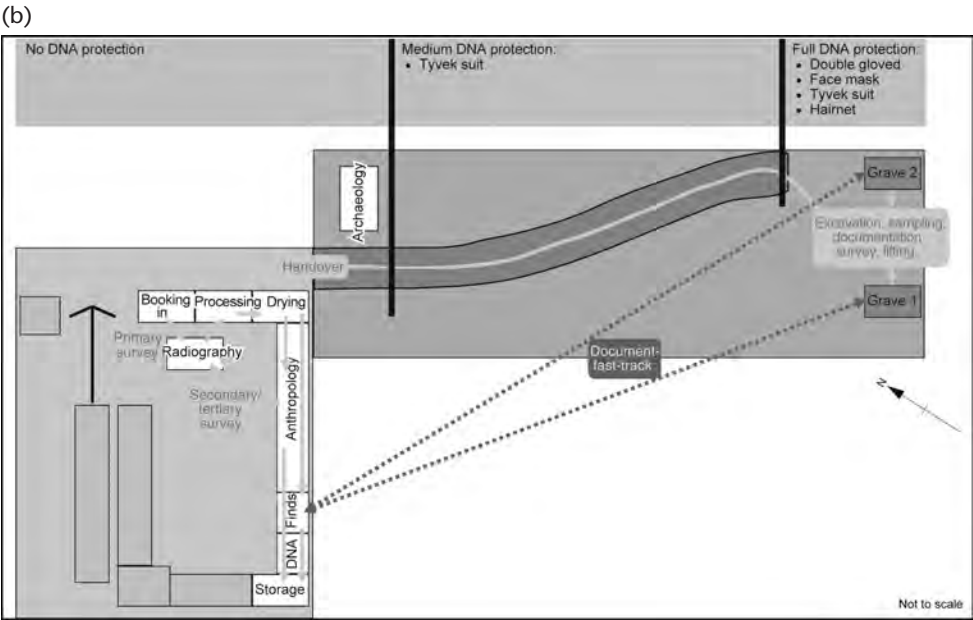


Figure 39.1 (b) detail of compound

In addition, soil samples taken from key locations around each body were collected and radio-graphed to check for items not observed *in situ*, such as badges from the upper arms. Sieving was precluded as the burial environment was in heavy clay.

Because the main aim was recovering evidence for identification, construction and form of the graves were of less concern. Consequently, to prevent water from entering the graves the Buried and associated evidence were pedestalled. Preventing water ingress into the graves was the main logistical challenge of the excavation (Loe et al. 2014: 26). Pumps and sumps were utilised in six graves, and a French drain¹ dug to sit under the walls of the marquee, which covered six graves.

Key Issues for Identification

In Northern France the recovery of WWI soldiers and their reburial in CWGC cemeteries is a common occurrence, because they are often accidentally discovered, but previously this activity has largely been reactive, and on a small scale, and forensic archaeological methods have rarely been employed. This project was the first time that established methods for the excavation and identification of individuals from mass graves have been applied to a WWI context. Crucial issues for identification were the recovery and secure management of DNA samples without contamination by operatives (Cox et al. 2014) and the application of a scheme of evidential weighting of artefacts based on location and integrity of context.

DNA Sampling

The preservation of DNA in buried human tissue is highly variable and is subject to numerous intrinsic and extrinsic variables that are not fully understood (Hollund et al. 2013). At the beginning of the project it was not known to what extent DNA would survive and, more specifically, which bones and teeth would provide the best material. A pilot study was undertaken

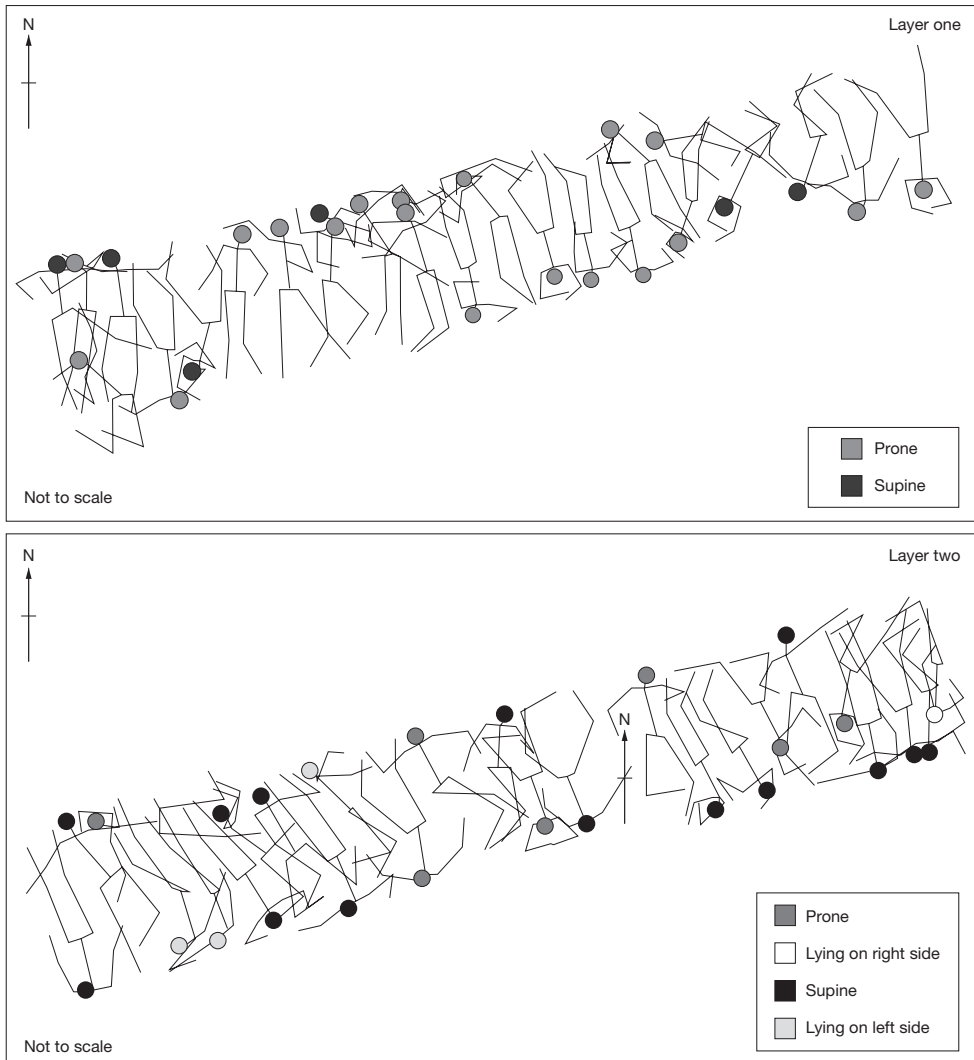


Figure 39.2 Survey plans of Grave One

in which several bones and teeth of the first 12 soldiers to be exposed were analysed. As was anticipated, teeth (Hollund et al. 2013) yielded the best DNA. No one specific type of tooth yielded better DNA than another. Incisors, canine, and, most commonly, molar teeth were all sampled, and even those with obvious signs of caries yielded suitable DNA for profiling. This situation allowed for a sampling methodology to be developed that was rigorous, free from error, and maximised the potential to obtain viable DNA (Cox et al. 2014).

Prioritising the Evidence

The Buried and artefacts were examined solely for information that would help to identify the army for which they served, their rank, and, if possible, their name. It was therefore important



Figure 39.3 Radiograph of a heavily corroded cigarette lighter

to develop methods that maximised the recovery of this information in a timely manner and avoided the collection of redundant data. Radiography was useful because it allowed items to be examined for identification information (Figure 39.3) that, if absent, made them a lesser priority for further cleaning and conservation.

Artefacts and Identification

No protocol previously existed for the recovery and interpretation of artefacts for identification from a WWI context. Approximately 5,900 items were found in association with the Buried, but their value and use were limited by a number of factors:

- 1 They largely comprised items from uniforms, military equipment, and generic items, such as smoking paraphernalia.

- 2 The German burial party removed identification papers and personal effects from casualties before they were buried to send to the British Red Cross and Intelligence (Barton 2007). Consequently, few personal items, military insignia, and items bearing names were found.
- 3 Soldiers present a particular set of problems for establishing individual identification, because individuality is minimised by the wearing of uniforms and use of standardised equipment. In the case of contemporary Australian and British armies, distinctions were blurred because Australians frequently wore elements of British uniforms at times of shortage.
- 4 Souvenir collecting (for example, buttons and badges) was extremely common and was observed on several occasions (Figure 39.4). Consequently, the inherent portability of items was a fundamental consideration in the use of artefacts for identification purposes.

A methodology was developed that took these factors into account and weighted evidence accordingly (Brady & Loe 2014). Items found in the areas of pockets were considered to be of less significance than those found where they should have been worn. This was the case for one of three recovered ID discs bearing names. Dress items that were unlikely to have been removed were weighted more highly than more portable ones. The Australian jacket belt buckle (Figure 39.4b) was useful because, differently shaped than the British one was, it was integral to the garment and could not be easily removed.

Lessons Learned

Evaluation sondages dug across the features (Pollard et al. 2008), and to their bases, meant that skeletons were exposed but left *in situ* when the graves were backfilled. Despite careful backfilling, during the intervening months water seeped in (the disturbed burial matrix being more easily infiltrated), resulting in movement and loss of association between some bones and artefacts. We recommend that evaluation of mass graves should be via methods that involve test pits at the outside edge “looking in,” thus minimising the removal of sediment from around human remains (Cheetham et al. 2008).

Another highly significant factor was the vast and varied, but complementary, experience of the different team members, who played a key role in project design and implementation. In particular, the requirement for innovative approaches and the ability to work under stressful conditions in the public eye and away from home. Experience is vital in such operations (Cheetham et al. 2008: 217; see also Wright & Hanson, Chapter 41 this volume), combined with effective team work.

Forensic Anthropology

The Buried were examined in a laboratory within the temporary mortuary by a team of six anthropologists. Each table was supported with exemplars, reference material, and an overhead camera connected to a workstation where site records pertaining to each soldier could be downloaded. Analysis was preceded by primary radiographic survey (to identify any hazardous material, fragile items and small bones, teeth, and artefacts), followed by cleaning, with input from anthropologists and finds specialists, as appropriate.

Analysis was carried out in accordance with standard, published guidelines (Loe et al. 2014: 39–53). This involved:

- Laying out each body and completing an inventory,
- Identifying and reassociating body parts,
- Assessing completeness, condition, and taphonomic alteration,



Figure 39.4 (a) Purse found with one soldier with a collection of coins, probably souvenirs
(continued)



Figure 39.4 (b) Australian jacket belt buckle

- Reconstructing skeletal remains (where appropriate),
- Assessing biological profile (ancestry, sex, age, and living stature),
- Assessing individuating characteristics (skeletal constitution, handedness, facial attributes, dentition, skeletal pathology, and trauma,
- Assessing perimortem trauma,
- Secondary routine dental radiography,
- Tertiary radiography (as required to explore pathology, skeletal variation, or trauma),
- Routine and detailed photography, including innovative use of overhead cameras and colour-coded arrows to record all sites of key information relating to age, pathology, and peri mortem trauma.
- Further DNA sampling (if required), and
- Packaging, labelling, and storing for reburial.

Key Issues for Identification

Analysis of the 250 Buried was undertaken blind to antemortem data of the 1600 Missing, so that the evidence could be interpreted free from bias (Nakhaeizadeh, Hanson, & Dozzi 2014). It commenced just after the excavation began in 2009, taking six months. It was followed by the reburial of the soldiers in January and February 2010, and consequently data were captured accurately and in great detail. Reflecting the possibility of photographs surviving of some of the Missing, innovations included making 360° videos of skulls to provide an opportunity to compare these to craniofacial morphology during the identification process. Facial reconstruction was not considered appropriate, because it was known that available photographs of the soldiers were generally too poor in quality with the soldier's eyes obscured by their hat and they were unsmiling, not allowing teeth to be seen and compared.

The choice of methods used for identification must always be considered in light of the nature and quality of the antemortem data available; methods that are highly regarded for the identification of the recently deceased are not often applicable in historic cases. For example, although dentition is a key source of identification information in most modern, Western

contexts (Thompson & Black 2007) for Fromelles, no dental records existed, and enlistment records noted only such detail as “bad teeth.”

Age at death and stature were primary sources of anthropological information for the ID process, because this information was recorded at enlistment and available in the records. Issues associated with the use of anthropologically determined age and stature versus documented age and stature have been discussed elsewhere (Loe et al. 2014). Unlike some forensic identification cases (for example, Zukanović, Sarajlić, & Škulj 2011), no population specific standards exist for Australian and British males living in the early 20th century. The effect of this lack is not important at a population level, but for individual identification it requires large error margins to be factored in.

Standardisation was also important for perimortem trauma analysis. WWI soldiers were exposed to high explosives, shrapnel shells, small arms, and machine gun fire (Knyvett 1918; Bean 1941; Cobb 2007; Lindsay 2008). Some of these reached the enemy's trenches, where soldiers engaged in hand-to-hand combat and were subjected to bombardment by hand grenades (Lindsay 2008). The fate of some soldiers is recorded in eyewitness accounts and, therefore, with caution, perimortem skeletal trauma can provide useful identification information (Loe, Barker, & Wright 2013).

Injuries affecting the skeleton were observed on the majority of the Buried and were often highly complex and extensive in nature. They were classified as blunt, sharp, projectile, and blast-force traumas, but identifying the mechanism was complicated by the fact that wounds caused by the aforementioned are not mutually exclusive to these categories. Further, many of the soldiers experienced more than one type of trauma mechanism (for example, firearms and explosive munitions), the multiplicity of injuries obscuring wound characteristics. In addition, further trauma to the dead lying on the battlefield could not be distinguished from those sustained by the living. Identifying trauma caused by explosive munitions was especially problematic and extremely limited comparative literature exists (see Cox, Loe, & Jones, Chapter 39 this volume).

Lessons Learned

An integrated and comprehensive approach was paramount in achieving a robust data set. Because the mortuary team was working in parallel to the field team and in the same location, it was possible for staff to exchange findings and make decisions in a timely manner, which maximised the power of the data. This approach was particularly relevant for addressing issues associated with perimortem trauma. Thus, explosive munitions casualties, indicated by a combination of multiple injuries, projectile and/or blunt trauma, comminuted fractures, shearing of bone, amputation, and an absence of exit wounds, could be confirmed by consideration of the archaeological context (for instance, burial posture), the radiographic identification of embedded degraded ferrous objects, and knowledge of relevant weaponry. A holistic approach to trauma interpretation is essential.

Comparison of antemortem (for example, eyewitness accounts) and perimortem trauma data showed good agreement in some cases, but not always (Loe, Barker, & Wright 2013). In addition, recorded hair colour was found to match that recovered with several of the soldiers, the keratin having been (unusually) preserved. The preservation of hair was not anticipated and raised the need for a standardised recording system, particularly for hair colour.

Other important insights into burial taphonomy were made, challenging current thinking and furthering knowledge of different burial environments (Barker, Wright, & Loe 2014: 141–42). For example, desiccated brains were preserved in over 50% of individuals, a similar finding to that seen in more recent Bosnian mass graves (Brothwell & Gill-Robinson 2002) but unusual in other WWI cases.

Pathology can also provide good individuating information (Thompson & Black 2007; see also Cunha and Pinheiro this volume), but only when corresponding antemortem records exist and where conditions were recognised and recorded during life (rare in the early 20th century). Observations relating to robusticity/musculoskeletal stress markers (Hawkey & Merbs 1995) were recorded but found to be too subjective, with broad classifications (for example, “gracile,” “robust”) proving less likely to mislead. Only a few conditions that were recorded in antemortem records were observed, including limb abnormality and facial asymmetry. Of course, cases with significant diseases/abnormalities (of greater individuating value) were always unlikely, because the men would not have been permitted to enlist (Loe et al. 2014: 147).

The value of pathology was reduced for this project, because the subjects do not represent a random population but were mostly young healthy individuals. Pathology was most useful when expectations of the data were redefined relative to the individuals in question.

Recording Data

An important issue when identification is the main aim is how the anthropological data and information are recorded. The Fromelles experience demonstrated that, for a coherent identification process, it is vital that all anthropologists conform to the same standard and level of recording, despite individual preferences or experience. Such issues as how to record and provide estimates in cases where multiple methods of, for example, age determination are recorded are critical. If statistical methods such as nearest neighbour analysis are to be useful in the identification process then a meaningful way of determining an age from multiple methods yielding multiple ranges must be determined and employed.

The Identification Process

Experts involved in the identification process undertaken on the individuals from Fromelles recognised their obligation to the legal (and other) institutions involved (Cox et al. 2014) and to the families of the Missing (Stover & Shigekane 2002: 864). The approach taken in identification and the guidelines followed have been discussed extensively (see Cox 2010; Jones 2010; Cox & Jones 2014; Cox et al. 2014); here we focus on key topics of wider significance.

The process of identification was multidisciplinary, utilizing anthropological, archaeological, historical, genealogical, photographic, and genetic data sets. It was staged, involving rigorously evaluating the reliability and, when possible, the probability values of all data, in a repeatable process that was free from bias. It employed statistics as appropriate but without losing sight of the potential, limitations, and relevant strengths of each data set, and it was conducted within a strict ethical code (see Cox & Jones 2014). The process was subject to independent external evaluation.

Most of the Missing had surviving genetically informative relatives willing to donate DNA samples. Identification of the Buried relied on the condition and completeness of their skeletons, dentition and DNA, the survival and traceability of informative genetic relatives, their willingness to participate in the process, and the availability of reliable antemortem data.

Important Limitations

Anthropological analyses, while useful for determining congruence or otherwise of potential Missing, are not a vehicle for providing precise and accurate data (Byers 2008) for individual identifications. For example, such analysis provides wide age brackets (for instance, 28–45 at

95%) and stature estimates (± 3 or 4 cms at 95%). The majority of the Missing were aged in their mid-20s and around 170 cms (5'7") in height; this made differentiation between individuals with common mtDNA profiles difficult in some cases. Few named and nonportable artefacts were found with the Buried, and the availability of reliable historical data to correlate with anthropological data and DNA was vital.

Historic data mainly comprised military records, which cannot be assumed to be accurate. Men lied about their age at enlistment at both ends of the spectrum (Loe et al. 2014), and when recruits or conscripts were needed this reality was condoned. Equally records of antemortem trauma and disease have to be considered in light of contemporary medical understanding and accuracy of recording at enlistment stations and field hospitals. As with any written source, principles of historiography were applied. Historical texts are polemic in nature, some more so than others, and questions to be asked are who made the record? when? why (was the recorder biased)? and was the recorder a first-hand witness to what he or she recorded, or did he or she accept second-hand information? All these issues affect the reliability of data. We had some Missing with multiple accounts of cause of death that all differed. There was no way of knowing which, if any, were correct and should be correlated against perimortem trauma; that fact then casts doubt on other witness testimony likely to have been influenced by posttraumatic stress.

Levels of Proof

When establishing a familial relationship between the Buried and Donors, we were reliant on the use of DNA. The available databases for Y and mitochondrial DNA are the Y-chromosome Haplotype Reference Database (YHRD) and the DNAP (European DNA Profiling Group mtDNA Population Database (EMPOP). Both are small when compared with National DNA Databases (for example, NDNAD). Thus the statistics used in establishing match probabilities for the Buried were relatively low and compounded by the fact that some profiles may not be unique to an individual (Hohoff et al. 2007). The small databases resulted in match probability values for the Buried vis-à-vis those of the Missing at a maximum of 1:1915 for mtDNA and 1:3387 for the Y-STR. Where we had both a paternal and maternal match for a buried soldier the two values were multiplied, which could yield maximum match probabilities of 1:6.4 million. However, in many cases we might have a donor from only one line, and so the match probabilities could be very low, typically $<1:500$.

It was therefore important to establish a baseline threshold for match probabilities strong enough to attribute an identification (1 in 1,000 being the minimum). This threshold would then ideally be strengthened by congruence with anthropological data (age, stature, *in vivo* health and trauma indicators, hair colour, and, with caution, perimortem trauma). Where key anthropological data (for example, age—to be checked against birth records and stature) were significantly divergent then the indicated identification was rejected.

In light of these facts, an overriding ethical and professional issue is just how likely a match is to be correct. Should the level of proof be “beyond reasonable doubt,” “substantially more likely than not,” “overwhelming,” or something else? The involvement of impartial external specialists in this decision is essential. For the majority of the Fromelles's Missing it was not possible to have strong enough match probabilities to attribute identifications beyond reasonable doubt—which can only rarely be achieved in historic or archaeological cases unless appropriate probability values are attributed to all data sets by relevant experts and where integrative Bayesian analysis is accepted as an appropriate approach and applied (King et al. 2014). The Fromelles Management Board decided to place the Fromelles's level of proof as “substantially more likely than not.”

Key Ethical Issues

An ethical code is crucial to any programme recovering and identifying the dead. The overriding principles are agency and dignity (Rosenblatt 2010). *Agency* implies that the dead and their deaths can influence the living in negative and positive ways. *Dignity* as a right is inherent and inviolable. To restore identity to the Missing, to accord them appropriate funerary rights, and to liaise with and inform their families are part of restoring the deceased's rights while also protecting and promoting the rights of the living.

Semantics

Certain semantics, used frequently in similar projects from all periods, can be perceived as offensive and are potentially dangerous. We consider the use of terms including “remains” and “sets of remains” and those more derogatory to be unacceptable. They are imprecise and potentially confusing, but, of greater importance, they and similar terms potentially demean and dehumanise the dead. Consequently, the victims might be treated as less than, or lesser, humans. The rights of the deceased and their families may consequently be ignored or treated in an inappropriate manner.

Sociocultural Implications

Management of the dead has important sociocultural implications, regardless of context, including behaviours dictated by the religious beliefs of the deceased and related survivors (Stover & Shigekane 2002; Green & Green 2006). Work must be conducted in a manner cognizant of this fact and must ensure that handling and treatment do not cause further distress (Morgan et al. 2006). In some circumstances (for example, the developing world or postconflict scenarios) an impact assessment should be undertaken before, during, and after a project when possible. In the case of the work undertaken at Fromelles, the names of the Missing and their enlistment records suggested that many of the Buried were Roman Catholic or Protestant but that a minority might be Jewish or of Aboriginal descent. Consequently, no overriding religious or ecumenical approach was adopted explicitly or implicitly.

Managing Expectations

Expectations of families, donors, and other interested parties (for example, media, general public) must be managed appropriately and realistically. The process, its context, and the potential and limitations of the methods used, including DNA, have to be explained—not to do so can create unrealistic expectations. With over 1,600 Missing from Fromelles, and 250 Buried, the chance of a donor finding his or her Missing was at best 1:6. Not all families of the Missing have genetically informative DNA donors, and some family lines may be impossible to trace or have become extinct. If one includes adoption and illegitimacy these facts means that some of the Buried will remain unidentified.

Incidental Findings

When DNA is part of a process to identify individuals by the names they were known by during life, identification shifts from being social and familial to something that also exists at a genetic level; while genetics and family names may correspond, they may not. This reality is something that families and social groups of the Missing must be made aware of. Nonpaternity/-maternity and adoption (incidental findings) take place regardless of time or place, and their rates are

neither constant nor predictable (Gilding 2005; Anderson 2006). There are no specific nonpaternity data for the early 20th century; however, the figure of c. 2% is now generally accepted (Larmuseau et al. 2013). Adoption and nonmaternity rates will increase the overall rate.

Any identification process reliant on DNA will be both impaired by and reveal incidental findings, reflecting nonpaternity and/or nonmaternity and adoption (Parker 2008; Wolf et al. 2008; Parker, London, & Aronson 2013). Incidental findings may also highlight unknown but genetically related individuals among the Buried to donors. Where DNA is the most heavily weighted data, such individuals cannot be identified by the name by which they were known in life, because their DNA is different, on one or both lines. An exception might be if there are unique and overriding biological and historical data sets that are powerful enough to overrule the genetic indicators. In this project, multiple DNA donors from the same family were employed (where possible) to help militate against incidental findings. For cases with a suboptimal match probability, autosomal testing of the Buried vis-à-vis a putative nephew or niece was undertaken and, when combined with the mitochondrial or Y profile, either excluded or confirmed a match.

The issue of whether to disclose incidental findings to affected families is far-reaching, and we followed existing guidelines reflecting the risks of discovering kinship discrepancies not being uniform across space and time (Parker, London & Aronson 2013: 225). It was considered that disclosure could negate the potential benefits of the process (ibid.: 226).

Images of the Dead

It is commonplace today to see images of the dead; the media frequently show human remains from archaeological and historical contexts. Under what circumstances an image of the dead can be appropriately shown, and to whom, is a topic that needs to be discussed widely and agreed on at the level of an accepted international standard.

The Fromelles's Buried were treated the same as those who die in warfare today. No images of them during excavation or analysis have been made public or been permitted to be shown in any general media coverage. However, it was agreed that images of the Buried (devoid of any coding or anything indicating identification) could be shown in approved scientific reports, presentations, and papers when the use is deemed professionally informative and educational.

Conclusions

As would be expected with any project that is the first of its kind, areas to consider and improve have arisen through its course, and this experience will help to inform future projects and contribute to the development of an ethically robust and defensible approach to the excavation, analysis, and identification of our war dead. Currently we have identified 144 of the 250 Fromelles Buried and are optimistic that this number will increase as more donors come forward.

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Note

- 1 Creating a French drain involves digging a 600-mm-wide channel under the sides of the marquee, filling it with gravel to levels ensuring that any runoff would drain away from the graves.

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Part V

The Professional Forensic Archaeologist and the Forensic Anthropologist

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More Than Just Bare Bones

Ethical Considerations for Forensic Anthropologists

Soren Blau

Forensic anthropology is the field of study concerned with the identification of suspected or known human remains from medico-legal contexts. Traditionally forensic anthropologists dealt with dry, complete, and fragmentary skeletal remains, but they now commonly work with a range of differentially preserved remains including fleshed, decomposed, burnt, dismembered, and heavily disrupted remains. In addition, forensic anthropologists assist in answering questions of identification in clinical cases, such as those related to the age of an individual (for example, Black, Aggrawal, & Payne 2010), and questions related to investigations involving missing persons and victims of crimes, accidents, mass disasters, and crimes resulting from periods of political, ethnic, and/or religious violence (Blau In press). Because of the emotive nature of the material forensic anthropologists work with and the diversity of contexts in which they may work, the ethical issues practitioners have to consider span social, cultural, and political realms. This chapter considers a number of ethical issues that a forensic anthropologist may face and, in doing so, raises questions rather than provide answers about the myriad ethical matters that should/do concern the practice of forensic anthropology.

Following a brief discussion about the nature of ethics, this chapter examines why ethics are important for the practice of forensic anthropology with particular reference to training, accreditation, the development of anthropological techniques, limitations of evidence, and research. Finally, individual versus professional ethical questions are considered.

What Is Ethics and Why Is It Important to Consider?

Ethics is a branch of philosophy concerned with the evaluation of human conduct. *Ethics* is defined as a body of principles or standards of human conduct that govern the behaviour of individuals and groups (Bottorff 2005). Most professions adhere to an agreed code of conduct, commonly referred to as a “code of ethics,” with the intention being that all practitioners should undertake “best practice.” In addition to rules of conduct, ethics is seen as “the science of morals, that branch of philosophy which is concerned with human character” (*Chambers English Dictionary* 1990: 490). Ethical considerations therefore apply to the profession *and* the individual (Sapir 2001; Hunter & Cox 2005) and have been addressed by many disciplines (for example, Plueckhahn & Cordner 1991; Barnett 2001; Turner 2004; Martin, Harrod, & Pérez 2013).

In the 18th century the philosopher Kant argued that system-wide consistency was a logical requirement of ethics. He stated that ethics begins with the rejection of nonuniversal principles and that any adopted ethical principle must be a desirable universal law applied by everybody (Urmson & Rée 1991). However, the nature of an ethical dilemma stems from what has more recently been acknowledged as part of the “postmodern condition”—namely, that there is not one correct way to engage with the world. We are conditioned by our environment and culture, and therefore we are socialised as to what actions and behaviour are “reasonable” and/or “appropriate.”

Ethics is deemed important essentially because there are multiple value systems. Different cultures, societies, and groups, have different value systems—namely, their own definitions of what is considered right and wrong (*appropriate*) (Walker 2000: 20; White 2000: 319). This fact is clearly borne out by peoples’ differing attitudes to death, the deceased, and human skeletal remains (for instance, Bradley In press). For example, in some Western countries physical contact with the dead is rejected as events surrounding death and dying are often suppressed (see Blaauw & Lahteenmaki 2002: 772). In contrast, in some Muslim societies there is close contact with the body of the deceased, which must be washed by a family member before burial. While some cultures actively and openly display human remains, as in the case of the All Saints Cemetery Chapel in the Czech Republic, other cultures are highly offended by the display of their ancestors, as with some Indigenous Australian and Maori communities (for further discussion on the different values placed on human skeletal remains see Hubert 1992: 117–18; Walker 2000: 12–18).

Sociocultural attitudes toward the dead should influence the conduct of practitioners dealing with the deceased. Although the living body is usually regarded as a person, some people have argued that after death the body becomes merely an object (for example, McEvoy & Conway 2004: 540). In the forensic context the body (object) is regarded at one level as empirically unchallengeable evidence.¹ This view is perhaps more applicable when one is dealing with human skeletal remains. Attitudes toward the human body, death, and dying in the contemporary world were anecdotally surveyed for students undertaking a Master of Science degree in forensic and biological anthropology in Bournemouth University (U.K.). Only half of the cohort ($n = 16$) who had excavated human skeletal remains identified with them as once being a living person (see also McEvoy & Conway 2004: 540). Such views, however, contradict the fundamental ethical principle for modern research in the biomedical and social sciences: respect for human dignity based on “the belief that it is unacceptable to treat remains solely as . . . objects or things” (Walker 2000: 20).

Although death is biological, it is also an inherently social process (Prior 1989: 13; McEvoy & Conway 2004: 541), particularly when one considers the “premise that human rights continue at death” (Vizenor 1996: 653). It is the dichotomy between human remains as utilitarian objects of scientific interest and human remains important for their cultural, symbolic and spiritual value that raises many ethical questions for the forensic anthropologist.

Ethics and Forensic Anthropology

Ethics is fundamentally about behaviour. To obtain general guidance on how to *behave* in a professional setting, most practitioners have a code of conduct or code of ethics provided by their profession. In the case of forensic anthropology, however, there are relatively few national and international associations with formal codes of ethics. Relatively recent exceptions include the American Board of Forensic Anthropology (ABFA), in the United Kingdom (U.K.) the British Association for Forensic Anthropology (Royal Anthropological Institute), and

foundations such as the International Forensic Centre of Excellence for the Investigation of Genocide (INFORCE) (Hunter & Cox 2005: 217). Such organisations provide relatively broad guidance about behaviour with little attention given to the specifics of practice.

The practice of forensic anthropology includes a range of analyses that may include determining whether the material is actually osseous—the bone is human or nonhuman—and whether human bone is of forensic significance. Analyses may also include describing the condition and preservation of skeletal remains; developing an inventory of recovered remains; estimating the ancestry, sex, age, and stature of the individual; and describing any individualising characteristics and any pathological and/or traumatic injuries. Each of these specific practices, including the formation of the final report, has associated ethical considerations. For example, in the case of skeletal trauma analysis, how far is it appropriate for the practitioner to go to describe the trauma? In the case of a 35-year-old female homicide victim who exhibited extreme perimortem soft tissue trauma to the head and neck, how much more information will be gained from decapitating the head and macerating and cleaning the remains (for example, Marks, Hudson, & Elkins 1999: 263)? Is it necessary to have a code of practice that stipulates the extent to which the practitioner can be invasive, or “is it just better to let the . . . anthropologists work to their conscience on the principle of ‘best practice’” (Hunter & Cox 2005: 220)?

Not only should forensic anthropologists understand the appropriate conduct at a scene of crime (such as their relationship with the forensic pathologist and their position in the investigative structure), they should also have an ethical responsibility to understand relevant legislation and how it relates to domestic casework. Cases may, for example, involve attending scenes where the recovered skeletal remains are determined to be nonhuman and/or archaeological but are obviously part of an assemblage of historic interest. Despite the fact that such cases are of no forensic significance, does the forensic anthropologist have an ethical responsibility to be aware of the legislation covering Indigenous remains and historic sites? A further role of the forensic anthropologist is to determine the forensic significance of any recovered human remains. If the skeletal remains are determined to be archaeological (and therefore again of no forensic significance), does the forensic anthropologist have the ethical responsibility to provide further information about the remains? It has been argued that “due dignity and respect should be afforded in the recovery, storage, investigation, and reburial of human remains regardless of their context” (Hunter et al. 2001: 176).

Typically in countries with a colonial history, it is vital that forensic anthropologists are aware of the potential social and political concerns and debates surrounding Indigenous remains (for example, Scarre 2012; see also Ubelaker, Chapter 8). In addition, practitioners must know the appropriate agencies with which to liaise. In Australia, for example, forensic anthropologists make a concerted effort to reinforce a rapport between state coroners and Aboriginal Affairs Offices. Such rapport is achieved by contacting the relevant agencies when skeletal remains of suspected Indigenous origin are discovered and by contributing to training courses for heritage officers.

Much has been written about the politics associated with Indigenous human remains (for instance, Ubelaker & Grant 1989; Hubert 1992; Pardoe 1992; Vizenor 1996; Jones & Harris 1998; Cantwell 2000; White 2000: 323–26; McEvoy & Conway 2004: 542–47; Aronsson 2012). Fundamentally, we must appreciate that the results of an ancestry determination may have serious political, social, and ultimately economic implications (Cantwell 2000: 92). Such implications perhaps support the proposal that training for forensic anthropologists should remain under the four-field approach, which incorporates the importance of being both scientifically competent in addition to culturally and politically sensitive (*ibid.*: 99) (see the discussion on practice and meaning).

Training

Training in forensic anthropology has traditionally been associated with education in archaeology. Because forensic anthropology is no longer merely dealing with skeletal material, there has been increasing discussion about the appropriateness of viewing anthropology/archaeology as simply the transference of anthropological/archaeological principles and methods to the crime scene (see, for example, Sledzik & Mundorff, Chapter 32). In the late 1980s and early 1990s in the U.K, for example, nothing was published on the legal framework of forensic archaeology and anthropology. There was no educational provision to inform anthropologists/archaeologists of the requirements of the subject (Cox 1998: 22). As a result some anthropologist/archaeologists are self-appointed “experts” who inappropriately call themselves “forensic anthropologists” or “forensic archaeologists.” The implications of individuals labelling themselves as forensic experts without the appropriate training and qualifications have been highlighted (Cox 1998, 2001; Hunter & Cox 2005). The standard of training in forensic anthropology is critical to ethical practice.

The quality of training in forensic anthropology is of concern, because both forensic anthropology and archaeology have been affected by the increase in fascination for anything “forensic” (for example, Fraser 2003; Thompson 2003). This situation has resulted in institutions, with little concern for the detail of the course content, appending the term “forensic” to courses merely to increase student numbers. Many courses offer a cursory introduction to the principles of forensic anthropology/archaeology, but few of them provide an in-depth education in both practical skills as well as the legal and moral responsibilities and serious implications of the work (Cox 2001; Hunter et al. 2001; Thompson 2001; Hunter 2002).

In the case of forensic anthropology in the U.K, debate is emerging about the need for practitioners of forensic anthropology to obtain training in medical schools (anatomy departments) rather than in arts faculties (archaeology departments) (Prof. Sue Black, University of Dundee, pers. comm. 2006). In contrast, attitudes toward training in forensic anthropology in the U.S.A. tend to advocate training with an arts background, because it provides the relevant broad social and technical skills to undertake ethical practice (see Ubelaker, Chapter 8).

Given the lack of familiarity with the dead in the majority of contemporary non-Western societies (for instance, Richardson 1987; Baudrillard 1993: 181–82; Adams 2000; Walker 2000: 5), such debates are associated with discussions about how students of forensic anthropology are appropriately prepared for exactly what it is they will be dealing with: it is far more than just the “bare bones” (Blau 2015). Whatever training one chooses to undertake, forensic anthropologists (and archaeologists) have the professional and therefore ethical responsibility to be, and remain, competent. The nature of how this competence is assessed relates to issues of accreditation and standards.

Accreditation

A wide range of courses is offered in forensic anthropology across the world, which has resulted in a broad variation of expert credentials. The potential effect on the courts of this variable expert credibility has resulted in an increased discussion about the need for accreditation and certification. Acceptance and implementation of accreditation for forensic anthropologists vary depending, not surprisingly, between countries and on the extent to which the discipline is established. For example, the American Board of Forensic Anthropology (ABFA) offered certification to American forensic anthropologists as early as 1977 (Reichs 1998: 14–15; Ubelaker 2010). In the U.K the Council for the Registration of Forensic Practitioners (CRFP) initially provided forensic anthropologists

with the opportunity of obtaining formal accreditation (Black 2003), and this accreditation has become even more formalised with the establishment of the British Association for Forensic Anthropology (in 2011) under the Royal Anthropological Institute (Black & MacKinnon 2014; see also MacKinnon & Harrison, Chapter 2). Certification for forensic anthropologists is also now formalised in Europe (Forensic Anthropology Society of Europe–FASE) and in Latin America through the Latin American Board of Forensic Anthropology–Directorio Latinoamericano de antropología forense (DLAF) (Groen, Márquez–Grant, & Janaway 2015).

With the increasing recognition in Australia of the role forensic anthropology can play in the identification process, issues of accreditation have begun to be addressed (see Donlon, Chapter 10). A symposium on standards and accreditation involving Australian forensic anthropologists (and forensic entomologists and forensic odontologists) was held at the Centre for Human Identification (Victorian Institute of Forensic Medicine) in December 2006. Practitioners identified the need for minimum standards for forensic practitioners to be established. However, as was the case in the U.K, Australian forensic anthropologists face a situation in which formal registers are deemed by some to create a “closed shop.” Such concerns are not of course restricted to the discipline of forensic anthropology (Beloff 2003: 15).

Reference Collections and Forensic Anthropological Techniques

The accuracy and precision of the forensic anthropologist in identifying an unknown individual from his or her skeletal remains or providing an age assessment of a living person depends not only on the preservation of the remains but also on the techniques employed. Forensic anthropologists have an ethical responsibility to consider the reliability and acceptability of all techniques being employed.

The majority of techniques used by forensic anthropologists today were developed using descriptions and measurements collected either from archaeological collections of artefacts whose age and sex were unknown (for example, Molleson & Cox 1993) or from anatomical samples (such as in The Robert J. Terry Anatomical Skeletal Collection at the Smithsonian Institution, and the Hamann–Todd Collection at the Cleveland Museum of Natural History) where independent records of these biological attributes exist (Hunt & Albanese 2005). While these reference collections have been invaluable for both forensic and archaeological research, it is now widely recognised that there are problems with the standards developed from these collections.

In the case of archaeological collections the majority of demographic data are inferred rather than independently known. Many modern reference collections exhibit socioeconomic and genetic biases that may affect biological trends. Many reference collections were small, some had skewed age distributions and disproportionate representation of the sexes and ancestry, and some were subject to the specific removal of biological outliers (Cox 2000: 63; Ubelaker 2000: 51–51). In addition, accurate recording of biological information was not always undertaken. In the case of the Hammon–Todd Collection, for example, the reliability of the documented ages for the skeletons has been doubted. In some cases, ages were estimated by anatomists on the basis of the external appearance of the cadaver rather than on known age. Many early studies that have compared dental age with skeletal age have been based on small archaeological samples of known chronological age (Bowman, MacLaughlin, & Scheuer 1992).

Because the factors affecting human growth and health (including diet and medical intervention) have changed since the collection of data in the early 20th century, it is now recognised that many aspects of skeletal morphology have changed markedly over the past century and a half. With the recognition that existing standards are becoming outdated more contemporary population-specific skeletal reference collections are being established (Ubelaker 2014), and

increasing research is being undertaken to provide contemporary population-specific data in order to develop relevant reference standards. Some examples include Australia (Franklin & Flavel 2014; Franklin et al. 2014); China (Li et al. 2012); Japan (Torimitsu et al. 2015); South America (Frutos 2002, 2005); and South Africa (Steyn & Işcan 1997; Patriquin, Loth, & Steyn 2003). It is no longer appropriate to say that “it is only something in the anthropologist’s experience that tells him [*sic*] there is an undefinable something about the skeleton that suggest one race over another” (Stewart 1979: 231). As outlined in the Daubert Guidelines, it is imperative that techniques are readily accepted and employed with known error rates, empirically tested, and subjected to review (White 2000: 322; Rogers & Allard 2002).

Limitations of Evidence

Even if appropriate standards exist, forensic anthropologists have an ethical responsibility to differentiate between objective observations and subjective interpretations (Lucas 1989: 724) and to know the limitations of the evidence they are dealing with. If the findings cannot be supported and justified should they be included in the report? Can, for example, cause of death be attributed to drowning as a result of examination of human skeletal remains alone (for example, Cantwell 2000: 85)?

Another poignant example of conclusions going far beyond the physical evidence is provided by White (2000: 321). The case involved the analysis of some 50,000 pieces of bone resulting from the death of 13 American men when a plane was shot down over Laos in 1987. Based on an anthropological analysis of the bone fragments, most of which had a maximum dimension of 1 cm (with the largest being 13 cm) long, an announcement stated that positive identification had been made and that all 13 men were accounted for. The remains were returned to the families for burial, but the relatives questioned the issue of identification, resulting in an independent investigation of the skeletal remains. It became clear that the conclusions about age, sex, and ancestry and individualisation went far beyond the actual evidence (Getlin quoted in White 2000: 321).

Research

To qualify for accreditation, practitioners must demonstrate a certain level of education, training, and professional contribution (Mario 2002: 104). One way to contribute to the profession is by undertaking research and publication. However, forensic anthropologists have an ethical responsibility to carefully consider both the context of their reference material (see Blau 2014) and the ramifications of their research findings and publications (see Thompson 2001). For example, is it appropriate for practitioners to base their research on collections of human skeletal remains curated in museums, particularly when such collections are viewed as a violation of fundamental human rights by some Indigenous groups (Walker 2000: 19)? Such questions take on a different dimension when the remains are archaeological (Webb 1987; Donlon 1994; Thompson 2003) and there are concerns about who “owns” the past. There is also ethical complexity in cases such as the analyses of the human skeletal remains from Spitalfields (the site of a former medieval priory and hospital in London), where individuals were of known age and sex and often had living relatives (Molleson & Cox 1993).

Is it appropriate to undertake research based on human remains exhumed for evidence in war crime trials? If it is considered appropriate, has consent from the relatives of victims been sought and given (Mann 2001; Hunter & Cox 2005: 215)? While assessment of the utility of forensic anthropology methodologies as applied to specific populations certainly has a place

in terms of addressing the relevance of standards (as discussed earlier) (for example, Schaefer & Black 2005), exactly how data are collected to develop population specific standards must be scrutinised (for instance, examples cited in Hunter & Cox 2005: 215). Consider research aimed at using cranial morphology to differentiate between a Croatian and a Bosnian (Griffis 2001). Does such research take into account the complicated politics resulting in the 1992–1995 Bosnian war? Such questions raise the importance of the need for cultural and ethical awareness and invite the larger question: what limits should one put on the expert's right to information (Meskell & Pels 2005: 5)?

Because of the sensitive nature of the material forensic anthropologists examine, and to avoid notions that forensic anthropologists can undertake any research they feel is appropriate,² all research or publication using skeletal material must be undertaken with the appropriate ethics research committee approval. It is not, however, enough to “do the paperwork”: the broad ethical implications must be considered throughout and beyond the lifespan of the project (Loff & Black 2004).

The use of human remains (physical or illustrative) for research, teaching, lecturing, or demonstration purposes should be undertaken only if it has a specific point to address (O'Sullivan 2001: 130). When it comes to publishing research results, the forensic anthropologist has to consider ethical problems associated with both publishing and suppressing text and images of human remains. Whether a domestic case or one involving international assistance, the main parameter should be the definition of what is appropriate and what is relevant to specific audiences. Just recently a Dutch forensic anthropologist was fired following his decision to show images of human remains resulting from the aviation disaster of MH17 (Anon 2015).

Is it ethical to undertake research but never to publish the findings? For example, one of the issues raised by some Australian Aboriginal groups in discussions about the return of a prominent skeletal collection was the fact that, despite the museum in question having held the remains for over 70 years, the researchers had published relatively little on their findings. What benefits, therefore, could be gained from the continued curation of these remains (Associate Professor Chris Briggs, The University of Melbourne, personal communication 2005; see also Hubert 1992: 116)?

Representations of the Dead

The propensity of humans to have a fascination with the macabre is associated with a dramatic increase in the West in the portrayal and representation of the dead. This increase is evidenced by the number of photographs of human skeletal remains that appear on the front pages of newspapers and academic and fictional books and by the popularity of public exhibitions such as *London Bodies* or *Body Worlds*. *London Bodies* was an exhibition in which the human remains were the “star attractions” (Ganiaris 2001: 267) used to display the effects of urban living on Londoners from the prehistoric times to the present day (ibid.) Approximately 70,000 visitors attended the exhibition, which was the highest number for a temporary exhibition at the Museum since 1992 (ibid.: 271). *Body Worlds* consisted of 200 plasticised human beings, organs, and body slices and has attracted 6.5 million visitors in three years (Biehl & Gramsch 2001: 271).

In addition, and perhaps most significant, is the popularity of such television shows as *Bones*, *Silent Witness*, and *CSI* (to name but a few) and the media's depiction of the dead and those associated with death investigations (Black 2000: 491). Some television shows claim to have consulted with forensic practitioners in the making of such shows (see Lester N.d.), and the impact of such “entertainment” cannot be underestimated. There has been significant discussion about the effect of such shows, the so-called CSI effect, on the judicial process (for example, ABC News; Tyler 2006; Schweitzer & Saks 2007), and the influence on education is evidenced by the

significant increase in demand for courses with a “forensic tag,” including forensic anthropology and forensic archaeology.

The ethics of such depictions in terms of the impact on the community must, however, be questioned. It is possible that increased (and possibly over-) exposure to fictional death and dying in the media has created a certain immunity (or blasé reaction) to the *idea* of the corpse. In reality, however, we know that there is limited correspondence between reality and images (Bartov 1996: 10). We may be subjected to numerous accounts of death through the media, but these accounts of death (whether by an onlooker who witnessed a motor vehicle accident death, a medical professional whose patient died, a journalist reporting on a war involving killings, and so on) are obviously very different from the experiences themselves and even from the experiences of forensic and medical experts attending a death scene (Taylor 1998: 4). The ability to regard the human corpse (both soft and hard tissue) merely as an object that contains evidence for the court represents a “cultural detachment of no small dimension” (Richardson 1987: 31; see also Hockey 1996: 57). Whether students choose to undertake degrees in subjects such as forensic anthropology and archaeology because of the increasing search for sensation (Taylor 1998: 84; Wholley 2001: 276) or for a genuine desire to learn a skill, educators have a responsibility to ensure that students are clear about the reality of what is involved in forensic anthropology investigations and are well equipped both with practical and social skills (Moss 2000; Blau 2015).

Personal Ethical (Moral) Dilemmas

As discussed, most professions have a code of conduct to which the practitioner must comply. It has been argued that “the cornerstone of . . . professional ethics is private morality” (Schroeder quoted in Lucas 1989: 727; see also Jones 2000: 29 for a discussion on professional vs. personal ethics). While practitioners must consider and comply with organisational/professional ethics, they cannot ignore individual (personal) ethical (moral) issues in everyday practice. Individual and professional ethical approaches to conflict must be considered (see Lucas 1989), and such consideration raises a number of moral questions. It has been argued that a true ethical code should exist not to judge expertise *per se* but to “facilitate the negotiation of expertise within as well as outside of the profession” (Meskell & Pels 2005: 3)—that is, to explicate responsibilities rather than rights.

Practice and Meaning

It may be argued that the role of the forensic anthropologist and/or archaeologist is simply to undertake a scientific investigation for service provision: the practitioner turns up, excavates and/or analyses the remains, and returns home. The occasional lecture may subsequently be presented using images taken from casework. However, as Weber (1948) pointed out, scientific investigations tell us nothing about the *meaning* of the world or the objects within it. Can practice really be undertaken in a cultural and philosophical vacuum (Jones 2000)? As forensic anthropologists (and archaeologists), we document the body and contribute to understanding issues related to identification and manner of death. Is it, however, necessary to take into account the social aspects of death?

While, on the one hand, the body has to be treated objectively (in terms of the law it is evidence), on the other hand, there are social and emotional attachments to the body that may require cultural flexibility. Since forensic anthropologists are now involved in both domestic and international casework, should such ethical concerns be expanded to include both the dead and the living? Is it important for practitioners to have training in the ways in which different societies view the dead and the body? Is it appropriate to encourage those working overseas to obtain an

understanding of the language and culture (including burial practices) of the destination country? Such information may be important in recognising what is and is not normal for a particular culture's burial practice (Burns 1998: 66; Congram, Sterenberg, & Finegan, Chapter 38 this volume).

In addition to practical considerations, to what extent do practitioners have an ethical responsibility to consider the political dimensions of the work they undertake (Congram 2005a, 2015; Hunter & Cox 2005: 208; Blau 2006, 2015)? For example, how appropriate is it to accept employment from a military organisation that is willing to provide an inflated salary for services but has originated from a country that has participated in questionable international military intervention? Such questions also relate to issues of objectivity. How does the anthropologist (or archaeologists) stay objective when he or she receives payment from a particular group, whether military or humanitarian.

Although the forensic experts travelling to foreign countries may have the best intentions, how ethical is it for them to undertake work in a country for a finite (usually relatively short) period of time without leaving any infrastructure (both in terms of resources and knowledge) for indigenous people to undertake future investigations for themselves (for example, Hunter & Cox 2005: 210, 222)? The answers to such questions hinge on personal views and reflect one's own political stance, thus emphasising that forensic anthropology is political and consequently must have an ethical dimension.

Standards of Work

When engaged in overseas investigations (whether humanitarian and/or judicial), consultants will experience varying working conditions (see for example, Wright & Hanson, Chapter 41). The physical environment may be different both in terms of climate and landscape but also in terms of available resources. Should limited resources dictate the standards of the work of the forensic anthropologist? In theory, we know the answer to this should be “no”; all remains from any context should be treated with the same respect. The challenge to forensic anthropologists is to ensure that in practise this is the case. The next logical question is this: whose standards should then apply (Hunter & Cox 2005: 220)? What if the choice is between undertaking work limited in quality and not undertaking the work at all?

The Rights of the Families

The benefits of including families during exhumations have been raised in the literature (Blaauw & Lahteenmaki 2002: 777; Fondebrider 2002: 887; McEvoy & Conway 2004: 560; Hunter & Cox 2005: 221; Blau, Fondebrider, & Saldanha 2011). If families of victims are present during the excavation of human remains, to what extent is it ethically (in)appropriate to familiarise yourself with the families? Does familiarity affect your professional ability to undertake work to the best of your ability? Further, although international criminal tribunals believe they are acting professionally by employing experts to excavate and analyse remains, this approach may cause unhappiness/unrest in situations where local people do not want “outsiders” touching the remains of their relatives.

Do forensic anthropologists need to consider the potential impact of their work on families of victims (Hunter & Cox 2005: 221)? Although excavating remains may provide closure for some family members, others are less than content with the knowledge that, in addition to disturbing the dead, the analysis of remains may result in confronting the reality that a relative is actually dead and no longer “missing” (for instance, Blaauw & Lahteenmaki 2002: 776; Williams & Crews 2003: 256). Further, “what level of predicted success for identification is necessary to justify exhumation and identification procedures?” (Williams & Crews 2003: 225).

Consequences of the Work

The evidence recovered by forensic anthropologists and archaeologist may be used in a variety of contexts and is typically highly sensitive in nature, with often extreme and long-lasting consequences for families, communities, survivors, and perpetrators (Blau 2015). For example, if forensic anthropologists (and archaeologists) participate in the excavation of mass graves and the analysis of the interred human remains for collection of evidence to prosecute war crimes, the evidence may be used to help convict an alleged perpetrator. In some countries those convicted of such crimes are subject to the death penalty. If practitioners find the death penalty abhorrent, is it ethical for them to engage in work in such countries (see Congram 2005b; Cordner 2005: 4; Hunter & Cox 2005: 222)? Alternatively, the decision not to engage in international work raises a number of social dilemmas that have potential social and economic ramifications (for example, Blaauw & Lahteenmaki 2002: 769).

Personal Safety

To what extent is it ethically appropriate to undertake work where one's personal safety is at risk? (Blau 2015: 224). Consider, for example, the death threats posed to the Guatemalan Forensic Anthropology Foundation and its team (Anon 2006). Again, not to engage in such work poses ethical dilemmas.

Questions of Justice

Forensic anthropologists will often be involved in the analysis of remains for judicial purposes. The aim is provide evidence so that justice can be served. But justice for whom? The recovery and analysis of a victim of homicide may contribute to solving a crime and delivering punishment to the perpetrator but devastate those associated with the convicted offender. Consider the example provided by Cox (2001) in which a man is convicted of killing his wife and having led his three children to believe their mother had left them some 25 years ago. At one level justice was served: the father was convicted of the crime he committed, and the mother of the victim could lay to rest her daughter, who she had always believed had abandoned her family; at another level the children were traumatised: their father had not only lied to them but killed their mother, and their mother had in fact not abandoned them, as their father had led them to believe (ibid: 151).

At the international level, one should consider the ethical issues associated with participating in the analysis of human remains where the priority is given to determining the cause and manner of death, rather than identification of the deceased (for example, United Nations 1991; Fondebrider 2002: 889). Although legal justice may prevail, issues of social justice may remain unaddressed (Stover & Shigekane 2002; McEvoy & Conway 2004: 558). Conversely, if the investigation is undertaken for humanitarian purposes only, how appropriate is it to participate where immunity for alleged perpetrators prevails?

Conclusion

Traditionally, texts on forensic anthropology have often provided cursory considerations of ethics. The previous discussion, however, illustrates that ethical issues are paramount in day-to-day practice and deserve greater attention. A set of ethical principles that specify a code of conduct is essential for the discipline of forensic anthropology to progress. However, ethics go beyond codification. Because of the implications of their work forensic anthropologists must consider what is "reasonable" and/or "appropriate" at both the personal and the professional level.

Notes

- 1 The idea of the corpse as an object is, however, different from the interpretation of a corpse under Anglo-Australian law, whereby the corpse “cannot be the subject of property so cannot be stolen” (Frekelton 1988: 259) and is therefore not considered to be an object (Hubert 1992: 119).
- 2 See Beloff 2003 for a discussion on notions of appropriateness cf. Bahn’s conclusion that “archaeologists have the right to do just about anything in the name of scholarship” (1984: 127). Bahn’s conclusions differ little from some medical practitioners in the 19th century who believed “they were entitled to make whatever uses of the dead they wished” (MacDonald 2005: 189).

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How to Do Forensic Archaeology under the Auspices of the United Nations and Other Large Organizations

Richard Wright and Ian Hanson

Fancy what a game at chess would be if all the chessmen had passions and intellects . . . : if you were not only uncertain about your adversary's men, but a little uncertain also about your own; if your knight could shuffle himself on to a new square by the sly; if your bishop, in disgust at your castling, could wheedle your pawns out of their places; and if your pawns, hating you because they are pawns, could make away from their appointed posts that you might get checkmate on a sudden. . . You might be the longest-headed of deductive reasoners, and yet you might be beaten by your own pawns. You would be especially likely to be beaten, if you . . . regarded your passionate pieces with contempt."

(George Eliot, Felix Holt: the Radical 1866)

Achieving a successful outcome in forensic archaeology is like playing a game of chess. However, it is the game of chess as described by George Eliot. The organization that you work for has a mind of its own. You have a mind of your own. Your team members have minds of their own. Any human piece on the chess board may move to checkmate the most technologically and logistically prepared of missions.

This chapter is a guide to achieving a successful outcome for those who are employed as forensic archaeologists by large organizations such as the United Nations (UN). More specifically, it is targeted at the needs of forensic archaeologists directing investigations of mass graves. The archaeological director is referenced as "you" in this chapter. It is assumed that such investigations employ project managers working with the team in the field on logistics and support, and head office managers of general field operations and administration.

The technical matters relating to the archaeology of mass graves have previously been discussed in Wright, Hanson, and Sterenberg (2005); this section expands on the psychosocial matters raised in that chapter. In fact, a meld of technical and social planning is necessary. Only through such a combination can a team deliver the evidence of criminal activities and personal identifications in such an impeccable manner that no challenge to the team's work will succeed.

It might be thought that attention to technical matters suffices. But to think this is a mistake, akin to thinking that people are pieces on a chess board that have fixed moves and that cannot move themselves. To consider only technical matters and protocols is not enough. There is also a psychosocial environment involved in successful forensic fieldwork; the team must be supported physically and psychologically. Complex relationships will develop between members of the team, between the director and the team, and between the sponsoring organization, other agencies, and the director. These complexities must be managed, particularly in a stressful environment. Bad relationships will make the field experience unpleasant. Unfortunately, things may get worse than merely unpleasant. At the very worst the evidence itself might become prejudiced by noncooperation between agencies or by dissident team members writing derogatory letters that might be tendered as evidence in court.

One might concede that psychosocial problems need attention but assume that a large sponsoring organization that employs many staff and has policies on occupational health and staff welfare will so nurture the team that problems will not arise. One might also assume that the dedication of the team to the mission will prevent selfish dissidence.

Some assumptions may be realistic, but this chapter is written on the basis that the director will prepare, manage, and intervene proactively. It attends to the archaeological director's management of forensic archaeological teams and to "upward management" of the sponsoring organization's head office director.

Why an Archaeologist as Director?

We have already given our specific technical reasons for having an archaeologist as director of the excavation team "within the tapes" and working with a crime scene manager (Wright, Hanson, & Sterenberg 2005). We will not repeat these reasons here.

We do not intend to devalue the role of other forensic professionals. However, we disagree with Snow's opinion that a forensic anthropologist can practice forensic archaeological work after reading a few articles and perhaps attending a summer school (Snow 1982; see also Congram, Sterenberg, & Finegan, Chapter 38 this volume). More experience than this is required to evaluate what went on at spatially and chronologically complex crime scenes and mass graves and to bring work to a successful completion.

Furthermore, an anthropologist with limited experience in stratigraphy may struggle as an expert witness providing evidence when parties may call a stratigraphically experienced archaeologist to test that evidence. Disturbance—in particular, robbing a grave—creates an intricate stratification. So the evidentiary danger is acute if there is a dispute in court about whether graves have been disturbed. In our experience working on mass graves in the Balkans, Guatemala, and Iraq disturbance is a common occurrence as perpetrators hide and destroy evidence and communities search for the missing. The planning and management of area surveys and excavations are a specialized but everyday professional undertaking of stratigraphically aware rescue/salvage and academic archaeologists: these archaeologists should be used as experts.

An area where archaeological expertise is often underutilized, and where investigations are often limited in their organization, is in desktop planning and analysis. The formal research and assessment of potential landscapes and areas of interest are standard approaches in rescue/salvage archaeology (see, for example, The Chartered Institute for Archaeologists 2014). Thorough and detailed assessment of the site in question and excavation strategy relevant to the investigations and analysis of the potential findings are necessary to effectively inform planning, resource, staffing, budgets, and administrative support, as well as shaping legal, investigative, and operational objectives. Part of the planning process should include discussion and agreement on

the procedures to be used and what is required to employ them. Failure to effectively research and plan is often the reason graves are not found or is the basis of unexpected problems that affect excavations.

There are psychosocial aspects of the work that go well beyond the technical. One point must be emphasized, because it bears on style of leadership. We stated that an experienced archaeologist will be familiar with managing (while under stress) large teams of people who have disparate experience and disparate egos (Wright, Hanson & Sterenberg 2005). We went on to argue that “some professions are hierarchically ordered, with attendant hierarchically ordered privileges and comforts. This culture does not transfer productively to the more egalitarian fieldwork scene. Making sense of the novel properties of each mass grave favors a seminar environment at the site rather than an unquestioning command structure, although a protocol for decision making is still essential” (2005: 157).

To develop this point we must note that each grave is novel in its size, number and condition of bodies, soil environment, drainage, and engineering requirements. The director, as an experienced field archaeologist, must come up with a unique plan of excavation that integrates all these interacting variables at the mass grave. One hopes that members of the team will have specialized archaeological knowledge that may not be part of the director’s compendium of experience. The director must tap that experience and incorporate it into the unique plan of excavation for each novel site.

By contrast, procedures in forensic anthropology, although requiring a great degree of skill and experience, have become formalized. Apart from the need to develop population-specific standards, most anthropology team members will probably not have something to offer that requires the rewriting of a plan of analysis of sex, age, ancestry, and interpretation of trauma. It is the director of anthropology’s duty to ensure that standard protocols are followed and to be wary of innovation. Consequently, a managerial structure is required for the anthropological laboratory that is more hierarchical than the looser structure that is beneficial on an archaeological excavation.

Leadership and Style

The archaeological director will initially have authority, because of his or her experience and because he or she has been appointed by the organization. At the start leadership should be easy. However as time proceeds, especially in an “exotic” environment, hierarchical leadership tends to weaken because of rotation and mixing of personnel, isolation, and the hardships that must be shared. An autocratic leader will have psychological problems with this weakening of authority. A sign for the breakdown of leadership is when a director starts living in a hotel, spends a large amount of time away from the team and site, or turns up at the site only when it is visited by important people or the media.

Of course, leadership need not be autocratic. Essentially there are three styles of leadership:

- *Autocratic*: the director decides, and members of the team do not participate in the decision making;
- *Consultative*: the director consults and interacts with members of the team but then decides unilaterally;
- *Laissez-faire*: members of the team make the decisions.

Autocratic leadership is maladaptive for a successful outcome. It isolates the director from the collective experience of members of the team, who may have ways of solving technical problems. Unless the director’s experience exceeds that of the combined experience of the team,

autocratic leadership encourages dissidence, which may break out after the fieldwork is over and prejudice the evidence.

Consultative leadership is the most successful method. It leads to a better technical outcome. Some members of the team may have uniquely relevant experience that the director does not have. Consultative leadership will tend to keep the team cohesive and free from dissidence.

Laissez-faire leadership on forensic excavations can be dismissed immediately, since it is too anarchic for evidentiary purposes. It will produce work that the director could not speak to in court.

The consultative style of management is the best approach, but it nevertheless requires some understanding. In a multicultural team, for instance, some members may not be familiar with the very concept of consultative leadership. They may not speak the predominant language of the team, they may be too embarrassed to express their views at a team discussion, and they may fear that offering advice will be seen as subversive. So it may be necessary for the director explicitly to seek their opinions privately until they become more accustomed to the culture of consultative leadership.

It should go without saying that the director takes the time to brief each new member of the team on his or her arrival. Unfortunately this practice is not always followed in general archaeology, and there are tales of persons working down a hole for weeks, having never been informed about what is being done and why. People treated in this way are likely to become disaffected and work in a manner that is incompatible with the planned process.

In forensic archaeology such neglect of new team members is not so likely, since each team member will have to be taken through the very necessary risk assessments, safety briefs, and protocols for the excavation. It is the director who should take them through the protocols. A forensic excavation is not a large manufacturing company factory; there is not a hierarchical management line within the team that is so long that the director is prevented from dealing directly with each new team member. The team is not made up of production line workers; they are intelligent and qualified professionals who benefit from a consultative, flat organization or management style.

The excavation will benefit from the director doing the rounds of the site, checking on the logging of finds, the surveying, and the security and safety of the site. Informal chats coupled with watchful eyes can uncover what might be going wrong in matters as diverse as undermining of section walls, deviation from protocols, and inadequate backing up of excavation logs.

In brief, the purpose of consultative leadership is not to make everybody feel good. The purpose is to produce the best outcome and to forestall dissidence that might prejudice the evidence.

Exotic Environments

Much forensic excavation will be done in environments that are exotic to members of the team. Appointing locals to the team would obviously ameliorate the effects of the exotic nature of the environment, but for evidentiary reasons appointing locals may not be acceptable (see Djurić, Chapter 36 this volume).

Harrison and Connors analyze the special relationship between exotic environments and small teams (1984: 53). They comment that published studies were virtually restricted to groups in submarines and in polar and outer-space settings. Among the groups they list as ignored are archaeologists.

The psychosocial dynamics of archaeological teams in exotic environments is specifically discussed in Hanson (2007), and some attention has been paid to tensions in small teams in nonexotic environments (Moore 1986) or large teams in exotic environments ameliorated by

massive infrastructure (Hamilton 2000). The problems associated with the work undertaken by forensic archaeologists have perhaps more in common with disaster management and mass-fatality incidents. These have been written about in depth (Levinson & Granot 2002; Pan American Health Organization 2004; Haddow & Bullock 2006).

To adapt the comments of Harrison and Connors to forensic teams: the climate may be harsh or unfamiliar; there may be physical danger from local perpetrators, unexploded ordnance, contamination, unfamiliar wildlife; facilities and supplies may be poor; the team is isolated from family and friends; and members of the team will be forced to interact with each other. The team must cope with “accelerated acquaintance processes, limited personal space, an inability to escape companions who have annoying traits or mannerisms, and an inability to keep conflicting individuals apart” (1984: 54).

It is critical that the head office does not force on the team domestic arrangements (for example, barrack-style accommodation) that exacerbate social tensions. Encourage the head office to concentrate on providing a postal service, international phone calls, and Internet access, and discourage the head office from interfering with domestic living arrangements. Wherever possible, members of the team should be left to their own devices outside working hours.

Working hours should vary according to the length of the mission. For two weeks people can work 12 hours a day for all 14 days—even under stressful conditions; however, they cannot work like this on a project that lasts six months. The head office probably works a five-day week, so the director can use that information when countering pressure for the team to work physically and psychologically damaging hours. Remind the head office that the team’s working conditions are going to be disgusting and possibly dangerous. Working under pressure is likely to result in errors and create tensions in the team that may lead to dissident complaints that prejudice the evidence.

Members of the team may benefit from reading handbooks devoted to working in exotic environments. John Ehrenreich (2005) has provided a very practical guide.

Composition of the Team

The team may embark with a strong sense of mission. Such a promising start makes it all the more distressing when tensions start to develop within the team—as they most certainly will. The archaeological director must manage these tensions lest they adversely affect the quality of the work and the integrity of the evidence.

The archaeological director should choose the team members. However, advice should be taken from others about “who’s who” in the world of forensic fieldwork, so that there is a proper mixture of nationalities and experience. A multicultural team is unlikely to be accused of being subservient to the prosecutors and the lawyers, or, worse still, of fixing the evidence.

Ensure that the personnel division at the head office requires a medical examination of team members, certifying fitness to travel and to undertake fieldwork. If it is anticipated that the excavations will involve the recovery of decomposed individuals, people with previous experience handling soft tissue should be hired. Emphasize to the head office that human remains may cause feelings of disgust, shock, distress, and/or anger in team members. A forensic exhumation is no place for an unproven person that somebody in the head office would like to provide with work experience.

Harrison and Connors (1984: 61) discuss the type of people suitable for working in small groups in exotic environments. The team needs people who are technically competent to achieve a successful outcome, but also people who contribute to the overall quality of the team’s social life. On its own, obsessive attention to technical matters can cause social stress in the team. However, an orientation that is too socio-emotional may cause the team to fall short of the required high performance standards.

People who are socially versatile (not so introverted that they provide little stimulation to the group and not so extroverted that they force themselves on others) often make up a successful team (Harrison & Connors 1984: 61). In the light of our experience, those who are employed on a contract and not volunteers make for a better team. Volunteers tend to be restless in exotic environments. They may resent having to miss the sights and decide to wander off. If having volunteers is inevitable then make sure that there is a core team of paid and trusted people under contract. A core team provides the advantage of continuity through the whole project and a fund of experience from which the team as a whole can draw.

In particular try to get a scene of crime officer (SOCO) to manage the handling of evidence through the whole project. Do not rely on SOCOs volunteered by a friendly country but who are rotated every two weeks. However good the individual SOCOs are, the lack of continuity creates a burden of induction and a threat to the admissibility of evidence owing to changes of style and record keeping.

Dealing with the Organization

The team will depend on the employing organization for its survival. Members therefore cannot avoid dealing with its bureaucracy and management. The problem is that the team will have very little time to learn how to deal with the organization's bureaucracy, and the organization little time to understand the needs and potential of a team. The mission's success or failure may take place over a short period—sometimes only weeks—so fulminate against the organization's bureaucracy later, and concentrate on achieving the mission objectives.

Many problems arise from an organization's management not understanding the potential of disciplines to contribute to investigations and what teams require to achieve their objectives. The expectations of an organization may often be different from those of the archaeologists. The role of the archaeological director includes managing those expectations and clearly demonstrating to an organization what and how archaeology, archaeologists, and the team can contribute (see also Cheetham & Hanson, Chapter 14 this volume). The archaeological director must liaise and coordinate with managers to define the responsibilities and roles of the team, and this responsibility requires ensuring that the archaeological director is involved in the planning, resourcing, budgeting, and staffing of investigations, as well as the setting of objectives. If the archaeological director does not contribute and clearly inform the investigation management of the capability of archaeology and anthropology, failure and frustration may result as organizations do not achieve objectives, archaeologists are underutilized, and evidence is not recognized and gathered.

People developing an innovative science often encounter an innate conservatism from within and without scientific disciplines, and this problem has been recognized for some time (Barber 1961). Organizations may be slow to understand and accept approaches outside their experience, and, in the dynamics of limited time to achieve objectives and of the gravitas of criminal investigations, advocacy for the adoption of new practice can create tension. The directing archaeologist often has an uphill struggle to demonstrate the veracity of archaeological approaches. In other circumstances, investigation managers may be persuaded of methods or new approaches without seeking or having been provided with the evidence that these new procedures are suitable, best practice, or justified. An example is an organization preempting the use of an archaeologist to undertake a remote sensing survey by getting a geophysicist who is unfamiliar with archaeological requirements and who has made promises of results that are not achieved or achievable. The result can often be increased suspicion by organizations of methods and disciplines, leading to an undesired effect on the potential effectiveness of future investigations.

A deliberate negotiated approach is needed with a clear outline presented of how archaeology can advise and assist in the specific investigation. A lack of experience within organizations of what support is required to successfully undertake field operations involving archaeological best practice may also extend to the sponsoring organization's administrative side.

Major problems often relate to the fact that a particular bureaucracy may literally not work—when an organization does not attend to its “bureaus.” For example, cash for maintenance expenses may not be delivered in a cash-only economy; crucial equipment may not be repaired or replaced; or flights for team rotation may not be booked.

In our experience a major cause of paralysis was administrators going on leave or being away from the office during operational hours. For example, it is normal to work on Saturdays but not Fridays in the Middle East, and so a head office working from Monday to Friday might be in office-hours contact with their in-country program staff only four days a week. There are also significant time-zone differences between continents to be taken into account. In business, if somebody goes on leave then it is normal that his or her desk is attended to by somebody else—lest the business's inefficiency cause bankruptcy. Such continuity may not be provided in an organization such as the UN, where going bankrupt is an irrelevant prospect. Nor is sacking much practiced. The best the team can hope for, if a particular person repeatedly lets it down, is that the person will be shifted over to some nonoperational section.

It may be aggravating that an organization that employs a team to do its critical work should then act as if the team is a nuisance. Yet if the team is treated in this way, it must accept that such contradictions often exist. The team must succeed if the work is to be satisfactorily completed, yet it often finds itself wasting time developing novel problem-solving ways to circumvent bureaucratic hurdles so that it can achieve its objectives in the operational timeframe. Highlighting the effects of hurdles as well as increasing the awareness of operational needs within the bureaucracies is a definite aim (that one hopes results in effective adjustments to support and policy). Therefore, the rest of this section provides advice on how archaeological directors can interact successfully with bureaucracy. The points are disparate and not listed in order of importance.

- Ensure that the team is provided with an experienced project manager who can attend to the life support, logistics, and planning and remain with the team. These managers need to be familiar with the organization that is sponsoring the team and with the local country of operation and see that these support roles are not pushed onto the team's technical staff.
- The team's archaeological director should get acquainted with people high up in the organization who can advise on its structure and policy. At times of emergency the archaeological director can appeal to these people to deal with a recalcitrant bureaucracy. The archaeological director should insist on a visit to the organization's head office well before the fieldwork starts and meet the key people in the legal section, personnel, finance, and the section that deals with procurement of supplies. The archaeological director should also regularly contact the managers at the head office. Give good news about the fieldwork first and bad news and requests second.
- The head office may decide that fieldwork will start on a particular date; it probably will not. In fact, the work may be repeatedly delayed. Some of the delays will be due to bureaucrats not doing their work. Some delays, however, will be legitimate and caused by unforeseen changes in coordination, the weather, or security. Whatever their origin, these delays can damage the finances of the self-employed who are sitting at home waiting and conflict with other planned work and leave arrangements of consultants and the self-employed. The team can try to mitigate the problem by getting contracts for fixed dates regardless of the delays, but the chances for this are not good.

- The contracts the team are asked to sign when they arrive in the field may differ from the draft contracts they were sent at home. Invariably we found that the differences favored the organization. Sometimes the potential reductions in pay were severe. For example, a team had for three years worked for a monthly flat rate of pay. Suddenly a novel clause was inserted that set the same monthly rate but abolished pay for days off. In other words, you could make the same money as before only by working seven days a week instead of the previously established five. This clause was discarded when it was made plain to the organization's administration that they would have no team for the fourth year. Why are such damaging actions taken? Probably because contracts have to be approved at a high level and somebody at this level does not attend to the process of approval until the team is ready to sign the contracts and start work. The approver nevertheless cannot resist tinkering with the contracts to save the organization money, regardless of timing and likely consequences.
- It is imperative that risks are formally identified and mitigated in a flexible and practical way. Paradoxically, organizations may have no formal risk-management or risk-assessment structures in place, and this situation should be addressed as part of the initial coordination and planning process.
- Has the employing organization taken into account the possibility of accident? Is it possible to prepare a helicopter landing area near the site? Does the team know where to go in the case of a medical evacuation? How will the team communicate with medical people if there is an emergency? Has the organization provided a satellite phone that can be operated from anywhere, and round the clock, in the case of emergency?
- Likewise, beware of having physically harmful health and safety procedures inflicted on the team. The archaeological director should make sure that the procedures are workable. In summer, in most parts of the world, excavation cannot proceed if the team is required to wear impermeable body suits, face masks, and arm-length gauntlets. We have argued elsewhere that mass graves are not, in our experience, inherently unhealthy environments (Wright, Hanson, & Sterenberg 2005). Those worried about catching diseases from dead bodies may take comfort from a Pan American Health Organization's manual (Morgan 2009): dead bodies do not cause epidemics after natural disasters. Most infectious organisms do not survive beyond 48 hours in a dead body. Exceptions are HIV, which has been found six days postmortem, and Ebola, which has been found seven days postmortem. Nevertheless, the authors of the manual outline some basic precautions that should be taken when handling dead bodies in the field.
- Has the organization properly considered whether the work is to take place in a potentially hostile social environment? What kind of protection will the team need? If the director concludes that the team needs armed protection, who can authorize its use and who will provide it?
- There may be a puzzling refusal by the organization to provide goods. To take an extreme example, for three years we were not provided with drinking water during work on mass graves in Bosnia. Team members had to bring dubious town water in bottles, drink chemically sterilized washing water at the site, or hope for bottles of water to drop off the back of the trucks of their military escort. Bottled water was unobtainable in the shops. There was a simple bureaucratic reason for the organization not providing drinking water: they gave us a living allowance and could not work out how to get the money back from us if they provided drinking water. We were slow to solve this problem. Victory over the accounting conundrum came only when we were able to show that the organization was in breach of the International Labor Laws by not providing drinking water at the workplace. We solved the problem by making it no longer an accounting issue. The moral is to get these basic issues resolved before deployment.

- Beware of having forensic protocols inflicted on your team by those who do not have relevant qualifications and experience in archaeology. The protocols may be unworkable, and your lack of compliance may then be used in court to question the value of your evidence. Be proactive and work out your own protocols if required, in liaison with the investigation managers. Keep them simple yet essential, so as not to prejudice the evidentiary value of your work owing to noncompliance.
- Consider how you and the team are placed over matters of insurance and legal liability. Does the organization cover its contracted team for injury at work? Does it compensate dependent relatives for death? The contracts with the UN stated that contractors were treated as if they were UN staff from the point of view of compensation. Does your organization explicitly adopt that proper attitude and comforting provision? The provision must reflect the potentially hazardous nature of working environments. If team members are made to provide their own insurance (necessarily through brokers because of the nature of the work and its location) they may find insurance premiums are so financially prohibitive as to deter them from taking on the job. Or they may not insure themselves.
- It is necessary to plan for sensible occupational health arrangements. Be wary of accepting counselors. In fact counselors can be a disruptive nuisance when managers inflict them on a professional forensic team. Their very presence implies that members of the team have undergone some sort of appalling stress. Usually they have not. Paradoxically, counselors may make the team feel guilty because they have not felt upset, because they have found the work interesting, because they have enjoyed camaraderie with others in the team and have enjoyed the occasional black humor. Persuade the head office that counselors are intended for those that have experienced out of the ordinary, sudden, and unexpected emotional trauma. Your team will not experience professionally out of the ordinary, sudden, and unexpected emotional trauma (Hanson 2007). Members of your team have started the job prepared for the worst. Counselors may be most beneficial in assisting people in the administrative and clerical positions in the head office who have to collate images in files or read and proof drafts of reports, which exposes them to gruesome forensic matters that are out of the ordinary and shocking to them.
- One good protection against stress impacting the team at mass graves is an obvious one: that the people recruited should at the very least have already had experience working with skeletal remains. They will thereby have already put behind them the disturbing “intimations of mortality” that first contact with any human remains can induce (see also Hanson 2007). Nevertheless, you cannot be careless about the psychology of your team. In particular, the team environment should be supportive. Look after team members who have no friends and who will be returning home to a place where they live on their own and with loss of team contact. Constrain, isolate, or get rid of any damagingly aggressive team members. Many stressors for the team come from administrative issues impacting operations rather than intimate work with the dead.
- Encourage members of the team to bring as much cash as they can if they are operating in a cash-only economy. The contract may specify that they will be paid a living allowance in cash in advance, but everyone should work on the assumption that they may not see the cash for a few weeks; during this time of paralysis at the head office members must pay for their accommodation and food. We were members of a team of which several ran out of cash and had to rely on the others, because of the persistent incapacity of the head office to provide the promised cash.
- The people who procure equipment should be provided with strict specifications about the equipment. We have experienced altered specifications leading to chiller vans whose doors could not be opened when they were mounted on their flatbed trailers; a dumpy level that

swung on a 400-unit base instead of the 360-degree base that our survey software required; trowels that had blades the size of an A4 sheet of paper (chosen perhaps because of an armchair notion that they would allow us archaeologists to shift more soil than would the conventional namby-pamby 4-inch blade); a laptop computer that had its operating system altered by an IT section that thought it knew better than Microsoft, with the result that it could not run our specialized laboratory-style DOS programs; and remote administrative control of computers, which meant that problems could not be addressed in an operational timeframe, since IT administrators were stationed in other countries or continents. All these deviations were discovered once equipment was delivered to the team at the operation's base. So the team's archaeological director should explain in advance to the procurement and IT sections that some items are technically vital and cannot therefore have their specifications altered. Such explanations may entail writing such a precise procurement description that no brand or model other than the one you require can be purchased and reviewing policies with an organization's managers as part of predeployment planning.

- The organization should have a well-planned media strategy. In some contexts, media should be discouraged, because in dangerous situations their presence may aggravate the perpetrators into attacking the team. Some members of the team may not want their faces to appear on internationally distributed public media (they may have worked on politically sensitive excavations elsewhere). Members of the team may be caught off their guard, being filmed smiling in a scene that includes a corpse. Media presence must be tightly managed, and therefore infrequent—which may be at odds with your organization's desire to publicize its work and the political need to demonstrate to local and international communities that work is being carried out. A balance needs to be negotiated.
- The archaeological director should not rely on the organization's head office to provide critical personal details that may be required in an emergency. Because an accident may happen over a weekend when head office staff cannot be contacted, it is necessary to ensure that team members provide information in-country about their blood group, special medical details (such as anesthetic or antibiotic allergies), names and contact details of next of kin, and their own contact details for the immediate postexcavation period.
- Team members should be reminded that they are ambassadors for the team and may need to restrain their behaviour in public. To reduce the chance of accident or incident the team should be instructed about where they can and cannot go on their days off. Details of the investigation should not be discussed with people they do not personally know. Raise these issues as part of the predeployment discussion of personnel and risk-management policies.
- After a group has been working for an organization for some weeks a caste system may develop. Administrators in the head office work in clean, air-conditioned comfort; the team is doing such inexplicably disgusting work that it is "unclean." Thus the head office may distance itself from having to think about the polluted team to such an extent that it provides inadequate support: people at the level of mass-grave diggers could not possibly have dependent families and mortgages, so what do delays in paying them matter? Discussion at the head office should help to dispel these prejudicial notions. More important, you should encourage administration to visit the excavations.

Dealing with the Dead

The team may be doing its fieldwork at the point of a gun and with the backing of a Security Council resolution. Or the continuity of its humanitarian work may require negotiations, renegotiations, and cooperation with the authorities and relatives.

Dealing with the dead, in contrast with the archaeology of artefacts, creates specific risks and responsibilities (for examples and contrasts see Márquez-Grant & Fibiger 2011; González-Ruibal & Moshenska 2015). Preparing a checklist of what to do is helpful; the director will ultimately be held responsible if dealing with the dead and the living is clumsily handled. In the chapter appendix we have included a suggested list of what to consider. This list covers only the context of dealing with the dead, not with general matters of the mission and the archaeological work.

Conclusion

In summary, all the team's actions should be directed to maintaining the integrity of the evidence that is necessary both for the successful identification of the dead and for prosecutions. Ultimately it is the team's work that may be the key to gaining convictions and repatriation of remains to families.

Without the physical evidence of killings, the perpetrators, their defenders, and revisionists can set up a contest in which we argue over the meaning of lines of text in historical documents or phrases in an investigator's intercepted telephone call and in which we argue over the integrity of a person's memory. Of course scholarship, investigations, and memories are critical. But we also need to look at the powerful evidence of the bodies: they are there, somebody killed them, and these actions demand an explanation. Such explanations must come through the eyes of the unbiased forensic professionals in a team. That is why the sometimes recalcitrant organization will have hired the team. The organization may see members of the team as pieces on a chess board, but you must seek to make the organization work for you by playing the style of chess that George Eliot's quotation describes at the start of this chapter.

As a postscript: in this chapter we discussed several "down sides" of working in forensic archaeology. However, on the positive side we agree with Harrison and Connors that exotic environments can provide substantial rewards for team members (1984: 69). These include:

- 1 an opportunity to become totally immersed in one's work;
- 2 an opportunity to be judged on the basis of performance rather than on the basis of extraneous factors such as age or race;
- 3 a socially and financially uncomplicated existence;
- 4 an opportunity to build self-esteem, and
- 5 adventure.

All this rings true. To the points of Harrison and Connors we add:

- 6 an opportunity to contribute to international justice;
- 7 an exciting and exotic experience in a short time;
- 8 opportunities to develop new methods, techniques, and research; and
- 9 interaction with diverse regions and communities.

At the end of a forensic field season many of us have said "never again" only to remember the enjoyment and return the next year.

APPENDIX: Checklist for Preparing to Excavate Human Remains

This checklist draws on personal experience and literature. Sources of advice have developed over the years and address a range of issues and considerations that can be reviewed in Giesen

(2013); Márquez-Grant and Fibiger (2011); Cox et al. (2008); Brickley and McKinley (2004); Williams (2001); NSW Heritage Office (1998); and Historic Scotland (1997).

Considerations before Excavation

- Can you honestly estimate the time the work will take?
- Who are you going to consult and from whom must permissions be sought? Consider:
 - owners, managers and tenants of the land
 - police
 - coroner or relevant legal representative
 - governments at various levels (for example, state and federal)
 - tribunals and commissions
 - health authorities
 - people claiming to be relatives and friends
 - religious authorities
 - heritage authorities if graves are in important areas of heritage
 - ethnic and other community groups that claim a direct interest in the particular dead
 - local historians/archaeologists/anthropologists and their societies, if graves are in areas of cultural significance
- Do you need a court order?
- Should you conduct and advertise a public meeting before starting work?
- How will 7-day/24-hour protection be provided for the human remains at the site, to guard against animal scavenging, looting, and tampering with evidence?
- What special health and safety considerations do the particular remains call for?
- Have you considered allowing relatives to perform religious rites on the site before and during the excavation/exhumation?
- What are the dress codes that locals will expect your team to follow?
- How much local involvement is allowed in the examination and recovery of the remains? In some cultures families and local people may want to take part. You may be able to accommodate their wishes, although questions of legal liability may need to be explored with your organization. However, at crime scenes, and at other evidential exhumations, no local involvement is likely to be permitted—regardless of local wishes. The reason is the risk of accidental or deliberate contamination of the evidence.
- How will you shield sensitive work from the unwanted view of the public and media? Shielding human remains may intensify public excitement and rumor. So it could be appropriate to have some skeletal remains on view. It is unlikely to be appropriate to have bodies with soft tissue on view.
- Where will the remains go immediately after excavation, and are storage facilities there adequate?
- What are the transport and packaging requirements for samples and remains?
- Do arrangements need to be made for reinterment, and, if so, when will reinterment happen, and how will the bodies be treated? Will they be put in their original graves, in new individual graves, or in a mass grave? Who will cover the costs of the reinterment?
- What ceremonies will be required at reinterment, and how will you resolve competing claims for rituals?
- What will the site look like after restoration?

- Will a monument or monuments be required, and who will pay?
- Who will require reports on the work, and what will they need to know?

In briefing the team, have you discussed why human remains are publicly sensitive items? For example:

- They remind people of their own mortality.
- They may disturb those that have lost loved ones.
- Seeing and disturbing the dead may be celebrated in some cultures but be taboo in others.
- The public may be concerned about whether relatives and friends have given consent for the work to be undertaken.
- Young children may find the sight of human remains traumatic.
- Human remains may stimulate morbid curiosity and macabre behavior in some people.

In briefing the team, have you asked them to:

- tell you if they are reacting badly to the task of handling the remains, with a view to being assigned more general duties?
- show tact and respect in dealing with human remains?
- follow appropriate dress codes? (Codes may be different for men and women, but the aspects to consider usually relate to covering the head, covering the shoulders, and wearing trousers rather than shorts.)
- ensure that the work of excavation is not presented as a spectacle?
- encourage visitors not to see the remains as bizarre but (where appropriate) to feel empathy with the dead and their former lifestyles?
- treat fellow team members with respect and understanding—the more so if the work is physically and psychologically disturbing?
- realize that emotionally disruptive behavior may lead to a person being asked to leave the team?
- enter into voluntary after work activities (such as a meal or outings) so that off-site interaction between members may help counter stress?
- Some human remains may have to be excavated at the point of a gun in a socially hostile environment—for example, in gathering evidence for an international tribunal. If this is the scenario, have you prepared your team for the abandonment of the channels of getting permission (channels that they will see as customary), and the consequent surrender of many of the ethical considerations included in these notes?

Protocols during and after Excavation

- Who can handle the remains during excavation and removal?
- Who can see the remains during excavation and removal?
- Have you assigned somebody to answer questions from the public?
- Would it be useful to have a leaflet about the work to give to interested persons?
- Prepare for dealing with the media before their arrival.
- Decide what you will communicate to the media, and how.
- If necessary get prior agreement from the media for restricting identity of victims, witnesses, and/or team members, and a moratorium on sensitive information.
- Assign somebody to answer questions from the media.

- Advise the rest of the team to politely decline answering questions from the media and to refer the media to the assigned person.
- Tell the team to watch what they say if approached by strangers (both on- and off-site);
- Make it plain to the media that any photography or filming must be restricted to specific periods; if the media is allowed to film at any time, that freedom places too much strain on the behavior of the team, who may, for example, be caught off guard laughing or engaging in the relief of stress by black humor.
- Be sure that you know the context within which the information given to the media will be used.
- Do not assume the media is on your side; do not assume the media will be well disposed in the representation of your work, regardless of what they say when they approach you.
- Specify clean areas of the site for eating, chatting, and smoking.
- Locate personal washing areas a respectful distance away from the remains.
- Determine where remains will be taken.
- Determine if remains may be put on public exhibition—if, for example, aggrieved relatives want this. Would this conflict with your organization's mission statement?

Photographs

- Who can photograph the human remains, including video and film? (Team members will want to take their own photographs. If they are forbidden then they will feel aggrieved when they see others taking unofficial photos. Consider the pragmatic guideline: what is open to the public and media to photograph is also open to team members to photograph.)
- Who can look at the photographs?
- Is enhancement of photographs allowed?
- Where can photographs be published? For example, in the media, in scientific papers or scientific books.
- Where can photographs be publicly exhibited? (If photographs are to be included in a report to local individuals consider including a statement on the front cover along the lines of: "Warning—this report contains pictures of human remains.")

Research

- Who authorizes any research on the human remains?
- What permissions are required and from whom?
- Have families of victims been consulted?
- Is the research being undertaken restricted to assisting in the identification of the victims, or is research allowed for more general scientific advancement?
- Who is allowed to undertake the research?
- Are researchers required to lodge copies of their field and laboratory notes?
- Can the results be published?
- What kind of research will be undertaken? For example, invasive; parts of the body temporarily removed for nondestructive analysis such as measurement; parts of the body permanently removed for nondestructive analysis—for example, to a museum of pathology; parts of the body removed for destructive analysis—for example, DNA, radiocarbon dating, stable isotope analysis.

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Contribution of Quantitative Methods in Forensic Anthropology

A New Era

Ann H. Ross and Erin H. Kimmerle

The emergence of any new field of study begins with a description of what it is and what it may become.

In the United States the first methods for estimating the biological profile of unknown individuals in a forensic context were developed in the 19th century by Thomas Dwight (1843–1911). Dr. Dwight, a Harvard anatomist, used “inverse regression”¹ to estimate stature, sex, and age from skeletal remains. Although the field of forensic anthropology would not become officially recognized in the United States by the forensic sciences as its own discipline until after 1972,² the methods produced by Dwight set the stage for the early development of the field and established its quantitative basis (Stewart 1979; İşcan 1989).

The need to identify war dead during World War II and the Korean War ignited a surge of research on methods for biological profiling and human identification. This body of work included methods for age (Todd 1920; Moorees, Fanning, & Hunt 1963; Hoffman 1979; Stewart 1979; İşcan, Loth, & Wright 1984, 1985; Ubelaker 1989; Brooks & Suchey 1990; Lamendin et al. 1992), sex (Krogman 1962; Giles & Elliot 1963), ancestry (Giles & Elliot 1962), and stature (Trotter & Gleser 1952, 1958; Trotter 1970) estimation—which have become known as the *four pillars of forensic anthropology*.

Statistical methodology for biological profiling has been largely based on descriptive and univariate statistical methods, such as regression, discriminant function analysis, and principal components analysis. In addition to univariate statistics, the concept of *descriptive methodology* appropriately characterizes much of the research in forensic anthropology. A qualitative approach, as evidenced through published technical notes, case studies, and the annual American Academy of Forensic Sciences (AAFS) academy meeting presentations, has even led to the idiom that forensic anthropologists are lower on the academic food chain, lest they present “gee whiz” cases in place of scientifically rigorous research. This problem is not unique to anthropology but has plagued all areas of forensic science to such a degree that scientific evidence has been called into question and at times excluded from trial (Robertson & Vignaux 1995; Lynch & Jasanoff 1998; Waits, Luikart, & Taberlet 2001; Saks & Koehler 2005). This paradox has even led some skeptics to question the very use of the term *science* with *forensic*.

In the past, forensics has been viewed as an *applied science*, relying on research and methodology from established disciplines such as biology and medicine, which in turn “apply” expertise to

legal and social problems. Statistical analyses have been largely descriptive (Gullberg 1993). As the forensic sciences have developed in recent years, the trend has emerged each discipline to be more research driven, including anthropology. The complex problems facing investigators today requires specialized knowledge and scientific pursuits directed toward answering a variety of specific legal and medical questions. In other words, the legal issues that arise during the process of a trial are now steering the direction of scientific research directed towards answering medico-legal questions (Christensen 2004; Rogers & Allard 2004; Steadman, Adams, & Konigsberg 2006; Kimmerle & Jantz 2008; Kimmerle et al. 2008a, 2008b).

One needs only to look at challenges to the presentation of scientific evidence in court to realize that a legal context changes the role and responsibilities of the scientist (Wilson 2005). Rogers and Allard (2004) outline the American and Canadian standards for the scientific presentation of evidence in court. The qualifications of a scientific expert witness and the admissibility of scientific evidence in the United States are defined in *Frye v. United States*, 54 App. D.C. 46, 47, 293F 1013, 1014, 1923; Federal Evidence Rule 702, 2001; and *Daubert v. Merrell Dow Pharmaceuticals, Inc.* 509 US 579, 199. The U.S. Federal standard is based on the Supreme Court ruling of *Daubert v. Merrell Dow Pharmaceuticals, Inc.* (1993), which requires a scientific method to be more than “generally accepted” and to have known or potential error rates associated with it, thus putting pressure on the forensic community to standardize and test their methods. Much of the driving force behind the push for quantitative methods and research driven methodology stems from challenges to DNA and fingerprint evidence (Robertson & Vignaux 1995; Waits, Luikart, & Taberlet 2001; Rogers & Allard 2004). Culminating from this trend, current research in forensic anthropology is largely focused on the use of quantitative methods, Bayesian statistical modeling, probability and maximum likelihood theory, and the use of new technologies such as virtual modeling of 3D imaging. The following section delineates the contribution of quantitative methods to the field of forensic anthropology.

Quantitative Methods for the Four Pillars of Biological Profiling

The question of human variation, as it pertains to biological profiling for unknown victims in medico-legal cases, is paramount for the increasing number of anthropologists working globally investigating crimes against International Humanitarian Law. Human variation was once an academic pursuit of interest to skeletal biologists, demographers, and palaeoanthropologists—not lawyers. However, the question of whether methods for estimating biological profiles are reliable universally is now a legal question. Consequently, the focus of forensic anthropologists on the identification of unknown individuals has contributed significantly to the study of human skeletal remains, especially in developing the standards used by the discipline as a whole. Aykroyd and coauthors wrote:

there is still a case to be made in favour of the “forensic” approach in situations where there may be a limited number of individuals available for study, such as the prehistoric tumuli of Western Europe, or whenever the anthropologist needs to know the age of a specific individual. The “forensic” approach should be seen as complementary to the emerging techniques of estimating population age structure.

(1997: 261)

As a result, forensic anthropology is at the forefront of innovative and modern quantitative methods for the study of human variation. In the last decade we have seen a transformation from indiscriminately and inappropriately utilizing equations developed from American populations on other populations to the development of population-specific identification standards

(for example, Ross & Konigsberg 2002; Del Angel & Cisneros 2004; Ross et al. 2004; Schaefer & Black 2005; Indriati this volume). Further, Kemkes-Grottenthaler provides a brief review of various studies that have found significant population variation in “biologically induced differences in the aging mechanisms” (2002: 64). In fact, this transformation can be unmistakably seen in the quality and nature of the papers being presented at the Academy³ meetings with much more attention being given to the “large-scale” issues that we have been criticized for lacking in the past. Multivariate statistical analysis and probability theory are essential to understanding human variation, improving existing methods, and developing new identification methods.

Sex and Ancestry

The estimation of sex and ancestry are key components when one is rendering a biological profile from skeletal or badly decomposed remains. The precise estimation of sex and ancestry are critical in the identification process, because they can narrow the search for an unknown individual, which can lead to identification. The estimation of sex and ancestry is the first step in a biological profile; other analyses such as age and stature are sex- and ancestry-specific and cannot be adequately determined without this information.

A key component to expediting the identification process is the ability to most accurately determine race or ancestral information from skeletal remains. Knowledge of the ethnic origins of an individual drastically narrows the search for missing persons, and this can ultimately increase the speed and likelihood of successful victim identification and facilitate the reconstruction of the events surrounding a crime.

Traditional Craniometric Methods

Since the 1960s forensic anthropologists have utilized their knowledge of population variation to develop measurement standards and discriminant functions to estimate ancestry from human remains (Giles & Elliot 1962; Ubelaker, Ross, & Graver 2002). In the mid-1980s Richard Jantz, from the University of Tennessee, created the Forensic Data Bank using traditional techniques of size and shape analysis based on linear measurements to assemble skeletal data for improving identification methods (Jantz & Moore-Jansen 1988; Moore-Jansen, Ousley, & Jantz 1994). This effort resulted in the computer program FORDISC 2.0 (Ousley & Jantz 1996) (recently upgraded to FORDISC 3.0), which is widely used by forensic practitioners and derives custom discriminant functions for up to 21 cranial measurements to classify unknown crania into 7 possible racial groupings (White, Black, Amerind, Japanese, Hispanic, Chinese, and Vietnamese) dependent on the sex of the individual. The utility of the software is dependent on the similarity of the unknown skull to one of the reference populations within FORDISC (Ubelaker, Ross, & Graver 2002).

Historically, methods of size and shape analysis, such as those employed by FORDISC, have relied on the application of multivariate statistical methods (for example, multivariate analysis of variance, discriminant function analysis) to sets of caliper measurements that correspond to linear distances, and sometimes to angles (Rohlf & Marcus 1993; Lynch, Wood, & Luboga 1996; Ross, McKeown, & Konigsberg 1999). One of the major limitations of this type of data acquisition and analysis is that the measurements or angles are ultimately based on the positions of the endpoints, or anatomical landmarks, by which they are defined, yet they encode only incomplete information about the relative positions of these defining points (Bookstein 1991; Slice 2005). In many such cases, for instance, information on biological variation crucial for ancestral determination may not be conveniently oriented along the span of such caliper measurements as are commonly recorded in a traditional analysis (for example, Ross, McKeown, & Konigsberg 1999).

3D Methods: Geometric Morphometrics

Modern methods of size and shape analysis, called *geometric morphometrics*, address the potentially serious problems of traditional methods by focusing on the analysis of landmark coordinates (Rohlf & Marcus 1993; Slice 2005). Such data completely and efficiently archive the geometric information available in the landmarks, and any traditional measurement based on the same points can easily be recovered by using elementary geometric formulae. Furthermore, since these methods retain the geometric relationships between the points throughout an analysis, graphical depictions are possible that allow one to more easily relate the results of abstract multivariate procedures directly to the morphology of interest.

Once sets of coordinate data have been superimposed in a common coordinate system, using the method of Generalized Procrustes Analysis (GPA) (see Rohlf & Slice 1990; Slice 2005 for methodological details), they can be treated as multivariate shape variables and subjected to familiar statistical procedures such as principal components analysis, the construction of multi-group classification functions, and canonical variates analysis. These newer morphometric methods using 3D landmark coordinates can provide considerably more anatomical information than their traditional counterparts, but they have received little to no application in forensic anthropology or victim identification (Ross, McKeown, & Konigsberg 1999).

The value of these newer methods in the forensics setting is illustrated by the results of Ross and colleagues (1999), who found that although the geometric morphometry classification results for an American Black and an American White sample were comparable to traditional discriminant analysis, the newer methods outperformed traditional methods in their ability to locate specific regions of variability that would otherwise have remained undetected. In addition, because geometric morphometry was able to detect the specific regions of variation, individuals could be classified according to a reduced set of landmarks instead of the whole suite of measurements necessary with traditional caliper methods. Using a reduced set of landmarks can also extend the utility of this method to the identification of fragmentary remains.

This technology would be particularly useful in geographic regions where large ethnically diverse populations predominate. In a recent study Ross and associates (2004) demonstrated that modern Cubans show a strong African affinity followed by a Spanish component while lacking an indigenous Amerindian biological affinity (Figure 42.1 and Figure 42.2). Figure 42.2 depicts the mean difference in relative landmark location of cranial landmarks in Mexican and Cuban populations. Here, differences in mean landmark locations are shown as difference vectors magnified by a factor of 2. The Mexican crania are shown to be characterized by more lateral zygomaxillare, more inferiorly placed opisthion, more superiorly placed eurions, and more posteriorly positioned landmarks throughout the upper face.

A study presented by Rosas and Bastir (2002) investigating allometry through 3D morphometrics and sexual dimorphism among a Portuguese population demonstrated that size and sex had a significant influence on shape of the craniofacial region. In a more recent study Pretorius and coworkers (2006) report preliminary findings that the shape of the eye orbits are more sexually dimorphic than the commonly used mandibular ramus. Morphometric techniques may help us to better understand the relationship between the size and the shape of craniofacial features. They may help to quantify the shape variables forensic anthropologists routinely use and, additionally, point out new areas of the skeleton to use for estimating sex from human remains. More recently, cross-population studies of sexual dimorphism also illustrate the importance of secular trends (Kimmerle, Ross, & Slice 2008). Therefore, the creation of population standards should take into account secular trends, as well as genetic diversity. This variation again highlights the importance of choosing the right reference sample for the creation of international parameters for estimation.

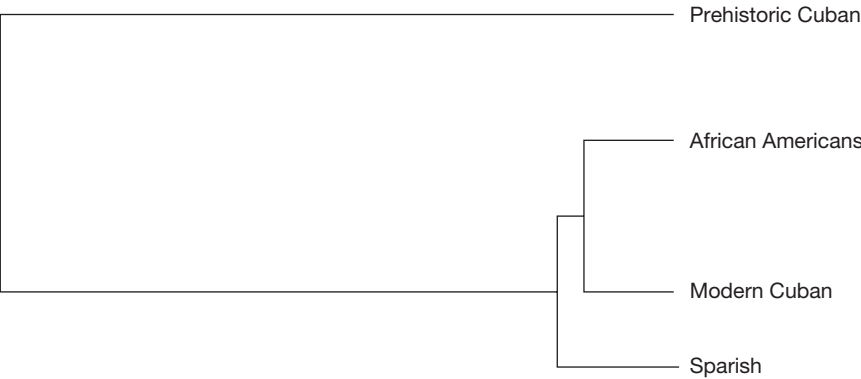


Figure 42.1 Phenogram showing the morphological affinity of modern Cuban crania to modern African-American and European Spanish samples and dissimilarity of the modern and prehistoric Cubans. Results based on UPGMA clustering of squared Mahalanobis distances between sample means computed from GPA-superimposed, three-dimensional landmark coordinates. See Ross and coworkers (2004) for details.

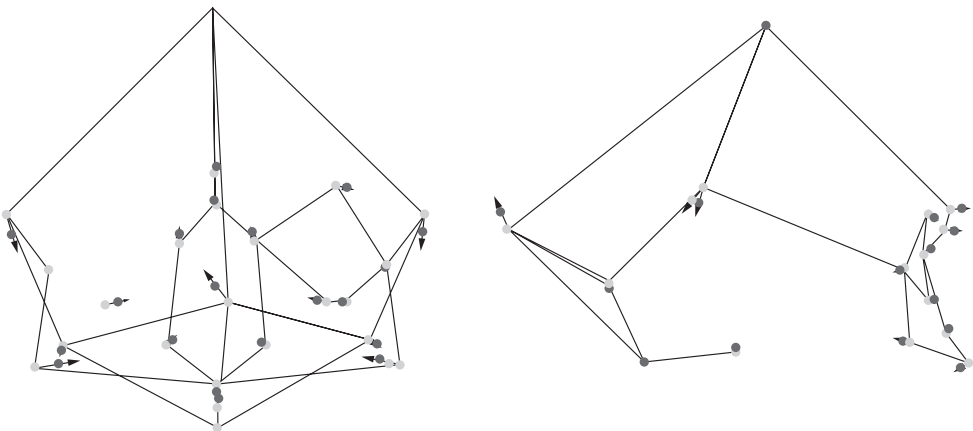


Figure 42.2 Morphological differences (x2) between modern Mexicans and modern Cubans

We do not anticipate that geometric morphometric methods will immediately replace more traditional methods, but they can be viewed as the next logical step in developing new tools for victim identification. As an added benefit these new methods conveniently utilize the same standard craniofacial landmarks known to most forensic scientists and can thereby address all the shortcomings associated with the analysis of sparse linear measurements in a familiar context.

Stature

Stature is one of the initial parameters of the biological profile used to confirm or exclude presumptive identifications. Traditionally, stature equations developed from U.S. skeletal samples have been inappropriately and indiscriminately applied to different populations. In the past

decade, however, the identification efforts in the Former Yugoslavia underscored the inappropriateness of applying nonlocal standards for sex, age, and stature estimation (Ross & Konigsberg 2002; Komar 2003; Schaefer & Black 2005; Steadman & Haglund 2005). Although the absence of antemortem medical and dental records was the major problem, in the former Yugoslavia it was evident early on that stature equations based on Trotter and Gleser underestimated stature in the Balkan populations.

Although a Bayesian approach for estimation or the preservation of evidence has been utilized in the forensic sciences, it has received little attention in forensic anthropology (Konigsberg, Ross, & Jungers 2006). Historically, a Bayesian approach to data analysis has been criticized by classical statisticians, who do not accept the use of informative or known priors, arguing that this method produces biased estimates (Ross & Konigsberg 2002). However, Konigsberg and colleagues (1998) discuss the arguments for applying a Bayesian versus a maximum likelihood approach to stature estimation and contend that, in forensic anthropology, the Bayesian model should be the preferred method.

Basically, Bayesian inference is based on the idea of using both unconditional (the *prior probability* of a particular stature in the target sample) and conditional (the probability from the reference sample of obtaining the observed long-bone length conditional on a given stature) probabilities to produce informed parameters. Bayes's theorem states that the probability of s is equal to s , given

$$P_T(s | lb) = \frac{P_R(lb | s) \times P_T(s)}{\int \{P_R(lb | s) \times P_T(s)\} ds}$$

where $PT(s | lb)$ is the posterior distribution for s . Ross and Konigsberg (2002) presented a Bayesian solution to stature estimation where the reference sample provided information about the relationship between long-bone length and stature [shown here as $PR(lb | s)$], but the prior for stature originated from the known stature distribution for the living population from which the forensic case was drawn [shown here as $PT(s)$]. Because it is known that Eastern Europeans are taller than American Whites, they used this information as a known prior in their analysis.

Age-at-Death

Statistical methods for estimating age-at-death from skeletal remains consist of univariate and multivariate statistical models that cover both morphological and metric data for teeth and bones. Therefore, a number of models have been used for continuous and discrete traits, among both juveniles and adults. Age parameters are generally based on descriptive statistics or regression (inverse calibration). Investigations into the accuracy and reliability of various techniques have also employed diverse statistical methods. Multivariate methods have been used to statistically combine multiple age indicators. Owing to individual variation and the wide age parameters associated with aging technique, it is imperative that multivariate trait analysis be used to establish the biological age-at-death of skeletons. Yet, the estimation of an age-at-death interval based on numerous criteria from a variety of skeletal traits is often problematic because of the suite of possible trait combinations at each age, the strong association between age-progressive skeletal features, and the lack of standardization among skeletal biologists in determining age parameters. Often, osteologists rely on experience to "average" the aging information for each individual and establish the age interval.

Increasingly, the need for anthropological methods to be based in probability statistics is being addressed. Probability theory establishes the outcomes that are possible and the likelihood

of achieving each of those outcomes. In other words, probability theory informs investigators if their conclusions are random and the result of chance or due to an actual treatment (that is, a correct identification).

In a Bayesian model, phase (i) is regressed onto age (t): $i = a + b \star t$. Phase is assumed to be dependent on age to calculate the maximum likelihood estimate of age conditional on phase: $\text{Pr}(\text{age} - \text{phase})$. Hoppa and Vaupel (2002: 2) point out that the probability of being a certain age, given a particular skeletal characteristic $\text{Pr}(\text{age} | \text{phase})$, must be calculated from the probability of obtaining the characteristic through Bayes's Theorem. Hoppa and Vaupel wrote:

Even the most experienced and intelligent osteologists cannot make this calculation in their heads. Pencil and paper or a computer is required, as well as information concerning $f(a)$, the probability distribution of ages-at-death (i.e., life span) in the target population of interest. (2002: 2)

A Bayesian approach requires the distribution of age, $f(\text{age})$, which must be estimated or taken from a reference sample of identified age.

Studies demonstrating the need for this methodological approach and several methods that actually offer a multitrait approach with aging parameters have been put forth to improve the accuracy of age estimation (Gustafson 1955; Acsádi & Nemeskéri 1970; Lovejoy, Meindl, & Barton 1985; Konigsberg & Frankenberg 1992; Konigsberg & Holman 1999; Boldsen et al. 2002; Holman, Wood, & O'Connor 2002). However, multitrait methods are rarely applied in practice and pose their own statistical challenges.

Kimmerle and Konigsberg (2004) presented an example of how a multivariate statistical approach may be applied to age estimation. This test used a set of Bayesian statistical methods, maximum likelihood estimates, and a Gompertz-Makeham hazard model (Wood et al. 1992) and demonstrated that a multiple-trait approach, in combination with an informed prior, produces the most accurate age estimates.

Three aging techniques were investigated, the sternal rib (İşcan, Loth, & Wright 1984, 1985), tooth wear (Ubelaker 1989), and tooth root translucency (Lamendin et al. 1992). The full conditional (on age) distribution of indicators using a "maximum weight dependence tree" was approximated (Chow & Liu 1968; Lucy, Aykroyd, & Pollard 2002). This approach uses a trivariate distribution:

$$\begin{aligned} \text{Pr}(\text{rib, wear, trans} | \text{age}) &\cong \\ \text{Pr}(\text{rib} | \text{age}) \times \text{Pr}(\text{wear} | \text{trans, age}) \times f(\text{trans} | \text{age}) \end{aligned}$$

Second, Bayes's theorem was used to estimate age:

$$\begin{aligned} f(\text{age} | \text{rib, wear, trans}) &= \text{Pr}(\text{rib, wear, trans} | \text{age}) \\ &\quad f(\text{age}) \\ f(\text{age} | \text{rib, wear, trans}) &= \frac{\text{Pr}(\text{rib, wear, trans} | \text{age}) \times f(\text{age})}{\int_{t=15}^{\omega} \text{Pr}(\text{rib, wear, trans} | t) \times f(t) dt} \end{aligned}$$

In this equation, $f(\text{age})$ is a probability density function (pdf) for age, starting at age 15 years (the minimum possible age) and running to the maximum possible age (100 years).

To demonstrate the advantage of using an informed prior, two methods for estimating the pdf of age were used. The first used a uniform prior, such that the pdf at any age between 15

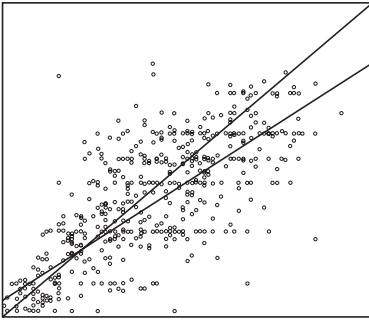


Figure 42.3 Using a uniform prior, a multitrait approach is used to estimate age-at-death. The top diagonal line represents perfect prediction, and the lower line represents the regression of estimated on actual age. Although this approach is based on “classical calibration,” using a uniform prior inappropriately assumes an equal likelihood of age for all individuals. As a result the age estimate for most individuals is misclassified (example and figure from Kimmerle & Konigsberg 2004).

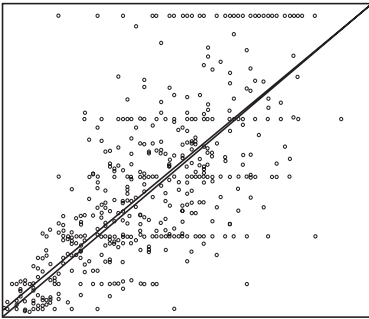


Figure 42.4 In contrast to using a uniform prior, a maximum likelihood (ML) derived hazard model is shown, for which separate Gompertz-Makeham models were calculated based on identified individuals. Note that the predicted ages are nearly identical to the actual ages-at-death (example and figure from Kimmerle & Konigsberg 2004).

and 100 is $1/(100 - 15)$. This approach is akin to “classical calibration”⁴ and should have been immune to the problem of “regression to the mean”;⁵ however, it unrealistically assigned equal probability to all ages at death (Figure 42.3).

The second approach was based on a Maximum Likelihood (ML) derived hazard model, for which separate Gompertz-Makeham models were calculated from a population of identified individuals. This approach demonstrated that using a standard multiple-trait estimate to calculate skeletal age intervals does improve the accuracy of age estimation. Through the use of maximum likelihood estimates, the predicted ages were nearly identical to the actual ages-at-death (Figure 42.4).

As forensic anthropology becomes more global, one should exercise caution when applying current aging methods to diverse populations. Because many adult aging techniques rely on degenerative changes of the skeleton, one must understand the population for which these methods are being applied to. Even within the U.S., these aging techniques can produce less than satisfactory results. A case in point occurred in the identification efforts in the aftermath of Hurricane Katrina, when forensic anthropologists were consistently under-aging the elderly from Louisiana.

Innovative Technology for a New Era

The computer revolution of the 1980s, coupled with technological advancements in computer digitizing, laser scanning, computerized tomography (CT), and magnetic resonance imaging (MRI), has empowered the anthropological and medical communities to enter a new era of research and methodology. As a result, multivariate statistics are used by anthropologists to compute metric and shape variables in all areas of human identification with sophistication and ease.

Innovative advancements in 3D imaging have enabled the use of computerized tomography (CT) and geometric morphometric techniques to analyze and implement biometric variables for personal identification and trauma analysis (Meyers et al. 1999). CT technology is



Figure 42.5 The Virtual Human Navigation System enables visualization and navigation of biometric image data in real time. Metric, shape, and volume metric data may be obtained, making this system the latest tool for investigative research in the biomedical and anthropological fields.

a powerful tool for identifying useful internal structures that are not externally visible, describing biological form quantitatively in three dimensions, and visually displaying such evidence to a jury or court. 3D-CT technology (Figure 42.5) is being used by forensic anthropologists to establish a baseline for understanding human variation as well as the various aspects of the biological profile of unknown, unidentified victims of criminal activity, natural disasters, terrorist attacks, and armed conflicts. CT technology is being used for facial reconstructions and to determine the sex, age, ancestry, and height of an individual from skeletal tissue. The accurate application of 3D imaging technology is a leading tool for investigators and has the potential to dramatically enhance the identification of missing children and adults. In addition, data from clinical CTs also would have the advantage of currency and quantity, since hundreds are produced at any given geographical location curtailing the issue of appropriate sample sizes. This advantage is potentially important, since significant secular changes have been documented in the cranial morphology in the U.S. over the past 200 years. Jantz and Meadows Jantz (2000), for example, noted considerable increase in heightening, narrowing, and lengthening of the vault along with heightening and narrowing of the face of American white crania within the last 135 years (see also Angel 1976, 1982; Jantz 2001; Kimmerle & Jantz 2005; Wescott & Jantz 2005).

The Virtual Human Navigation System (Hilbelink 2005a, b; Hilbelink & Lothe 2005) is at the forefront of cutting edge technology and is a leading tool for teaching anatomy and virtual surgery to medical students. This system also has the potential to become an important teaching and analytical tool for forensic anthropologists for whom anatomy and osteology are critical. The Virtual Human Navigation System permits the import of any volumetric medical image data set for use in the system and its registration in 3D space using the Cartesian coordinate system. The precise location and orientation of the pciBird tracker relative to the volumetric data can be followed in real time and can be used to obtain specific feature measurements of the structures contained within the image volume. This system offers the opportunity for a virtual

classroom where the culmination of osteology, human anatomy, human variation, trauma analysis, and human identification are explored for instruction or for multivariate-based research for any biometric data.

Conclusion

Trotter's work on WWII casualties has formed the basis of stature estimation for several generations of forensic anthropologists. To discard vital information from war victims would be a disservice to those who seek identification of the victims. The development of local identification standards would be impossible without preservation of skeletal information. This approach has been used to good effect in forensic cases resulting in the Forensic Anthropology Data Bank.

The burgeoning field of forensic anthropology has come full circle as the methods and studies produced to answer medico-legal questions are being applied to more traditional areas of study such as in human biology, bioarchaeology, and palaeoanthropology. The subfield of biological anthropology, once viewed as merely an application of knowledge, is now a dynamic and innovative field of study wherein problem-oriented questions are a driving force in medico-legal research, even setting new standards for biological anthropology as a whole.

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We would like to thank Lyle Konigsberg and Richard Jantz for forcing us to take many years of statistics courses and ensuring that our research approach was through rigorous quantitative methods. We would also like to acknowledge Lyle for use of Figures 42.3 and 42.4 and the associated research example, extracted from a 2004 presentation. We also thank Dennis Slice for introducing us to and training us on the use of Geometric Morphometrics—his software made such research possible. We also thank Don Hilbelink for use of the Figure 42.5.

Notes

- 1 "Inverse regression" is one means of establishing a relationship between variables. In inverse calibration, the y variable is predicted from the x variable. Continuous y variables in this example include age, sex, and stature.
- 2 The first section of Forensic Anthropology organized for the American Academy of Forensic Science annual meeting was in 1972 (Rhine 1998).
- 3 "Academy" refers to the American Academy of Forensic Sciences, which publishes abstracts for the Annual Meeting Program.
- 4 "Classical calibration" is an alternative approach to "inverse calibration." In "classical calibration," y is regressed onto x . The results are used to estimate the unknown parameters of x from the known parameters of y . "Classical calibration" is considered a superior form of calibration and is recommended for forensic methods, particularly in formulating aging estimates (Konigsberg, Frankenberg, & Walker 1994; Aykroyd et al. 1997).
- 5 "Regression to the mean" is a common problem when using regression or "inverse calibration" techniques. It refers to the phenomena of age estimates over-aging young individuals and under-aging old individuals (Konigsberg & Frankenberg 2002).

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The Expert Witness and the Court of Law

Maciej Henneberg

Most professionals are unprepared for the rigors of the courtroom and have no formal training in providing effective courtroom testimony. Aggressive cross-examination can often make the courtroom experience stressful and anxiety producing. By knowing what to expect, professionals will better manage their courtroom presentation and thereby become more effective witnesses.

(Brodsky 2004: 3)

Expert witnesses are engaged to determine specific facts and provide expert opinion for a case that may be ruled by civil or criminal law. The vast majority of the cases that archaeologists and biological anthropologists are involved in are criminal cases. Although this chapter is limited to descriptions of actions of an expert witness in criminal cases, most of the content applies also to civil cases.

Although expert witnesses may be called either by prosecution or by defence, the role of such witnesses is to determine objectively and impartially all facts falling into their area of expertise and to formulate a professional opinion that may help the court. Presenting an opinion is a task specific to an expert witness. Testimony from other witnesses, such as eye witnesses, for example, is limited to helping the court to establish facts only.

Although any person who has relevant expertise can be called in as an expert witness, recently increasing concerns about reliability of expert witnesses' testimony have been raised. One of the major concerns is that witnesses engaged by one party (that is, prosecution or defence) may not be entirely objective but rather support the view presented by the party who pays for the witness's services. For this reason various sets of criteria are proposed by the forensic and legal community and increasingly used in courts when they are determining admissibility of expert evidence. The best known among those are the Daubert Criteria, which require that an expert testimony: (1) is based on a testable theory or technique; (2) is the product of reliable methods; (3) is used with a correct and reliably applied method by the expert; (4) was subject to peer review; (5) has a known error rate; (6) has standards in place to control its use; (7) has a basis in generally relevant science; and (8) is based on sufficient facts or data. The first three of these criteria are the most important, especially when novel techniques are used by an expert (Crumbley & Cheng 2014; Ireland & Beaumont 2015, see also Grivas & Komar 2008).

Expert witnesses usually start their involvement in a case by examining the evidence and providing a written report to the crime investigating authority. This report starts with a statement

on the expert's qualifications, proceeds to describe facts, and ends with an opinion. Particular jurisdictions have specific rules determining the format of a report and types of information to be included. There are even specific forms to be used for witness reports. Depending on the case the report may need to be supplemented by additional materials, such as detailed notes from an examination of evidence, radiographs or CT scans, photographs, video illustrations of superimpositions, or photographic boards comparing video evidence from the crime scene (security closed circuit television systems) with photographs of the accused. If crime-investigating authorities, usually the police, decide to press charges, the prosecution uses determinations made by an expert witness to prepare a formal charge to be laid in the court of law. If the accused pleads guilty to the charges, sentencing follows and the case ends; thus ends the involvement of an expert witness.

If the plea of not guilty is entered an expert witness oral testimony may be needed in court. At this stage of a case another expert witness may also be engaged by the defence. Testimony from this expert witness will also be presented in court. Whether an expert is engaged by the prosecution or by the defence, her/his first responsibility is to help the court to establish the facts of the case objectively, not to advocate for or against the accused. In many clear-cut cases in which an expert witness established material facts without the need for expressing specific opinion (for example, when sex and age of a skeleton were identified) there may be no need for the witness to appear in court. Compared to forensic pathologists, forensic anthropologists and archaeologists are relatively rarely called on to provide evidence in court. Thus many forensic anthropologists and archaeologists may be unfamiliar with the environment of courts of law and their procedures. When the forensic anthropologist and/or archaeologist do give evidence, it typically relates to questions about trauma rather than issues related to identification (see Steadman and associates this volume).

The court of law must hear testimony in the case rather than just read the reports, because each witness's testimony is subject to scrutiny by the court and to cross-examination by the prosecution or the defence. If the case is heard before a jury then the jury must hear all testimonies as a series of witnesses' answers to specific, clearly formulated questions. Members of the jury come from all sectors of society and do not need to be able to understand technical details provided in the experts specialised reports. However, they must take the statements and opinions of expert witnesses into account when formulating their verdict.

While it is difficult for anyone to remain completely impartial especially if one is engaged, and often remunerated, by the police, prosecution, or defence, practitioners have an ethical obligation to be aware of potential biases that affect their role as an expert. The way expert witness evidence should be presented both in written reports and in the court is regulated by Practice Directions issued from time to time by the courts (for example, Federal Court of Australia 1998; Supreme Court of South Australia 2002; *County Court of Victoria Practice Note: Expert Evidence in Criminal Trials* 2014). The precise role of expert witnesses and rules of their ethical conduct are subject to continuing debates (Freckelton, Reddy, & Selby 1999; McAbee & Freeman 2006, Crumbley & Cheng 2014). Such debates have a bearing on the conduct of an expert witness in court. Detailed advice on how an expert witness should act may vary from one area of expertise to the next and may depend on particular positions preferred by legal practitioners and experts with respect to fine points of ethics and interpretations of specific laws.

Duties and Rights of an Expert Witness¹

Like any participant in legal proceedings, an expert witness has duties and rights. These duties and rights may be regulated by specific Practice Directions in different jurisdictions, but generally

they follow similar rules. Adherence to these rules ensures that the testimony is clear and helpful to the court. The witness testifies under oath (or an affirmation, if nonreligious) and is thus liable to prosecution for perjury for making deliberately false statements. However, there is a general principle of “witness immunity” ensuring that no loss of objectivity occurs in an expert testimony. It has been thus expressed by the Texas Appeals Court: “no civil liability exists on the part of an expert witness . . . even though he may have been negligent in the process” (*Clark vs. Grigson* 1978). This principle, however, does not apply to deliberate errors or omissions in the expert opinion.

Duties of an Expert Witness

The duties of an expert witness include:

- Using all available knowledge and skills to determine the facts of the case. This normally calls for a peer review of expert’s findings before they are presented;
- Remaining impartial and truthful in formulating an opinion;
- Providing information as required to prosecution, defence, and the court but to no one else. This includes not talking to the media before the case is complete;
- Explaining findings fully and clearly so that they can be understood unequivocally by laypeople;
- Not venturing beyond your area of expertise;
- Not judging guilt or innocence;
- Appearing in court when called (usually under subpoena); and
- Disclosing any conflict of interest that may produce bias.

Rights of an Expert Witness

The expert witness has the right to:

- Examine all exhibits and information related to the case (but only that which is relevant to the specific area of expertise);
- Request technical assistance;
- Be fairly compensated for time, expenses, and equipment used;
- Ask for an adjustment of dates/times of court appearances to expert’s availability (adjustment is not always possible, because the witness is under subpoena and must appear as directed); and
- Ask to be excused after cross-examination is completed. This is not always possible, because the parties may wish to call the witness again at a later stage of the case.

Sequence of Events When the Case Comes to Court

There are several steps in the process of criminal justice. The involvement of an expert witness may be terminated after any of these steps.

Conference with Prosecution and Defence

Ideally, before a court hearing the witness will be asked to meet with both prosecution and defence legal teams simultaneously. This meeting takes place irrespective of which side engaged the witness, but it is not always required. The meeting has an informal format of a conversation

between the witness and the parties. Conference is often held on the day of the trial in a separate room in the court building, but it may occur at another time and place mutually agreeable to all parties. Lawyers for both sides have the expert's written report available to them and during the conference may question the witness on anything relevant to his/her role in the case. They usually probe details about the witness's qualifications, experience, and statements made in the report. The opposing side will try to gather information useful for weakening the importance of future testimony by the witness. The side that engaged the witness will listen carefully to questions asked by the opposing side and to the witness's answers in order to modify their future line of questioning in the court. This process will bring out important aspects of the witness's findings that may not have been clear enough in the written report.

During the conference the expert must remain meticulously truthful and answer questions precisely but as briefly as possible, in order not to volunteer any peripheral information that may be used by the opposing side against the testimony. All answers will be scrupulously analysed by both parties, and any information additional to the written report will be scrutinised by the lawyers after the conference with the aim of bringing it out during cross-examination. Most experts, not being trained in the practice of the law and being naturally enthusiastic about their expertise, tend to volunteer information beyond what is necessary for the case—which should be avoided.

Barristers who question witnesses in court are skilled at using psychology and sometimes even theatrical effects in order to win the case. During the conference, they may try to assess the personality of the witness to gain future advantage by choosing an appropriate style of questioning. Thus the demeanour of the expert during the conference should be calm, composed, self-assured, and helpful, but reserved.

Layout of the Courtroom

The rest of the case is heard in the courtroom. The layout of a courtroom reflects the way a case is conducted. Size of the public gallery and some details may differ, but the essential elements of all courtrooms remain the same.

The bench for the presiding judge is located at the head of the courtroom on an elevated dais opposite the main entrance. The box for the jury is on one side of the bench; a dock for the accused is located on the other. The witness stand is near the jury's box or the dock. A table for stenographers, secretaries, judge's associates, and sheriffs is below the bench. Barristers' tables are located in the centre of the courtroom facing the bench. Each barrister is accompanied by a legal team usually comprising a solicitor, a junior lawyer, and sometimes an expert witness or a clerk. Seats for the public are at the back of the room in the space between the barrister's tables and the main entrance. The bench is the focal point of the courtroom and, when occupied by the judge, requires all persons present in the courtroom to face it and bow toward it when entering and leaving.

In the lower court (local court, magistrate's court) there is no jury. The case is heard by the presiding magistrate only. The layout of the courtroom is essentially the same but without the jury stand. In cases of minor offences the guilt or innocence of the accused is established by the magistrate thus ending the case, unless an appeal is launched against the magistrate's decision. In criminal cases the role of the lower court is to establish whether the case should be committed to full trial in the committal hearing.

The Lower Court Hearing

The lower court hearing is a formal court hearing, normally open to the public, presided over by a magistrate but with no jury. The witness appears under oath/affirmation. The party that

brought the witness leads in questioning the witness and cross-examination by the other party follows. The magistrate may interject to clarify the expert's answers or to rule on objections raised by one barrister with regard to the line of questioning by the other party. When all evidence has been given by witnesses and followed by cross-examinations, a magistrate makes a determination either regarding the guilt or innocence of the accused, or in more important cases whether to commit the case to a higher court trial. This decision is based on the strength of evidence in the case. If the accused pleads not guilty but the evidence of guilt seems to be strong enough to be considered by the court the case proceeds to trial. If the accused pleads guilty there is no need for the trial and the case goes directly for sentencing. In such cases there is no further need for witness testimonies.

Admissibility of Evidence Hearing in a Higher Court

The admissibility of evidence hearing (*voir dire*) is the first enquiry to be held in a higher court and allows the judge to determine whether the evidence of an expert witness is good enough to be presented at the trial. This is not a public hearing. Only the judge, defence, prosecution, and accused are present. The witness appears under oath/affirmation, and proceedings are recorded. Questioning concentrates on establishing the qualifications of an expert and on the quality and relevance of the witness's findings. At the conclusion of the hearing, the judge rules whether the witness may be called during the trial. The judge uses specific rules of evidence applicable to the legal system of the court's jurisdiction to determine the admissibility of a witness. The rules of evidence vary somewhat between the states and are being periodically altered in response to progress in specialist areas and in legal theories and practice (for example, Federal Court of Australia 1998; Supreme Court of South Australia 2002).

The Trial

The trial is normally held in an open court, often with a jury that determines whether the accused is guilty. The prosecution leads the case and presents its witnesses. The defence then cross-examines these witnesses. Next the defence calls its witnesses, who are subject to cross-examination by the prosecution. All witnesses testify under oath/affirmation. Examination and cross-examination proceed in a way similar to that at a lower court hearing. Greater attention is paid to the facts and opinions of an expert. The examination starts with establishing the qualifications of the expert. Details of the expert's formal education and professional experience are presented with special attention to the relevance to the case. Questions about the facts discovered by the witness and witness's opinions follow. Various exhibits may be shown to the witness, the judge, and the jury at this stage. The witness may present and discuss exhibits (for example, photographs, videos, photo-comparison boards) as required. Cross-examination follows. The presiding judge may interject instructing a witness or ruling on objections to various questions. The judge's instructions must be followed. If the objection is raised after the witness has already answered a question, the judge may instruct the jury to disregard the answer. Formally, the jury must do so, but they have already heard the answer and the information provided may influence their thinking. Such situations happen, for example, when an expert speculates beyond the factual evidence and his area of expertise (Kassin, Williams, & Saunders 1990).

The witness should answer questions clearly and succinctly. If in any doubt about the meaning of a question, the witness must ask for clarification. Although the jury is not playing any active part in the proceedings, it is the jury who will make a decision. Thus the witness must

give evidence in a way that will be clearly understood by members of the jury. It is difficult to assess how a jury receives a witness's evidence, but sometimes a pointed answer from a witness makes the jury react spontaneously by smiling, or even laughing. The witness should provide answers directly addressing specific questions and avoid longer lecture-style presentations, or complex qualifications of answers, such as "yes, but only if one considers that the degree of certainty of the method applied under circumstances." Simple "yes" or "no" is usually sufficient. If a qualification of an affirmative or negative answer is necessary, it should be started as "possibly, but I am not certain."

During cross-examination barristers use a technique of making a statement and then asking the witness—"do you agree?" If the witness does not agree with the statement made the answer must be very clear—"no, I disagree." Any "well, yes, but not really" will confuse the jury. All questions must be answered truthfully. The witness may refuse to give an answer to a question outside his/her area of expertise or to speculate if there is not enough evidence. The witness's opinions are treated very seriously and thus must be expressed responsibly. The opposing party may try to discredit the witness by quotations from the literature or by testimony of another expert witness showing that the original opinion was based on inadequate knowledge. Thus a witness should not make statements that cannot be supported by professional literature or by well-established specialist practice. The attitude "trust me, I am an expert" is dangerous. If an expert witness becomes discredited in an open trial, he/she will not likely be approached again to work on new cases. Modesty, reliability, clarity, and truthfulness are the best implements of an expert witness. It is much better to say "I do not know" than to make a statement that can be shown to be false. In summing up the case the prosecution and the defence will refer to statements made by the witness under oath.

Each case proceeds with full respect for all aspects of the law and fairness to all parties. Time is taken to fully explore all aspects of the case. The conduct of all persons in the courtroom is serious and polite even if diametrically opposing views are expressed. Witnesses should act and express themselves accordingly. Displays of emotion or use of strong language must be avoided. The judge makes all decisions concerning how the case proceeds, and he/she must be deferred to. The judge is addressed as "Your Honour," and if in any doubt about what to do, the witness must turn to the judge for decision. "May I stand up Your Honour?" or "Your Honour, may I show this photograph to the jury?" are correct ways of action, rather than just getting up or showing a picture to jurors.

After both sides exhaust their lines of questioning and the judge is satisfied that the witness gave full evidence, the witness is excused. In most cases this ends the witness's involvement in the case, and he/she is free to go. The witness, however, can be recalled later in the case, depending on how the trial proceeds. There is no need for the witness to be present during the entire trial. In certain cases, a witness may testify by telephone or video link. If the case is successfully appealed, the new court proceedings will be instituted, and the witness may be called again to testify. Thus all case notes and materials relevant to the case must be kept on record by the witness, since some appeals happen after many years.

Although it is not required, in the interest of objectivity experts should abstain from following details of the case that are not relevant to their area of expertise. These details may influence a witness's personal feelings about the case and lead to bias in his/her opinions. It happens that witnesses try to influence the outcome of the case by stressing some facts beyond their actual significance or by formulating their opinions categorically instead of presenting them cautiously (Crawford et al. 2005). Such behaviours must be avoided, because they will eventually undermine the expert's reputation.

Conclusion

The role of the expert witness is extremely important; a person undertaking this function must do so with a full understanding of responsibilities and commitments. To accept the task of an expert witness in a particular case, one must ensure that up-to-date professional knowledge relevant to the case is available. The expert must have skills necessary to apply this knowledge, demonstrate integrity and independence, and ensure that the time and resources necessary to carry out all tasks, including court appearances, will be available. Given the complexities of procedures of various legal systems, the extent of an expert's involvement may be much greater than initially estimated. Responsible behaviour at all stages of the case, integrity and truthfulness, in addition to excellent professional knowledge and skills, are hallmarks of a good expert witness.

Note

- 1 This section is based on personal experience gained during appearances before courts in Poland, the United States of America, Republic of South Africa, and in various Australian jurisdictions.

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Legal Aspects of Identification

David Ranson

All death investigation takes place in a medical, scientific, administrative, and legal environment that is specific to the type of community and legal jurisdiction within which the death occurred. The differences among jurisdictions arise from a variety of interrelated factors including social, religious, political, and legal influences, as well as the development of the medical profession and its specialties. At the most mechanical level, records are generated and retained about who has died. A cause of death is assigned within a registry office inside government bureaucracy, generally by recording on a death register the cause of death given in the report or certificate of the treating doctor. The maintenance of a death register and a birth register has important social implications. A community needs to know information regarding those who make up its population. From a practical perspective, this information is needed to ensure that community services are appropriate to the size and makeup of the population. However, at a deeper level our concerns about threats to our safety generate a desire to find out more about deaths that occur in our community and to understand their causes so that we can feel less threatened. Community and personal grief involve important emotions that can have deep effects on the functioning of individuals, families, and in some cases the whole community. In this environment a society's ability to independently investigate critical deaths from a perspective that is focused beyond that of any individual professional group, such as scientists, the medical profession, or the police, is important.

Our popular media seem to be obsessed by death, disaster, and accident, responding to, and fanning, our community's seemingly insatiable drive to know the details and profiles of both victims and perpetrators of homicide, lethal error, and catastrophe. Cases involving the discovery of hidden bodies, terrorist attacks, pandemics, tsunamis, uncontrolled bushfires, homicidal medical practitioners, toxic spillages, gangland killings, and dangerous workplaces are just some of the deaths that particularly concern the community and as a result receive the attention of the public media. This focus places death investigators directly in the public eye, which for many is a radical departure from their traditional quiet and private scientific role.

Those involved in death investigation should never lose sight of the social importance of the work they undertake. It is all too easy to become involved in the technical and scientific aspects of solving the death puzzle and as a result fail to be aware of the personal, family, and community loss. Similarly, it is easy to become enmeshed in the often complex administrative and bureaucratic processes that surround death investigation with the result that the human aspects of grief and loss become invisible.

Broadly, the European and Scandinavian systems, as well as a number of medical examiner systems, focus on whether criminal behaviour has brought about a death. By contrast, coroners'

death investigations in the Anglo–Australian jurisdictions take a broader and more public health perspective, inquiring in a wide variety of circumstances whether the conduct that gave rise to a death could or should have been different and whether alternative processes might in the future avoid such deaths. Put another way: at the heart of the distinctive systems of coronial investigation is accuracy in both the public record about deaths and prophylaxis—learning from deaths so as to minimise the risks of recurrence, where possible. This approach means in practice that the purview of the coroner extends into non-criminal matters such as deaths in natural and man-made disasters, workplace and transport accidents, and unsatisfactory medical treatment events, to identify just a few examples.

From a legal perspective the coroner functions as an “inquisitorial” oasis in the broader “adversarial” legal system. In the death investigation court hearing or inquest, the coroner functions as both an investigator assembling the evidence he or she needs and as a decision maker, working without the constraints of the rules of evidence and formal procedure. This arrangement is quite different from the systems in place in the criminal and civil courts in the same jurisdiction that operate in an adversarial fashion. In these courts the judge sits as an impartial observer and decision maker but is not involved directly in the management of the investigation process. In addition, coroners are not Royal Commissioners. They do not have an open mandate to investigate at large. A question that is regularly posed in specific inquests is this: Where do the lines need to be drawn, beyond which a coroners’ investigations, findings, and recommendations should not trespass?

Death and the Coronial Investigation

Before instituting an inquest, a coroner must be persuaded that a dead body is within the jurisdiction or that a person died an unnatural death within the jurisdiction. The definition of *death* is relatively wide, and in some jurisdictions a coroner’s investigation can be commenced in relation to a suspected death but when no body has been found. Establishing that a death has occurred by reference to remains is sometimes not altogether straightforward. The presence of disembodied parts of a human body may not be determinative. A severed arm or leg has been held not to constitute conclusive evidence that the body from which it comes is dead. Thus, it was held in *Ex parte Brady; Re Oram* (1935) 52 WN (NSW) 109 that the finding of a tattooed arm, severed from a human trunk by a sharp knife, was not sufficient to constitute a body for the purpose of giving the coroner jurisdiction to hold an inquest, since an arm may be removed from a body without loss of life (Clark 1936). However, it is recorded in *Jervis on the Office and Duties of Coroners* that in an English case

portions of human lung were found in the sea at the point at which an aircraft had crashed, without any trace of the pilot being found. [T]he person from whom the lung material had come was shown to have had the same blood group as the missing pilot. The coroner held that the lung material constituted a body and accordingly he had jurisdiction because of its presence in his area. Similarly, in another case the coroner held that he had jurisdiction to hold an inquest where the lower half only of a girl’s body was found in the street, and the rest was not recovered.

(Matthews & Foreman 1993: 57–58)

The question, then, is whether the separate parts of the body that have been located are necessarily inconsistent with the person still being alive whose potential death is being investigated.

With their responsibility to investigate deaths, coroners are often required to investigate the finding of suspected human remains, which permits them to control the scene and order specialist investigators to attend and carry out their work. In the case of skeletal remains, they may well be subsequently identified as those of a nonhuman animal. At this point the jurisdiction of the coroner ceases, and there is no basis for further coronial involvement in the incident. Essentially, the role of the coroner in investigating the suspected death at this stage is an administrative one, consequent on the coroner's legal jurisdiction.

Latitude has traditionally been extended to the coroner to enable him or her to investigate a death even when no body has been found, provided the death has some real connection with the relevant jurisdiction. Likewise, the fact that a body has been destroyed or is not recoverable does not preclude the holding of an inquest. A local coroner may investigate the deaths of persons ordinarily resident within the jurisdiction that have occurred overseas as a result of a man-made or natural disaster. Today international travel is far more common than when much coronial legislation was formulated. As a result the need to investigate the sudden and unexpected death of a traveller overseas is not an uncommon requirement of the modern coroner's jurisdiction.

In addition to the presence of a body a coroner must be satisfied that the body is dead. In terms of coronial practice, obtaining proof of death is usually not a problem. Coroners have tended to take the view that a person is dead if an appropriately qualified medical practitioner has stated that he or she is dead. Definitions of death have become more complex with the development of organ transplantation and the ability to artificially sustain the circulation of blood and breathing.

However, as a matter of practice coroners' inquests do not take place while a body is hooked up to life support systems, even though a persistent vegetative state may have commenced and a person may be wholly brain-dead (Matthews 2002). This practice does not mean that the coronial jurisdiction into a reportable death has not been initiated. The death of a person who has been officially declared brain-dead and whose death is reportable to a coroner should be reported even if his or her somatic organ systems are being medically supported and maintained. Such a death comes under the coroner's jurisdiction, and in principle the coroner has legal control of the body. It could be said that the clinical medical staff managing the brain-dead patient is acting under an implied authority of the coroner.

The question as to which deaths must be investigated by a coroner is answered by reference to the legislation in the given jurisdiction. A distinction exists between the holding of an inquiry or an investigation, and the holding of an inquest. Today, in Anglo-Australian jurisdictions, as well as in other countries, the legislation varies as to when a coroner is obliged to conduct an inquiry and when an inquest must be held. In general, where there is reasonable cause arising out of an inquiry or investigation for the coroner to suspect that a person has died a violent or unnatural death or died in circumstances that are unclear, or in a prescribed facility, such as a prison, police cell, juvenile facility, or psychiatric hospital, then an inquest must be held.

The endpoint of a coroner's investigation, whether or not an inquest is held, involves the setting out of a finding and the delivery of a verdict. The transition from a coroner's *verdict* to that of a discursive, structured set of *findings* is a particular feature of the modern development of the coronial jurisdiction as it has moved away from its English origins in Australia, New Zealand, and Canada. Traditionally, coroners have to determine the identity of the deceased, when and where he or she died, the cause of death, and how he or she died. The identification of individuals who have contributed to a death may also form part of a coroner's finding. Indeed, in some jurisdictions the coroner has the power to refer individuals to the Director of Public Prosecutions when the coroner believes a criminal action may have been involved.

Modern legislation often permits coroners to make specific recommendations in matters affecting public health and safety and the administration of justice. The power to make a recommendation as part of a finding is not unfettered. Indeed, there should be a clear nexus between the comments or recommendations made and the circumstances surrounding the death into which the coroner inquires. In the context of an inquest into the deaths of prisoners in a jail fire in Victoria, in the case of *Harmsworth v. State Coroner* [1989] VR 989, 996, Nathan J. noted the power to make comments and recommendations but held unequivocally that the “power to comment is incidental and subordinate to the mandatory power to make findings related to how the deaths occurred, their causes and the identity of any contributory persons.” The cause and circumstance of death together with recommendations regarding death prevention are perhaps the most important outcome of a death investigation and inquest. However, the key administrative outcome of an inquest is the determination of the particular items of information required to register the death. This information is essential in order for the public record to be made complete and if necessary “set straight.”

The Coronial Investigation Process

The legal requirements regarding deaths that must be reported to a coroner differ from jurisdiction to jurisdiction. Legally reportable deaths must be reported to a coroner. However, the legislative reporting requirement is often satisfied where the death is reported to the police, who in turn have a duty to inform the coroner and assist in the coroner’s investigation. Although the whole community has a responsibility to report reportable deaths to the coroner, this duty is usually made a specific statutory responsibility of the medical profession and the police. This is for purely practical purposes, in that these two groups are most likely to be involved following a death.

When a death or the discovery of unknown human remains is reported to the coroner by a person other than a police officer, the coroner’s office will usually contact the police station closest to the site and request that a police officer attend and obtain the necessary details. This process effectively identifies a particular officer as the reporting officer attached to that case, so that, subsequently, if the coroner requires further information about the circumstances of the death, there is a local police contact point that allows for additional information to be collected. Regardless of who takes the initial report of death the basic principles are the same. Relevant demographic details are recorded, including the name (if it is known) of the person who has died and the name and contact details of the person reporting the death.

The quality of the initial investigation that takes place within the first 48 hours after a death sets the scene for all subsequent investigations and is crucial in ensuring that a thorough overall investigation takes place. Errors and omissions in the initial processes of investigation often cannot be corrected later. The coordination of the initial investigation process is therefore a task that is essential. Involvement of the coroner in this coordination process is variable. In some jurisdictions the coroner will leave the initial coordination of the investigation to police and clerical staff. In other jurisdictions the coroner may insist on being informed of each and every death regardless of the time of day. In jurisdictions with centralised coroner services the coroner may set out protocols that determine which cases he or she should be directly informed about, so that he or she can attend the scene and coordinate the initial death investigation. Scenarios where the coroner may wish to step in and direct the investigation include deaths in custody or during a police response, incidents involving mass loss of life, work-related fatalities, and aviation or marine fatalities.

The organisation of a coroner's investigation is dependent on the administrative structures that are in place to manage and support the coroner's jurisdiction. In some jurisdictions, such as England and Wales, the coroner's administrative structure is provided by local government and lies outside the administrative services of the civil and criminal courts. In other jurisdictions it may be that the central justice ministry or the police provide most of the support and investigative services for the coroner. Regardless of the exact administrative structure of the organisation of a coroner's office the tasks that are carried out are remarkably similar from jurisdiction to jurisdiction. In some small offices one person may carry out many roles, whereas in larger organisations each role may be taken by an individually trained member of the coroner's staff, seconded government administrative staff, external medical staff, or independent contractors.

The tendency for recent coronial legislation in Australia has been to create centralised offices headed by a State Coroner (or Chief Coroner or Territory Coroner, as the case may be) with Deputy Coroners to assist him or her. Generally, legislation provides in reasonably short form for the role of the State Coroner. Section 71 of the *Coroners Act 2003* (Qld) is an example: The State Coroner's functions are

- a to oversee and coordinate the coronial system; and
- b to ensure the coronial system is administered and operated efficiently; and
- c to ensure deaths reported to coroners that are reportable deaths are investigated to an appropriate extent; and
- d to ensure an inquest is held if
- e the inquest is required to be held under this Act; or
- f it is desirable for the inquest to be held; and
- g to be responsible, together with the Deputy State Coroner, for all investigations into deaths in custody; and
- h to issue directions and guidelines about the investigation of deaths under this Act; and
- i any other function given to the State Coroner or a coroner under this Act.

As can be seen, the role of the head of the coronial service is principally administrative. However, this administrative role exists in addition to the specific responsibility of any coroner to investigate reported deaths.

Much of the day-to-day aspects of a coroner's death investigation is carried out by a variety of individuals, some of whom are directly employed by the coroner's office and others are external contractors.

Court Clerks

Within the coroner's office administrative officers or coroner's clerks manage the day-to-day case work and ensure, through liaison with the coroner, that an appropriate level of investigation has been carried out. The coroner's clerk must ensure that the investigation of the death is sufficient to meet the needs of the coroner in dealing with an inquest or arriving at an appropriate chamber finding or verdict. It is usually the coroner's clerk who receives the information about a reportable death from the police, a medical practitioner, or member of the public. The clerk will evaluate the case and, after discussion with the coroner or by applying general coronial guidelines, organise the administrative matters resulting in the performance of an autopsy by an appropriately qualified pathologist.

While most of the day-to-day administrative procedures in a coroner's office are delegated to court clerical and administrative staff, office procedures in many jurisdictions require that the

coroner be contacted directly for particular types of cases, in order to attend the scene of a death and to initiate special investigations.

When an inquest is to be held the coroner's clerk has a similar duty to that of other court clerks in organising the listing of hearings and ensuring that all interested parties including the family are informed of the proceedings. The court clerk manages the administration of the hearing, including the liaison with legal representatives. At the completion of the inquest, the clerk ensures that the finding or verdict is appropriately recorded and that the death is formally registered with the registrar of births, deaths, and marriages. The clerk will ensure that records of the inquest are kept and cross-referenced with any other material relating to the death, including any criminal justice processes that may also be under way in other courts.

Police Assistants

In some jurisdictions, police officers seconded from other duties may perform some of the court clerical duties. Often they act in a combined liaison/operational role between the coroner and operational police units, including general duty police and detectives. Police on general duties have a limited involvement in death investigations, whereas coroners' police assistants deal with the issues on a daily basis. Indeed, coroners' police assistants help in the investigation of many more deaths than a specialist police homicide investigation unit. The investigation of deaths occurring in the setting of medical care as well as transport-related deaths involving aircraft, marine craft, and trains is often supervised and managed by coroners' police assistants. However, when a death involves police operations, such as a death in custody, there is the potential for allegations of conflict of interest. In such cases, the coronial service needs to have special procedures in place for the appointment of other investigators, legal counsel, or independent supervisors who can oversee the police investigation. Such cases are a minority within coronial practice; for the most part, the advantages of the close working relationship between coroners and the police outweigh the disadvantages.

Bereavement Support Staff

The introduction of a counselling service based at a coroner's court has the capacity to greatly enhance the services for clients and also to improve the efficiency of the coroner's process. These counselling services are not usually designed to provide long-term bereavement care. They are usually fashioned around acute intervention services to provide initial support, counselling, and information in an environment that maximises the autonomy of the family. Inevitably, many families require far longer periods of support and counselling. To enable these services counselling services at coroners' courts usually have close working relationships with other community support services and health services to which families can be referred.

Specialist Investigators

Many deaths involve complex investigations that lie outside the knowledge of the general police or the coroner's staff. Issues involving medical treatment, pathological processes, homicide investigation, death and crime scene investigation, engineering, military procedures, fire services, maritime matters, accountancy, and the wide range of forensic sciences may arise in cases from time to time. It is appropriate that these issues are comprehensively addressed. To this end the coroner may well contract out this part of the investigation by commissioning external experts in the relevant field and providing them with relevant information from the coroner's case file.

The most common external medical investigation service used by a coroner is the autopsy service provided by forensic pathologists. Death investigation systems, such as those operated by a coroner, usually have the power to order that an autopsy be carried out to assist in the determination of the manner, circumstances, and cause of death.

Although pathologists are the group of medical practitioners most closely involved in the work of coroners, increasingly other medical specialists are also utilised by coroners in death investigation. Deaths occurring in the setting of medical treatment may require investigations by nonpathology medical specialists. Experts in anaesthetics, intensive care, and accident and emergency services, as well as specialist physicians and surgeons, may have an important role to play in the evaluation of such deaths. Today the advent of the use of alternative death investigation processes, in addition to or as a replacement for the autopsy, demonstrates the need for a wider range of medical specialists to be engaged by a coroner.

Death Scene Investigation and Retrieval of Human Remains

A coroner's jurisdiction in respect to death investigation starts with the report of a death. This death will have occurred at a particular location that may not necessarily be the location where the dead body was found. In many cases these locations will have a direct or indirect relationship to the death. Indeed, the place in which the death occurred may contain evidence in the environment that can suggest what the cause of death might be or help explain the circumstances in which the death occurred. Detailed evaluation of the death scene may help identify environmental hazards that contributed to the death, and the recognition of these may even assist in future death prevention. From a criminal perspective, when homicide is suspected, the death-scene environment may contain important physical evidence that can link an offender with the scene. It follows, therefore, that the steps taken in the initial phases of the investigation of the scene of death lay the foundation for the whole of the death investigation. Mistakes made in the initial examination of the scene often cannot be rectified later. Once a body has been moved and multiple people have walked in and out of the death scene, objects within the death scene have been touched or moved, or the scene has been affected by environmental factors such as rain or extremes of temperature permanent damage may have been caused to the investigation. Consequently, sound procedures must be put in place to ensure an adequate examination of the scene of death.

Clearly, the nature and scope of a death-scene examination that occurs in the case of a suspected homicide or the finding of skeletal remains will be different from that required in the case of an individual dying at home in bed from apparently natural causes. Because of the variability in the types of death reported to a coroner it is difficult to be precise about the scope and depth of death-scene investigation that may be required. Although most deaths investigated by a coroner do not involve crimes, crime-scene management principles form a solid foundation that should underpin all death-scene investigations. Indeed, because one of the roles of a coroner in investigating a death is to consider the possibility of criminal acts associated with it, the investigation must proceed in a manner that allows for the possibility that a criminal charge may be laid, and the evidence-gathering process must be sufficiently rigorous to withstand forensic scrutiny in due course in the coroner's court and the criminal courts. A "crime scene" can be considered to be any venue that has the potential to reveal evidence of the commission of an offence or to rule out the commission of an offence. Such a scene is capable of revealing considerable information regarding the behaviour of individuals and objects in and around the scene both before and after a death.

Locard's theory of interchange underlies the principles of crime-scene investigation. Although the theory can be described in many ways, in practical terms it means that a contact between objects or individuals and objects will leave evidence of that contact through the transfer of trace evidence from one object or individual to the other. Such traces may be visible or invisible. They may be stable and permanent, or temporary. The identification, analysis, and documentation of this trace evidence can be critical in determining what happened at a death scene.

The identification, collection, transportation, and documentation of trace evidence are the responsibility of all investigators at a death scene. However, the crime-scene examiner plays the major role in this respect and takes responsibility for ensuring that the appropriate evidence is collected or suitably sampled. It is also the examiner's role to take steps to avoid loss of potentially useful evidence by destruction at the scene in the course of a careless examination or by contamination during the process of transportation from the scene to the laboratory. In many cases, specialised techniques may need to be employed to preserve material evidence; they can involve taking impressions of the material, such as tire tread marks in mud, and ensuring that biological trace evidence is appropriately refrigerated or dried so as to preserve its character.

There are a number of general considerations regarding the investigation of a death scene. One of the most important is the determination of the extent of the death scene and what limits should be set on the range and scope of the investigation. In many straightforward death scenes the immediate environment constitutes the appropriate boundary of the death-scene examination. However, where there is evidence of blood, other bodily fluids, or human remains in other locations it may be necessary to include all these locations as separate scenes.

To ensure that evidence collected from a crime scene or a death scene can be used in court, one must be able to show that the evidence is reliable and truly reflects the material present at the death scene or involved in the death. There must be continuity of evidence or a clear "chain of evidence." To this end it is essential that the death scene is effectively secured and controlled. There should be no possibility that evidence from the scene could have been interfered with, altered, or adulterated. As noted, a key factor in planning the security measures is the identification of the boundaries of the death scene. This process involves a combination of physical practicality and scientific or investigative necessity. Some death scenes are composed of multiple small scenes within a defined area, whereas others, such as those involved in a mass disaster, may be spread over tens of kilometres.

Managing the media is an important aspect of death-scene investigations. Simply keeping journalists out of the way is an inappropriate response to these issues. The media can in fact be very useful in a death investigation. By making the community aware of a death that has occurred in particular circumstances additional new information may be gained from unanticipated sources within the community. However, this advantage must be balanced against the risk of confidential forensic information being deliberately or inadvertently distributed by the media in a way that prejudices the investigation. The provision of timely information to media personnel present at a death scene is an important task. Police departments regularly employ public relations personnel in the form of media liaison officers who can assist in this work.

The recording of evidence is a critical aspect of any forensic investigation. In the case of death scenes, particularly those that are thought to be suspicious, it is essential that a complete, thorough, and timely record be made of the appearance of the area. The usual way in which death scenes are recorded initially is by means of video-recording and photography. However, detailed drawings, sketches, and plans are also useful ways of recording a scene. Some investigators, particularly forensic pathologists, rely on textual descriptions of a scene rather than visual records, usually because a visual record is already being made by police investigators for the

coroner, and it would be a duplication of effort for the pathologist to make a further visual record. Notes taken at a death scene will vary depending on the nature of the scene and the environment. The initial assessment of the nature of the death scene will also determine the range and scope of the investigation and the quantity of notes recorded. Clearly, in the case of a suspicious death where criminality may be involved, there will be a higher standard expected for recording of data and collection of material. In such a case there will usually be extensive use of video and photographs, as well as detailed written notes and sketches.

The medical examination of the body at a scene is necessarily limited by the resources available and by the physical restrictions posed by most death-scene environments. Factors such as lighting, physical access to body surfaces, and difficulties in moving a dead body all limit the scope of the medical examination of the body at the scene. Despite these difficulties, a pathologist may attempt to ascertain whether there are any significant wounds to the body and look for signs that suggest a possible mechanism for the death. This examination should be limited, however, so that procedures are not undertaken that would compromise the later examination that can be carried out in the context of a full forensic autopsy.

On completion of the medical examination of the body at the scene of death the pathologist should consult with the coroner and the investigating police about an appropriate time for the removal of the body from the scene, its transportation to the mortuary, and the subsequent forensic autopsy. When these matters have been agreed on, the pathologist should supervise the collection of the body in order to ensure that there is no damage or inadvertent loss of evidence from the body as a result of extracting it from the scene or its transport. When a body is moved, other evidence may come to light beneath the body or from the clothing. Pathologists need to be aware of this possibility, because it may alter the scope of the subsequent examination at autopsy. Pathologists may also need to document and collect objects left by ambulance officers on and around the body. These can include drug administration sets, intravenous fluids, and airways and other resuscitation devices. Analysis of these objects may help in reconstructing what occurred during resuscitation, including what drugs were administered to the patient.

Exhumations

Exhumations are a special example of a complex death scene. Exhumations may be required particularly where allegations are made, sometime after a death, that an unnatural process was involved, such as negligent injury, incompetent medical treatment, or most particularly, homicide. Homicide investigations are sometimes undertaken many years after a death, because new information has come to light as a result of other criminal investigations.

The coroner will usually seek the advice of a forensic pathologist regarding the feasibility of conducting the exhumation and the relative likelihood that a postmortem examination of the exhumed remains will reveal information pertinent to the allegations that made the death reportable. To provide the coroner with this information about the potential for the autopsy to materially assist in the death investigation, the pathologist needs detailed information about the time interval since death and the funeral procedures and processes, including the nature of any embalming procedures performed and the type of coffin. Information about the depth of burial, the soil composition, and the drainage of the cemetery may also be required in order to assess whether pathological and toxicological examination of the exhumed remains is likely to lead to new evidence.

If the coroner concludes that an autopsy may provide useful information, he or she will inform the cemetery authorities (and, depending on the circumstances, the family of the deceased) that an exhumation is to be performed. Usually a funeral director and the staff of the cemetery will work with coroner's investigators, including the police and the forensic

pathologist, to determine an appropriate time for the exhumation. Frequently, exhumations are performed early in the morning, before the arrival of members of public at a cemetery, in order to minimise the impact on the local community. The exhumation of a body needs to be carried out with considerable care so as not to disturb nearby graves. Occasionally, when a plot contains more than one body or plot markings are unclear, an exhumation may result in the uncovering of other bodies, in which case the issue of identity needs to be very carefully addressed. In such situations, it may be necessary to bring more than one body to the mortuary for detailed identification processes as well as pathological examination.

The exhumation of a body from a grave can easily result in damage to the remains if special precautions are not taken. Although a mechanical digger may be used to expose the upper levels of a grave, its use close to the coffin may result in damage to it and/or to the body inside. For this reason a degree of manual digging (sometimes involving a forensic anthropologist and/or archaeologist) is usually required toward the end of the mechanical exhumation process. Some coffins, particularly those made of veneered chipboard, are prone to disintegration, and in such cases additional support of the coffin may be required during the lifting process, through the use of a stretcher-type device. If the coffin has completely collapsed or disintegrated, the fabric or plastic lining of the coffin containing the body may be removed directly from the grave, acting as a body bag. If this, too, has been destroyed, a more archaeological approach to the removal of individual portions of human remains from the grave may need to be considered.

The process of exhumation needs to be clearly documented with photographs that include images of the plot site before exhumation, any identification markers present on the plot, the exposure of the coffin, the state of the coffin, and any identification markers on the coffin itself. During the removal of the coffin and the body from the grave it may be necessary to take samples or specimens from the vicinity of the grave site. These may include samples of soil from above and below the coffin or from the substance of the coffin itself. Drugs and toxins that were present in the body at the time of death may be identified in the soil adjacent to the coffin rather than in the bodily remains. In some exhumations, there will be a visible body fluid drainage area present in the soil adjacent to the coffin. Samples from this region may prove valuable for toxicological analysis. Control samples of soil from some distance away from the grave site must also be taken to ensure that the soil in the cemetery is not generally contaminated with some suspicious chemical substance.

With the completion of the medical examination of exhumed remains and the collection of samples for forensic scientific testing, the body is usually returned to the cemetery within a few days and buried in the same grave plot. It may be necessary for the coroner to assist the family in arranging a further funeral service at the time of reinterment.

The Autopsy

The autopsy can be considered a “highly invasive” and “all-encompassing” pathology test that, using a combination of both screening and diagnostic analyses, surveys the body for the presence, nature, and extent of disease or injury. It also represents the most comprehensive type of medical examination or procedure performed on an individual. Because the autopsy is a “one-off” procedure and is followed by the disposal of the body by burial or cremation, repeating parts of the procedure if mistakes or omissions are made is difficult or impossible.

In jurisdictions that employ pathologists to carry out medico-legal autopsies, it is the coroner who must determine whether the death investigation requires an autopsy and, if so, formally order that it be undertaken. Within certain limits the coroner can control the extent of the examination and choose who performs the autopsy. In practice, there are many agencies,

individuals, and groups who may have an interest in an autopsy. Each might reasonably expect to be consulted regarding the extent of an examination. For example, police officers, occupational health and safety inspectors, treating medical practitioners, and the family of the deceased may all have a view as to the extent of the autopsy.

There are two types of “autopsy”: the clinical autopsy and the medico-legal autopsy. A clinical autopsy, sometimes referred to as a hospital autopsy, is distinctly different from the medico-legal autopsy ordered by a coroner. Clinical autopsies in Australia, and in many other jurisdictions, require the consent of the next of kin and can be performed only for the purpose of contributing to our understanding of disease and the effects of medical treatment. They must not be performed to determine the cause of death; if the cause of a death is unclear to the treating clinician, the death must be reported to the coroner, in which case a medico-legal autopsy may be undertaken.

A variety of autopsy procedures and associated scientific techniques can assist with a coronial investigation. In terms of the medical examination of deceased persons or unknown human remains, the pathologist usually acts as the coordinator and team leader of the medical, dental, anthropological, and scientific units involved. In addition, during the autopsy the pathologist can provide information on the injuries, diseases, and individual physical characteristics of a body, going far beyond the features that could be observed by superficial inspection.

The aims of the autopsy (forensic and clinical) include:

- confirmation or determination of the identity of the deceased
- identification of injuries and natural disease
- reconciling events in life with the presence of anatomical and pathological features
- determination of the extent of injuries and natural diseases
- evaluation of the effect of medical treatments
- assessment of the mode of death
- determination of the cause of death
- comprehension of the mechanisms involved in the death
- provision of an educational resource for the medical profession
- provision of tissues for use in medical research and therapeutic procedures
- retrieval of trace evidence and other samples for use as evidence in court
- reconstruction of the circumstances surrounding the death

The autopsy alone cannot meet all these aims. Indeed, the autopsy is an examination carried out to identify pathological processes and anatomical abnormalities at “a point in time,” namely, at death. It is only when these findings are integrated with information about the death scene and the individual’s medical history and lifestyle that the information obtained from the autopsy can be put into a proper context.

Whether undertaken for clinical or a medico-legal purposes, the autopsy has three elements:

- 1 Initial contact with the family, outlining the autopsy procedures and the family’s rights with respect to the extent of the autopsy, and the use of any tissues and organs retained, as well as the potential implications the autopsy information may have for family health.
- 2 Conduct of a detailed macroscopic and microscopic examination of the body, including all medical and scientific tests necessary to meet the wider purposes of the autopsy, including but not restricted to determining the cause of death.
- 3 Postautopsy consultation with the family, providing information about the findings with respect to the death and its implications for the health of family members. This consultation would also include any appropriate medical or legal referral.

In theory, a complex autopsy could take months to complete. However, in practice most physical autopsies take a few hours—which means that the performance of an autopsy, whether for medical or medico-legal reasons, should not introduce any significant delay to a family's funeral arrangements.

Information obtained from autopsies conducted in an environment of open communication with the family and the community has the capacity to be of enormous private and public benefit. It is the responsibility of coroners and forensic pathologists to ensure that the community is made aware of the value of the autopsy and that families are included in the decisions surrounding the medical examination and able to benefit from the information that the autopsy provides.

Identification of Human Remains

The identification of the dead is essential for the lives of others to return to normal. From an emotional standpoint the uncertainty and anguish suffered by families who have a missing loved one who they fear may be dead can be tremendous. From a practical standpoint, if the identification of the deceased is problematic or proves to be impossible, the consequence can be that many others suffer real hardship. For example, the family may not be able to wind up the financial affairs of the deceased, and disbursement of property according to the deceased's wishes may be significantly delayed.

Ultimately, it is the coroner who must determine identity on a legal basis. To do so, he or she relies on statements of identification provided by witnesses and on the results of specialist medical and scientific investigations. The weight that the coroner places on different types of information uncovered in relation to identity is a critical factor in accurate human identification. The circumstances of a death may suggest the probable identity of the deceased, but this information is rarely sufficient on its own for a coroner to make a formal legal determination of identity.

Several identification methods are available to investigate human remains. They include:

- visual identification
- fingerprint identification
- serological identification
- molecular biology (DNA identification)
- dental identification
- craniofacial reconstruction
- medical and anthropological identification
- radiological identification

Visual Identification

The identification of someone who was a friend or a relative is almost invariably a very stressful ordeal for the witness. Even in the best of circumstances, where the body is fresh, intact, clean, and un-mutilated and when it is displayed in a clean, bright, non-threatening environment, such as a modern mortuary, with the support of an enlightened and sensitive staff, the family of the deceased may still find it difficult to identify the body. Inevitably mistakes will be made, occasionally frauds will be perpetrated, and in some cases bodies will be unrecognised and remain visually unidentifiable. There are a variety of reasons why this may be so. The most obvious (and overstated) is “denial” on the part of the relatives, who just cannot accept that it is a member of their family who has died. However, a dead body may bear much less similarity to the person in life than might be anticipated.

In more difficult cases, bodies may have significant injuries and be disfigured. They may remain bloodstained from the events in which they were killed or may be so damaged that the general configuration of the body is lost. At some stage a decision has to be made as to the degree of psychological stress and trauma that may have to be inflicted on witnesses in order to achieve a “visual identification.” The decision to proceed with a visual identification has to be balanced against the likelihood of a reliable outcome and the distress to the family.

Some bodies are completely unrecognisable by any conventional visual criteria as a result of gross decomposition, severe burning, or other gross disruption. Visual identification given in such circumstances must be treated with a high degree of suspicion.

Fingerprint Identification

The taking of fingerprints from a deceased person is well established as a technique for confirming identity. It is one of the mainstays of the identification procedures in mass disasters, in part because a record of fingerprints can be stored as a paper record, as an electronic image, and as a coded database entry. In addition, where a fingerprint record is not available for a deceased person, latent prints can be lifted from objects that are likely to have been handled by that person. This ability to use latent fingerprints from a person's normal environment greatly enhances the utility of fingerprints for the identification of deceased persons. Most people whose deaths are investigated by a coroner do not have a criminal record and therefore are unlikely to have their fingerprints recorded on a police database. However, where the identity of the deceased person is suspected and fingerprints can be collected from the body, a comparison can be made between those fingerprints and latent prints lifted from various objects and surfaces at the person's home and place of work.

Such a form of identification is less accurate than a comparison with fingerprints taken from a known individual in life. In the case of multiple fatalities occurring in the same family or workplace, the use of this type of latent fingerprint comparison will not provide sufficient discrimination among individuals.

Before taking fingerprints from a deceased person, one must ensure that the procedure will not interfere with other examinations of the body. In some cases, this may mean that the fingerprints will have to be collected after the completion of the autopsy. If photographic recording of injuries to the hands or fingers is an essential part of the autopsy, then the presence of fingerprint ink may obscure the photographic appearances. In addition, trace evidence in the form of hairs, paint flakes, bloodstains, and so forth could be lost or contaminated in the process of inking the fingers.

Where the body is decomposed or severely desiccated, the taking of fingerprints may be particularly problematic. The early processes of decomposition are associated with the lifting and degloving of the superficial layers of the skin that retain the friction ridges or fingerprints. A careful operator can remove the separating layer of superficial skin and ink and fingerprint it by placing this over his or her own gloved finger. If the tissue is too friable, a photographic method can be used to record the fingerprint pattern. Even the tissue beneath the degloved finger retains the friction ridge pattern, but it may be more difficult to record.

*Molecular Biology (DNA Identification)*¹

The study of the genetic basis of disease was the foundation for the technology of DNA analysis that is now widely used in criminal investigations. However, the role of DNA analysis for human identification by the coroner is still relevant. When DNA analysis is required in coroners' investigations, it is usually applied in circumstances quite different from those in criminal case work.

Identification of deceased persons subject to a coroner's investigation does not require the use of DNA technology. Indeed, molecular biological techniques are usually employed only when other methods of identification have failed. The only exception is in the case of a mass disaster, when the use of multiple individual means of identification for each and every body or body part may be required.

Dental Identification²

The application of forensic odontology to human identification involves two main methods of comparison. The first relates to the anatomical structures of the teeth, the jaws, and associated facial regions. Genetic and developmental factors influence the structure and relationship of teeth to various oral structures; as a result there is enormous variation among individuals in dental anatomy. The second method of comparison relates to identification and documentation of dental treatment, including the effects of restorative dentistry and other forms of dental treatment. With the improvement in oral hygiene in recent years, many young people show no evidence of having received restorative dentistry. However, the advent of modern radiographic techniques to assess dental structures in the living for the purpose of orthodontics has provided a means of comparison with postmortem forensic odontological radiological examination.

Craniofacial Reconstruction and Superimposition³

The recovery and identification of human skeletal remains may pose particular challenges to investigators. Forensic anthropological assessment of the human skeleton can provide important information regarding general features of the deceased including ancestry, sex, age, and height. This information can be useful in narrowing the field of individuals who might be the deceased—that is, in creating a biological profile. When it comes to actual identification of skeletal remains, some of the newer techniques of craniofacial reconstruction and comparison may be of considerable use (see, for example, Clement & Ranson 1998). However, these techniques tend to be more useful in exclusion than in confirmation of identity. Nonetheless, where limited material is available for identification, craniofacial reconstruction and facial superimposition techniques may be extremely valuable.

Medical and Anthropological Identification⁴

Medical information about the presence of disease, together with the description of general characteristics of a body, can form important information about identity. As part of the routine process of autopsy the external characteristics of a body are described. These include hair and eye colour, the presence of tattoos, scars relating to surgery or previous injury, and “birthmarks” or skin lesions. External characteristics on the body can provide useful information that can assist with at least a general classification or group into which the deceased can be placed. In the case of mass disasters where there are many dead, information about previous surgery such as an appendectomy can be highly useful when added to other data. In individual case identification, information about tattoos or scars from previous surgery may narrow the field of possible missing persons who could be the deceased.

Internal examination of the body can reveal evidence not only of current disease but of previous disease processes. This information can prove useful when compared with antemortem records that include notes of previous medical history. Effects and alterations of anatomy caused by previous surgery identified at autopsy can also be important for identification. Sometimes

prosthetic devices have been left in the body, for example, from orthopaedic surgery whereby replacement joint surfaces or internal fixator devices are used. Some of these devices have serial numbers or batch numbers, and it may be possible for the manufacturer's records to be used to identify where the device was dispatched. Review and assessment of such devices by an orthopaedic surgeon may be helpful. When it comes to evidence of other types of surgery, it may be appropriate to obtain the advice of a surgeon from that field of practice, because styles of surgery and techniques employed may differ over time and between schools of surgical practice. The information that the deceased perhaps underwent a surgical procedure more than 20 years ago in Europe may be a useful discriminator in the process of human identification.

Although a pathologist records details of anatomy during the course of autopsy, a specialist anatomist or anatomical anthropologist, experienced in the analysis of a range of differentially preserved human remains, is regularly involved in examination of skeletal remains and may provide far more detailed information about the remains (see Part III this volume). They can also provide very useful assistance in cases requiring exhumation and in the examination of decomposed and disrupted remains. In the case of persons who have been involved in explosions there may be considerable fragmentation of the body, resulting in the need to identify grossly distorted body parts among commingled remains (see for example, Buck & Briggs, Chapter 35 this volume).

Radiological Identification

The use of radiology in human identification is a useful adjunct to the work of many medical and scientific professionals engaged in the task of human identification. Radiographs taken of people in life may be compared with postmortem radiographs taken at the time of autopsy. Even if there has been subsequent severe bone damage at the time of death, reconstruction of bone fragments and subsequent radiology may still provide enough information to enable a direct comparison. If the skeleton is widely fragmented, it may be possible to match up the characteristic micro-architecture of a bone fragment with a small region of a radiograph taken in life.

A number of areas of the human skeleton show very individual characteristics; the skull is a good example. The pattern of the air sinuses, particularly the frontal sinuses of the skull, may provide enough information to confirm identity. As discussed, this method is usually carried out through the use of two-dimensional X rays of a skull specimen that is positioned to match the orientation of the original antemortem X ray. The use of 3D computerised tomography scans of the skull can assist with this process: a virtual 2D slice can be made of the 3D data set in any plane or position to allow computerised manipulation of the image to match the orientation of the 2D radiograph taken in life.

One of the advantages of radiology in assessing the human skeleton is that it can provide a record of the skeletal structures of the remains, which can be retained even following disposal of the body. Because the specimen is close to the X-ray film when postmortem radiographs are taken, measurements of the bone can be taken from the radiograph directly. Such measurements can be used by anthropologists and radiologists in estimating the deceased's height or measuring key features that can be used to suggest the ancestry or sex of the individual. Computerised tomography (CT) scans of the body provide an ideal 3D record of the remains, which allows for detailed measurements of the morphology of individual skeletal structures.

In addition to bone shape and size, radiographs of skeletal structures can also identify the existence of current or previous disease. This determination is not limited to disease of the bone but can include information about other systemic disease markers that can be seen in bone changes. People who have been subject to debilitating diseases in early life may show lines

of maturation arrest in irregularities of bone formation that occurred during childhood bone development.

In skeletal remains of young person's radiological assessment can assist in determining the probable age of persons at the time of their death from a variety of factors, including the appearance and closure pattern of epiphyses (the ends of long bones). In older people radiological assessment of age-related changes and wear patterns may again assist in determining the person's probable age at the time of death, although this determination is likely to be less precise than the age estimation that can be calculated for younger individuals.

Disaster Victim Identification⁵

Among the major death-investigation and death-scene management processes involved in a mass-casualty scenario, the identification of deceased persons is usually the foremost consideration for the community. Coroners have overall responsibility for this function in addition to their broad death investigation role. Although in some mass-casualty events visual identification of the victims will be possible, when fire or explosion is involved the bodies may not be identifiable without recourse to special scientific and medical techniques. It is essential that the process put in place to investigate the cause of a major disaster causing multiple loss of life does not interfere with the process of identification of the victims. Identification and incident investigation should go hand in hand; indeed, each relies on the other for information. For example, in the case of a bomb blast identification of the most fragmented body can assist in determining the location of the bomb and perhaps the identity of the "bomber."

For a coroner who has ultimate legal responsibility for both incident investigation and human identification, the coordination of all phases of a mass disaster investigation is an important responsibility. In most cases a coroner delegates individual tasks to various specialists, and the coordination of the identification of victims is often handled for the coroner by a senior police officer. When the circumstantial, scientific, medical, and dental information that establishes the identity of a victim has been collected to the police officer's satisfaction, this information is presented to the coroner during the process of reconciliation. The identity of the individual is not confirmed until the coroner is satisfied with the information provided.

The Inquest

In traditional coroners' jurisdictions based on the English model, the inquest is the legal hearing that finally determines those matters that the coroner is required to state publicly. An inquest is an investigative process concerned with setting the public mind at rest when there are unanswered questions about a reportable death. The process of inquiry is principally inquisitorial but has been described as containing both inquisitorial and adversarial elements. In this way, it differs from a fundamentally investigatory process such as a Royal Commission. The coroner receives evidence in the form of documentary statements, certificates, and expert reports as well as oral testimony. It may well be that the coroner has personally visited the scene of death and been directly involved in the more practical aspects of the investigation. The role of the coroner is fundamental to the inquest process. In a number of respects it is more significant to the outcome of hearings than is the role of the judge in standard civil and criminal hearings. This importance is because inquests are coroner-driven: the coroner is principal investigator in the sense of generating the search for evidence to be taken into account in the decision-making phase. The coroner also has a range of administrative responsibilities that must be discharged and, in most contemporary jurisdictions, is the judge of the facts and of the law.

The most important product of an inquest is the decision. Traditionally, the formal decision of the coroner's court was termed the "inquisition." Currently, it is variously referred to as the "findings" or the "verdict" of the coroner or the coroner's jury.

Coroners' court decisions are unique among decisions by judicial officers in two respects: they are the result of an inquisitorial inquiry (as opposed to an adversarial process), and they often attract the attention of media to a degree not encountered by any other courts. For this reason they can devastate reputations, can generate very strong emotions, and can have major ramifications for affected persons and bodies in terms of both commercial and vocational viability. They can also have an indirect effect on secondary criminal, civil, and disciplinary actions.

Coroners' court decisions also place on the public record a formal determination of the circumstances in which a person has died and the causes of the death. Although the finding as to how a death occurred or as to the circumstances of death is perhaps the most important outcome of an inquest, the key administrative outcomes, including the particular items of information required to register the death, are an important aspect of the coroner's role. This information is essential for the public record to be made complete and, if necessary, "set straight."

Another aspect of the inquest is that it is traditional for coroners and coroners' juries, when they deem it appropriate, to add to the findings a "rider" in which recommendations or suggestions are made, directed toward reducing the likelihood that similar circumstances will occur and lead to avoidable deaths. Technically, riders are not part of an inquisition; they are comments or recommendations arising out of the findings. Riders can be contentious and can have major pecuniary ramifications for institutions, employers, and government.

Riders were abolished in 1980 in England and Wales and replaced with a very limited power on the part of coroners to make suggestions to government. In other jurisdictions, in particular in Australia, New Zealand, and Canada, the potential for formal recommendations to be made as part of the outcome of the inquest has broadened the focus of coronial practice.

Today the benefits of the broader form of the coronial inquest process include:

- determining the medical cause of death, including social and psychological factors
- advancing medical knowledge, including facilitating accurate statistical information on causes of death
- investigating deaths to allay rumours or suspicion and thereby to ensure that no foul play or wrongdoing slips through the net
- making recommendations to avoid future fatalities
- checking on the death registration system
- enabling family and friends to find out how the deceased died
- assisting in personal and community grieving processes
- providing an independent review and investigation of the deaths of individuals in the care or custody of state agencies
- providing families with medical information that may have direct relevance to the maintenance of their health and well-being

Conclusion

Death investigation systems commonly involve a combination of medical, legal, and administrative structures. The differences among jurisdictions arise from a variety of interrelated factors including social, religious, political, and legal influences, as well as the development of the medical profession and its specialties. Balanced perspectives in assessing death can be difficult. It is not easy to come to terms with the fact that sometimes people simply pass away—that deaths

just happen. It is very tempting to expect or insist on having someone to blame when a loved one passes away. This is so whether the person is young or of advanced years. Could not something have been done? If someone had intervened, would not the person still be alive? If more care had been taken, would not the likelihood of death have been reduced? Lives lost in such a manner call for explanation, and there is a temptation that someone must be found to blame.

Grief can readily lead to guilt, frequently unwarranted but nonetheless burdensome to survivors and to careers left behind. This situation means that there is a constant pressure for investigation into circumstances of death and a need to evaluate whether conduct that brought about death should not have occurred. The other inquiry is into what needs to be done to avoid repetition of the events that caused the death. Sometimes there are ready answers, such as criminal prosecution of the homicidally culpable. Sometimes there are complex, systemic responses that might reduce the potential for other fatalities.

The focus on the role of the coroner in preventing injury and death has become a prominent characteristic in the evolution of coronial law in Australia and Canada, particularly since the mid-1980s. Recognition has increased that the value of death investigation goes beyond resolving legal issues and simple identification of facts surrounding a death. Although even today coroners' inquests are largely directed toward ascertaining direct causes of death, such as accidents or a deficit in provision of care, natural-disease deaths (which constitute the majority of coroners' death investigations) are acknowledged as having significant public health implications.

As risk management, occupational health and safety, and preventive medicine have grown into important vocations, together with integrated systems for coroners' inquiry, the application of these disciplines as part of a coroner's death investigation has assumed a greater importance. This change represents a significant departure from the traditional role of the coroner's jurisdiction and is an example of expansion in response to perceived community needs.

Notes

- 1 See Baker this volume.
- 2 See Clement this volume.
- 3 See Stephan and Claes this volume.
- 4 See Sauer, Wankmiller, and Hefner; Rogers and Willey, all this volume.
- 5 See Sledzik and Mundorff; Black; Buck and Briggs, all this volume.

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The International Commission on Missing Persons (ICMP) and the Application of Forensic Archaeology and Anthropology to Identifying the Missing

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The International Commission on Missing Persons (ICMP)'s Mandate and Technical Capacity

The International Commission on Missing Persons (ICMP) endeavors to secure the cooperation of governments and other authorities in locating and identifying persons missing as a result of conflicts, human rights abuses, disasters, organized violence, and other causes and to assist them in doing so. The ICMP also supports the work of other government and nongovernment organizations in their efforts, encourages public involvement in its activities, and contributes to the development of appropriate expressions of commemoration of and tribute to the Missing. The ICMP was created at the initiative of U.S. President Bill Clinton in 1996 at the G-7 Summit in Lyon, France. The Dayton Peace Agreement, which ended the fighting in the former Yugoslavia, was in its first year of implementation, and the ICMP's initial mandate was to help to account for the approximately 40,000 persons reported missing as a result of the fighting from 1991 to 1995. While the ICMP is focused on developing and applying political and rule-of-law-based strategies to address the issue of the Missing in different societies and situations around the world, it also brings a unique element of technical assistance to its set of activities. As a consequence of the ICMP's success in the former Yugoslavia, and with the financial support of a growing number of donor governments, in 2003 the ICMP's mandate and sphere of activity were extended by supporting governments to address the global issue of missing persons, including cases arising from natural disasters. On December 15, 2014, a Framework Agreement was signed granting the ICMP a new legal status. The Agreement constituted the ICMP as a treaty-based international organization with its own system of governance and international capacities. The ICMP has played a leading role in supporting countries emerging from conflict or from large-scale disasters. (It is increasingly the norm for domestic stakeholders to assume ownership of the missing person's process.) In addition, more cases are being properly investigated and more perpetrators are being held to account; civil society is actively engaged, and modern forensic methods, including

DNA analysis and the effective search and recovery of the Missing, are being used. These changes in turn have had a significant bearing on criminal justice, on strengthening the rule of law, and on efforts to make sure that relatives of the Missing can assert their right to know the fate of loved ones and have the means to seek justice and reparations.¹

The ICMP has two key sets of program activities, the first being to ensure the cooperation of governments and other relevant organizations in addressing the issue of missing persons, including provisions to build institutional capacity, and to encourage public involvement and address the needs of justice; and the second to provide technical assistance to governments in locating, recovering, and identifying missing persons. The two activities are closely linked. For diverse national institutions to effectively marshal a response to missing persons' issues, they must better understand how technical support and investigations can gather evidence and identify the Missing. The same kind of understanding is needed to help to address family and community expectations. Effective technical training and the implementation of investigations provide the results that allow national institutions' and society's confidence in the capability to resolve missing persons' cases to grow.

We can determine what forms the content of this understanding by asking several key questions:

- Are the structures of rule of law in place?
- Are governing authorities and institutions in place that can address the missing person's issue?
- Who is missing?
- Are mechanisms in place to determine who is missing?
- Are laws in place that provide for a system to find and identify the Missing?
- Are laws coordinated to allow for an effective process of criminal investigation and identification?
- Are investigative, forensic, and medical-legal institutions and facilities in place to undertake the process?
- Are the resources required for undertaking of the process assessed and estimated?
- How are families and communities of victims provided for?
- Are the laws and institutions that provide that support in place?
- Are families and communities organized for mutual support and civil society development?
- Are the time frames and consequences of undertaking the process known?

After conflict, and in response to national and international crises involving the Missing, the need arises to address these questions and issues from political, legal, societal, justicial, and technical perspectives. Development activities should target not only technical aspects but institution building as well. However, the response by national and international authorities often focuses on the technical aspect—the attempted recovery and identification of the Missing—that occurs first, before effective institutions are in place and before necessary legal and societal structures are functioning. The aim must be to develop an integrated system that can address these issues in a synchronized way and provide an effective framework for development. In practical terms immediate response to crises by families is often to search for the Missing, and by authorities it is often the undertaking of physical investigations and exhumations.

Forensic archaeologists should be aware of the potential effects their work has on families, communities, and society (Blau 2015; see also Cheetham & Hanson, Chapter 14, this volume); they should also understand the political, legal, and social influences and pressures that may be encountered. The outcomes of the work must be considered both for the importance of identifying the Missing but in how evidence and information will be critically used by courts, communities, and the media.

The ICMP has developed the biggest technical identification program of its kind in the world, utilizing a DNA-led identification system that successfully locates, examines, and accurately identifies large numbers of persons missing from armed conflict and disaster. The effective use of archaeological approaches for the search and investigation of crime scenes and the recovery of the Missing has been a driving force in the success of such identification programs (Hanson 2015). The ICMP retains an Archaeology and Anthropology Division (AAD) that provides several functions:

- Undertaking assessment of the needs of authorities, including what requirements and resources are needed for a successful investigative process, in coordination with other ICMP departments and international and national bodies.
- Providing advice for authorities about the planning, design, management, coordination, and implementation of investigation processes from data analysis and modelling, site location, and preparation work to evidence recognition and excavation, forensic anthropological analysis and examination, formal identification, and review processes.
- Offering technical support in field operations, including desktop planning, search, analysis, and use of excavation methods and techniques; and
- Technical support in mortuary operations, including workflow design, analysis, examination techniques, and methods as well as review of cases and investigations.
- Setting up training and capacity building that provide understanding, advice, and standards concerning evidence and identifications for investigating authorities, medical-legal entities, and judiciaries.
- Developing reliable standards and procedures for recording and documentation suitable for use by authorities to effectively undertake investigations.
- Providing effective collation, management, analysis, and research of data through use of dedicated database modules that are part of the ICMP's data management system.²
- Reporting on scientific technical support, analysis, and the outcomes of training and capacity building to provide documented results for relevant authorities. This function includes the ICMP experts being called on to provide evidence of findings for courts and tribunals.
- Coordinating with the ICMP's other forensic departments, legal experts, and civil society and political staff to ensure effective implementation and support of programs and investigations.

The practical application of these functions is provided through AAD teams coordinating with the other divisions of the Forensic Science Department and the ICMP. A central management, advisory, research, and analysis capacity is supplemented by specific program training teams. These teams are augmented with specific support teams depending on operational need.

Recently the ICMP training programs have supported authorities in Iraq and Libya, developing national capacity to undertake search, excavation, and examinations. In the Western Balkans extensive assistance over many years has been provided to authorities in undertaking excavations and examinations. The ICMP has supported the examination and resolution of complex cases in Bosnia-Herzegovina (BiH) related to events in the Krajina region and related to Srebrenica, with staff based in three facilities: the Krajina Identification Project (KIP) in Sanski Most, the Lukavac Reassociation Center (LKRC), and the Podrinje Identification Project (PIP) in Tuzla (see Yazedjan & Kęsetović 2008, Sarkin et al. 2014). Recently, extensive ICMP anthropological support has been provided to the NN Working Group (NNWG) in BiH. Participating partners in this process include prosecutor's offices, the Missing Persons Institute (MPI), expert witnesses for legal medicine, the Ministries of Interior, the Republic Center for Researching War, War Crimes and Searching for Missing Persons, and the ICMP (Sarkin et al. 2014). The primary goal of the process is to investigate the unidentified cases (NN) held in mortuary

facilities across the country. Such investigation includes resolution of cases when possible, as well as recommendations for further case completion work and wider management and organization recommendations. Current ICMP archaeological field staff continue to support excavations of large complex grave sites and to undertake data analysis and modelling to determine further grave locations, and they have provided assistance to prosecutors in both BiH and Serbia in recent years. The division is equipped for large-scale mass grave excavations and field support and to undertake high-throughput skeletal examinations and sampling (Hanson 2015).

The following sections provide some detail of the application of forensic archaeology and anthropology to identifying the Missing by the ICMP.

Developments in BiH and Western Balkans since 2009

The development and use of forensic archaeology and anthropology in BiH up to 2008 is described in some detail (see Djurić, Chapter 36 this volume), with further examples of the issues and scenarios encountered up to that time described in various accounts (Simmons 2002; Skinner, York, & Connor 2002; Komar 2003; Skinner & Sterenberg 2005; Klonowski 2007a, b; Simmons 2007; Yazedjan & Kęsetović 2008). These issues have included political and community tensions, lack of resources, authority and decision making on crime scenes, defined standards of work, capacity to find grave sites, technical recovery challenges, complexity and scale of cases, lack of antemortem records, identification methods, data management, and national capacity building. These are common issues seen globally in missing person's investigations under international law. Many of these issues continue to be addressed since 2009.

The work in supporting excavations and assisting with examinations has continued since 2008, and the numbers of excavations as well as cases identified and reviewed have accumulated. The results of the work undertaken in BiH to find the Missing from 1996 to 2014 have been summarized by the ICMP in a wide-ranging *Missing Persons from the Armed Conflicts of the 1990s: A Stocktaking* (Sarkin et al. 2014). Further contributions of archaeology from 1996 up to the present are described in Hanson, Rizvić, and Parsons (2015).

In BiH approximately 70% of the persons reported missing as a consequence of the war have been accounted for. As of December 2014 more than 25,000 missing persons, out of an estimated 31,500 reported missing as a consequence of the war in BiH, have been located in single and mass graves, cemeteries, caves, buildings, surface sites, rivers, and other locations. Of this total number the remains of around 8,192 missing persons have been accounted for by putative identifications based on “traditional” techniques (many using presumptive methods), while a further 14,792 have been identified using DNA-assisted methods (Huffine et al. 2001; Davoren et al. 2007; Miloš et al. 2007; Parsons et al. 2007; Amory et al. 2012; Huel et al. 2012). The ICMP DNA match reports with a minimum statistical certainty of 99.95% provide the basis for individual identification, and matches are found by advanced computational comparison of 71,816 DNA profiles from families of the Missing with 34,097 DNA profiles of skeletal remains. There are over 9,000 individuals still to be accounted for in BiH. It is clear that there is broad support for the continued dedication of state resources to solving the fate of the Missing; in 2012 more than 70% of BiH citizens believed the search for missing persons contributes to reconciliation and a better future for the country (Sarkin et al. 2014).

The various national and international authorities and commissions have supported the assessment and excavation of an average of around 200 sites per year since 1996. The ICMP archaeologists and anthropologists have assisted at excavations and exhumations at some 1,500 sites between 2001 and end of 2014. Remains were recovered from 57% of these sites, with the recovery of over 27,000 separate cases of human remains (bodies, discrete body parts, or sometimes

loose assemblages of disarticulated skeletal elements). Movement and fragmentation of remains was common, resulting from efforts undertaken by perpetrators to destroy or hide evidence—for example, through the creation of secondary graves and/or such things as remains being left on the ground surface, in rivers, or in burnt buildings. A recent detailed analysis of the excavation and examination work undertaken between 1996 and 2013 has assisted in developing current strategies to increase the number of graves found and the number of missing recovered, examined, and identified. The analysis indicated that while the number of graves and remains found had diminished since 2008, the reasons for this decrease were not that the bodies were destroyed and did not exist to be found but that the graves had not been located. Patterns indicated that many of the remaining Missing were likely to be in mass graves and therefore recoverable. A witness-led approach to finding graves had effectively run out of steam, but analysis suggested that combining use of witness data, archived imagery, and modelling of potential grave locations using integrated data analysis could pinpoint further grave sites. Additional technical search approaches were recommended as having potential to find surface and other remains (for further analysis details and recommendations see Sarkin et al. 2014; Hanson, Rizvić, & Parsons 2015).

As a result of a review of excavation and examination records and systematizing the observed trends and primary difficulties (including legacies of the issues described), the following steps are currently being pursued in an attempt to address the main ongoing issues in the field:

- Integration of intelligence on potential grave locations and planning of effective excavation operations is being promoted through technical working groups and by sharing of information between organizations and authorities;
- Location of potential mass grave sites has progressed through the analysis and study of aerial imagery, using both archived aerial and satellite imagery;
- Study of patterns of grave deposition, assessment and comparison of witness statements, assessment of known identified cases, and comparisons with outstanding missing persons lists is providing priority locations for search in the forensic landscape;
- Review of previous site assessments, probes, and excavations is being undertaken to determine if further excavation is required;
- Excavation standards and the promotion of the systematic stratigraphic excavation of grave sites are being encouraged; they facilitate an understanding of the original construction of graves, sequence of activity, dating of sites, and the deposition of remains;
- Standard scene-of-crime procedures are being promoted through use of forensic photography, field archaeological observations and notes, evidence numbering, body collection forms, and three-dimensional mapping of grave features, recovered remains, and other associated evidence;
- Physical anthropological assessment on-site to provide understanding of the context of cause and manner of death and the collection of properly associated sets of remains.

The stocktaking and analysis highlighted the consequences in the mortuaries of the collection of commingled and complex remains from the field. While the facilities at KIP, PIP, and Lukavac had been able to fully assess complex cases of body parts and manage them using formal database systems and case managers, such assessment had not been possible in other facilities. In many facilities anthropologists have not been always present during all examinations, and facilities hold a legacy of cases going back to recoveries and body swapping during the conflict when there were limited formal forensic examinations. There are 12 mortuaries around the country holding remains of missing persons. In November 2012 there were still an estimated 3,270 cases classified as unidentified remains (NN) in 10 mortuaries that had not been formally reviewed by the NN working group and the ICMP. The two remaining facilities, PIP and KIP, had all cases

reviewed under the ICMP management and contain a further 4,400 unidentified cases; most of these (some 3,300) are classified as “ossuary” remains—that is, skeletal material (often single, fragmented, or small groups of bones). This material cannot be reassociated to identified cases and is not suitable for sampling for DNA extraction because of either condition or practical considerations of cost-effectiveness. The ICMP’s DNA analysis has shown that the KIP and PIP remains represent at least 2,653 different individuals.

The continuing work at PIP and KIP has allowed processes to be developed on how best to resolve these complex cases. A formal case review process was developed that collates all information on cases, including excavation data, and that undertakes physical examination and further DNA sampling where necessary. The cases are given a status and recommendations for further required work to close the case. In many examples this involves assessing DNA results, matching and reassociating different cases, reexhuming already buried and identified cases, and correcting identification, labelling, and documentation errors. The analysis suggests that more than 15% of cases held in the diverse mortuaries do not relate to the conflict and that errors in identification are more likely in complex commingled assemblages of remains.

Using the strategy and recommendations provided by analysis, the main ongoing issues in the mortuaries (including legacies of the issues already described) are being successfully addressed.

- The case review of the unidentified NN cases began in May 2013, with authorities agreeing that all remains in the facilities across BiH should be assessed, supported by the ICMP. The process has resulted in the successful review of three facilities, with a further two under review as of February 2015. Over 800 body bags holdings cases have been reviewed, and these were found to contain around 2,000 sets of human remains. Assessments have determined that around half of the cases can be resolved with further work. The overall review is expected to take until mid-2016.
- Analysis of work at KIP and PIP before the implementation of the NN case-review process led the ICMP to recognize the need to employ case managers to organize, follow, and manage database entry and records for cases during and after review. The case data and additional work required to resolve cases need consistent and effective management.
- Updating of databases has provided more analytical power. Assessment of assemblages formed from remains taken from related primary and secondary graves has determined through a “gap analysis” whereby the skeletal elements that are found to be missing from each case are tabulated. Compared to the total number of DNA profiles associated to an assemblage, the pattern of missing skeletal elements provides indicators of where to focus searches for new grave sites among known grave clusters.
- Results of gap analysis compared to lists of those still missing and unaccounted for from specific events provide indicators of where to focus further investigative efforts to find graves.
- The DNA sampling strategy for examinations has been updated so that pathologists can undertake more effective sampling for DNA and develop common standards of work (see Hines et al. 2014).
- The setting up of an Institute of Legal Medicine in the Federation BiH (FBiH) has been proposed by the ICMP as a vehicle for providing a national forensic capacity, standardized excavation and examination support, and a home for forensic practitioners. As part of its mandate, a forensic institution in FBiH may be able to provide standardized quality control and management, centralized examination and analysis, central databases, and management of all missing person’s cases. The proposal for the institute is currently in front of the BiH parliament. The ICMP would recommend the consideration of a single state-level forensic institute.

The results of the cases review process are providing outcomes that will guide further work. Many cases are categorized as ossuary material, and others appear not to relate to the conflict but to WWI, WWII, and older historic or prehistoric periods. The BiH prosecutors and the Missing Persons Institute (MPI) should work to a proper resolution of these cases, including liaising with War Graves Commissions and state, entity, and cantonal authorities for the permanent disposition of archaeological material (see, for example, Zukanović, Sarajlić, & Škulj 2011).

Large numbers of skeletal remains have been determined to belong to already identified and buried individuals. If these cases are reexhumed, reexamination would probably determine some misidentified/misassociated body parts. The ICMP found that an average of 12% of cases receiving an element reassocated through DNA already had such an element included in the case, indicating commingling that had not been previously detected (Hines et al. 2014). Note that around half of the cases reviewed under the NN process have been found to have DNA profiles but no DNA match to reference samples. One reason for this situation is that families who received remains identified through traditional means in the years immediately after the conflict did not, in many cases, provide blood reference samples. When the accuracy of identifications has been in doubt, in some instances additional DNA reference samples have been collected from families who had already received remains; this approach might be used as a wider strategy to resolve such issues. The NN working group with the ICMPs support is discussing the development of practicable policies for investigating misidentifications and the determination of the proper disposition of remains that cannot be identified (see Sarkin et al. 2014). Ultimately, however, it is the decision of the BiH authorities whether they wish to embark on a full accounting procedure of exhumation, examination, sampling, possible identification or possible reassociation, and reburial. In some instances this series of steps could involve an iterative process wherein examination and DNA testing of exhumed remains discovers additional misidentifications within other buried cases, causing the need for additional exhumation and subsequent examinations and sampling. Such a decision must take into account both cost to the state's budget and the distress such a course of action might cause for families of the Missing who buried people they believed to be their missing relatives, often many years ago.

The potential for unmatched remains and misidentifications is clear when, as in BiH, there was a transition from an identification system relying on review of clothing, personal effects, medical observations, anthropological assessments, and limited antemortem information on the Missing to a system providing positive identifications by matching DNA samples between families and recovered remains. The latter system provides a far greater potential for positive identification and a far lower chance of error than does the former.

Developments in Iraq since 2009

Some of the developments and issues concerning the use of forensic archaeology and anthropology in Iraq up to 2008 are described in some detail in Congram and Sterenberg (2009), who focus on the background issues of variety of contexts, lack of organized data, disorganization of approach, and ability to investigate and coordination to investigate. The developments and issues have been updated (see Congram, Sterenberg, & Finegan, Chapter 38 this volume). Additional examples of the issues and scenarios encountered up to 2008 are described in various accounts (Stover, Haglund, & Samuels 2003; U.S. Department of State 2003; Cordner 2005; Hunter & Cox 2005; Cox et al. 2008; Steele 2008).

These issues have included political tensions, lack of national staffing and resources, national capacity building, legal authority to undertake investigation, definitions of standards of work, capacity to find grave sites, technical recovery challenges, complexity and scale of the missing

persons issue, ethics, and legislation; many of these issues have continued to be addressed since 2009. The ICMP began working with Iraqi institutions in 2005 and established an office in Baghdad in 2008 and in Erbil in 2010. Grants from the United States, the UN, and Germany from 2009 provided formal training programs that allowed capacity building within Iraqi ministries. The training involved development of crime scene, excavation, and mortuary processes; sampling for DNA; antemortem and blood reference sample collection; and database development, as well as DNA analysis processes.

As part of this training, participants reviewed the legislation relevant to dealing with missing persons, including laws on the responsibilities of forensic doctors and pathologists, the criminal code, and Antiquities laws. The ICMP had assisted in the development of the Law on the Protection of Mass Graves, which came into legislation in 2006. The law provides a legal mechanism, with the Ministry for Human Rights (MHR) responsible for locating missing persons, conducting excavations of mortal remains, and identifying victims exhumed from mass graves. Participants also reviewed requirements for data protection and ethics. Training and standards are geared toward the Iraq criminal code and relevant laws governing investigations, as well as responsibilities to the missing and families.

The ICMP training courses concerning archaeology and anthropology developed from 2009 to 2014 with a focus on building managerial understanding as well as technical capacity to undertake the process of locating, recovering, and performing physical anthropological examination of human remains. Eight basic training courses and numerous advanced courses have been completed by over 300 trainees, both men and women and from all parts of Iraq. The MHR and in the Kurdistan region Ministry of Martyrs and Anfal Affairs (MoMAA)—as well as the Medical-Legal Institute (MLI), which undertakes examinations—now have mass grave departments in their institutions, whose staff participate in the training courses. Some managers in the departments were previously trained in 2004–2005 (see Congram & Sterenberg 2009), as were the ICMP national staff trainers. The ministries have to some extent coordinated activities and now have field teams that undertake mass-grave investigations, with examinations undertaken in MLI mortuaries across Iraq. Teams have been mentored and monitored by the ICMP, developing both technical skills and experience, despite the trying security conditions and environment in which they operate. Many investigations concern ongoing prosecution cases and are coordinated under the relevant laws, with data collected during investigations being used to identify the missing and to provide evidence for the courts. Since 2008, concerning the Missing from the Saddam Hussein regime era (1979–2003), there have been over 60 mass graves investigated and 4,000 bodies recovered. The ICMP has not been involved in investigations into the missing from the Iran–Iraq war (1980–1988). The MHR and MLI have also undertaken field recovery and examination of missing persons cases from post-2003. Some 1,500 bone samples and several thousand blood reference samples have been submitted to the ICMP, under agreement, for DNA analysis to be undertaken in their labs in Bosnia as part of the effort to identify the remains recovered through mass-grave excavations (Hanson 2015).

In 2012 the ICMP signed an agreement with the four ministries engaged in addressing the missing-persons' process (the MHR, the Ministries of Health in Baghdad and Erbil, and the MoMAAs) and instituted the creation of an interagency expert group to improve cooperation on this issue and promote building of institutional capacity. The agreement covered the recognition that families have a right to know the fate and whereabouts of their missing relatives, that uncertainty surrounding the fate of the missing is a continuing source of anguish and an obstacle to rebuilding civil society in Iraq, and that the government has direct responsibility for efforts to locate and identify the missing. A main objective was to coordinate a concerted effort to address the mass graves issue in a systematic way, including targeted DNA reference sample

collection and corresponding field reconnaissance and excavation work. As part of its ongoing Civil Society Initiatives program, the ICMP is also working with key ministries to facilitate dialogue on missing person's issues between civil society and government institutions and to strengthen the capacities of victims' groups.

In February 2015 the ICMP held a seminar workshop in The Hague for senior government officials and legal experts from Iraq, which focused on the use of forensic evidence in court-ordered processes regarding mass graves and missing persons as part of a new initiative to find the Missing in Iraq. The current fighting in large parts of Iraq means that the number of missing persons is rising rapidly, adding to the already high numbers estimated from years of dictatorship, war, and internal conflict.

Developments in Libya

According to the Libyan Ministry for the Families of Martyrs and the Missing (MFMM), up to 10,000 persons are estimated to be missing in Libya. This number includes persons missing as a result of the 2011 conflict, as well as those who went missing during Muammar Gaddafi's 42-year rule, including in the 1977 war with Egypt, the 1979 war with Uganda, wars with Chad in the 1980s, and in the Abu Salim prison massacre in Tripoli in 1996. In January 2012 the General National Congress (GNC), formerly the Libyan National Transitional Council (NTC), and the MFMM invited the ICMP to help Libya locate, recover, and identify these missing persons.

The ICMP's program in Libya has concentrated on the development of a Libya-led missing person's process that is nondiscriminatory, scientifically valid, and based on the rule of law. The program seeks to advance the engagement of civil society, especially families of the missing, and to help the authorities set in place legal measures to safeguard the rights of families of the Missing. The ICMP has helped to set up the Libyan Identification Center (LIC) as an initial and important step in enabling Libya to develop a sustainable and nondiscriminatory missing person's process.³

Extensive training was provided for Libyan MFMM staff involved in investigating mass graves, including crime scene control, excavation methods, osteological examinations, sampling of remains, and field-to-mortuary processes. MFMM staff were drawn from a variety of backgrounds, including medicine, dentistry, and geology, and had initially volunteered their assistance. Initial training and mentoring in taking DNA samples were provided in March 2012. Formal training began in March 2013, with two basic courses in Tripoli completed by 40 trainees, followed by advanced courses. More than 50 MFMM staff undertook training in 2013. Two excavation and examination teams began operating nationally based in Tripoli and Benghazi in 2013, with plans for more staff and teams to be trained. Mentoring at excavations began in 2013 with sites investigated in Tripoli, at a mass-grave site of known casualties from 2011 and also (as has occurred in many other countries) at a site that was subsequently determined during assessment to be a historic cemetery and of no forensic interest to MFMM (Hanson 2015).

Political and family pressures led to some excavations being undertaken in 2011 and 2012 and also to examinations of remains held by the former regime in a hospital mortuary refrigerator in Tripoli. The most substantial excavation was at Bin Jawad in December 2011 (Bassouni 2013), where MFMM staff exhumed some 156 bodies. DNA samples were taken from the remains when they were examined at the grave site; however, families present at the exhumation took bodies they identified as relatives based on clothing and personal effects. The same issues have occurred in other countries concerning initial unofficial exhumations and repatriations based on visual identifiers after conflict ends—for example, in Iraq (Congram & Sterenberg 2009).

The family groups set up in Libya began an effective pressure campaign to get MFMM to undertake further excavations in 2012 and 2013, but this undertaking was resisted until teams completed the ICMP training. By the end of 2014 the ICMP had made a total of 137 DNA matches, including the identification of the mortal remains of Dr. Mansour Rashid Kikhia, a former Libyan Foreign Minister and Ambassador to the United Nations who later opposed the Gaddafi regime and was believed to have disappeared in Egypt in 1993. The majority of matches relate to the Bin Jawad grave, with two matches related to the remains examined from the Tripoli mortuary refrigerators. The ICMP provided MFMM with recommendations and advice on the formal closure of cases and for the undertaking of case reviews. Unfortunately, in 2014 the deteriorating political and security situation affected the ICMP's capacity to operate in the country. In addition to paramilitary unrest, legal competency for missing person's issues has been contested among involved government agencies.

Conclusions

The developments in several of the ICMP programs since 2009 highlight a number of complex issues, common to all postconflict countries attempting to deal with their missing person's issues and that are difficult to overcome. Existing challenges have been addressed by the ICMP through supporting authorities with an integrated system that provide advice and training to help to establish rule of law and technical solutions in dynamic environments where there is never a "clean start" to finding and identifying the Missing.

From the archaeological and anthropological perspective, the determination of solutions to the limitations of witness-led approaches to finding graves and the potential for misidentifications after presumptive identification efforts switch to DNA-led systems are examples of how new approaches are addressing the Missing persons issue. Such development is necessary so that the Missing can be identified and evidence of crimes brought to light. All developments throw up new challenges to be defined and addressed.

There are no quick fixes for large-scale problems involving Missing persons across the globe, but the success the ICMP has had in utilizing technical processes including archaeology and anthropology demonstrates what can be done when systems are combined.

Notes

- 1 See ICMP's website: www.ic-mp.org/about-us/.
- 2 See the ICMP's website: www.ic-mp.org/what-we-do/technical-assistance/databases-and-data-processing-systems-include-elimination-databases/.
- 3 See the ICMP website: www.ic-mp.org/where-we-work/middle-east-and-north-africa/libya/.

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Conclusion

International Perspectives on Issues in Forensic Anthropology

Soren Blau and Douglas H. Ubelaker

This revised handbook presents diverse perspectives on the nature of forensic anthropology, its history as played out in different regions of the world, its applications to various medico-legal issues, and the background and training of personnel. With increasing frequency, forensic anthropologists are involved in domestic criminal cases and law enforcement initiatives thought to involve human remains, international investigations of atrocities and humanitarian missions directed toward victims of such atrocities, recovery and identification of war dead, mass-fatality incidents, and training at a variety of levels. In addition, forensic anthropologists contribute to what has been termed “judicial anthropometry” (identification of the living), scene management, and interaction with family members. Those practitioners with a background in social anthropology have also proven useful in forensic contexts working with communities in assembling antemortem data on missing persons, especially in areas where medical and dental records are rare.

Clearly, definitions of *forensic anthropology* and *forensic anthropologists* vary considerably (see Blau & Ubelaker, Chapter 1 this volume), and to a large extent they are regionally determined. Although the forensic anthropology practitioner may hold a Ph.D. in physical anthropology or a medical degree or come from a variety of other educational backgrounds, the science applied is universal, grounded in experience, casework, research experimentation, and the vast and rapidly growing published literature. The investigation of domestic and international mass disasters that result in mass casualties may involve specialists with worldwide perspectives, experience, and formal training, as well as those working with local communities who have abundant experience and knowledge of the working conditions. All these perspectives are important, and all are needed in forensic investigations.

This volume provides regional historical perspectives on the development of forensic anthropology from the United Kingdom, France, Italy, Spain, South America (including Colombia), the United States, Canada, Australia, Indonesia, and South Africa. Although particular regional developments are noteworthy, many common historical developments exist, specifically: (1) deep roots in anatomical studies with early anatomists, physicians, and anthropologists becoming involved in forensic casework; (2) similar trajectories in the growth and development of the field of forensic anthropology as measured by the formation and increased enrollment in organizations, publications, teaching, and the incorporation of anthropological perspectives in investigative efforts. Decisions about which personnel become involved in casework and what academic perspectives

are followed usually are made not by anthropologists but by judges, magistrates, and others who have such responsibility by law. Clearly, extensive educational efforts have improved the nature of anthropological involvement worldwide, especially in the inclusion of archaeological perspectives in recovery efforts and the addition of anthropological skillsets to identification teams.

A variety of case studies are presented in this book to reflect on the diversity of applications in what has become forensic anthropology and forensic archaeology. These cases range from involvement in domestic homicides and routine investigations of what are believed to be human remains to large-scale mass disasters and victims of atrocities. Many common issues emerge throughout the discussions of these case studies. These include the nature and the extent of involvement of forensic anthropologists and archaeologists at critical steps in the investigation, the approach to thorough recovery efforts, accuracy of identifications, consideration of health issues, approaches to complex sites (including secondary deposits), and debates over the bureaucratic classification of sites as either judicial or humanitarian and how such classifications affect the use of resources. Throughout the discussion of all the various cases, the important role of family and community is paramount, not only as a key source of antemortem information for identification but also for their continued involvement in case resolution and commitment to justice and closure. Insight is provided in this volume on the realities of site investigation and on working within large organizations. Other perspectives examine the value of including those working locally, of familial involvement, and the trade-offs involved in the selection of personnel with extensive local experience versus those with advanced degrees and international perspective.

Search and Detection

Many of the authors in this collection speak to the key issue of anthropological involvement in search and detection efforts, especially those involving recovery efforts that include excavation. It has been argued that these areas of forensic anthropology/archaeology have a greater likelihood of bringing the anthropologist to court as an expert witness. Even in geographic regions where forensic anthropologists/archaeologists by training are not involved in analysis of recovered remains, they become involved in recovery because of their unique qualifications.

In spite of the availability of forensic anthropologists/archaeologists to assist or to direct recovery efforts, actual participation varies considerably. In the case studies reported here, factors dictating whether anthropologists or archaeologists are involved in investigations (which in turn affect the quality of recovery efforts) are

- the perceived need for rapid results to press charges against the accused;
- limited goals of identification of the deceased rather than full understanding of the events involved;
- perceptions of the pace of recovery and how it might be affected by careful excavation; and
- lack of institutional control of sites.

Examples are presented regarding how much can be learned about relative events through careful excavation and documentation. Such examples illustrate how limiting the factors just listed can become. Clearly, proper location and recovery are important and are enhanced through proven techniques that may include remote sensing such as soil resistivity studies, magnetometry, and the use of ground-penetrating radar, as well as physical approaches such as the use of probes, coring, and ultimately limited and extensive excavation. All sites involving human remains are complex, but those including secondary deposits reflecting multistage behavior can be resolved only through careful anthropological excavation and analysis.

Skeletal Analysis

Skeletal analysis begins by determining if the recovered elements are human. If remains are extremely fragmented, it may be necessary first to ascertain if bone and/or tooth are represented, since many particles of other materials can resemble these tissues. To determine if remains are of human or nonhuman origin, morphology, histology, and even protein radioimmunoassay can provide solutions.

Usually, it also is important to determine as accurately as possible the time since death, especially in the case of suspicious deaths. In the types of cases requiring an anthropological perspective, this determination can be problematic to accomplish from morphological indicators alone, since so many variables affect tissue alteration. Other approaches include chemical analysis, immunology, analysis of fat content, colorimetry, and ion-exchange chromatography. The most promising techniques, however, appear to be radioisotope studies, especially those involving radiocarbon and strontium-90, isotopic variables influenced by atmospheric testing of thermonuclear devices in the 1950s and 1960s. The aim of future research will be to produce a user-friendly method that provides results in a timely and cost-efficient manner.

The estimation of sex is an important element in establishing the biological profile as part of the identification process. Bone morphology usually allows successful estimation for adults, especially if the pelvis is well preserved. Size-related differences are apparent throughout the skeleton but, except for those of the pelvis, usually are not of sufficient magnitude to allow sex estimation with great certainty. Of course, molecular approaches are now available, and especially useful are those techniques that evaluate the amelogenin gene and/or detect indicators from the Y-chromosome. Molecular approaches have the advantage of allowing sex determination for subadults whose sex cannot be determined reliably from morphological assessment.

Estimation of age at death has become complex with many methods available. The general age (neonate, infant, child, adolescent, young adult, old adult) determines which methods should be employed. This area of forensic anthropology has been augmented with statistical advances, as well as rigorous testing of multiple techniques on documented samples. There is a continued need for further population-specific research to be undertaken to improve the contribution that forensic anthropology can make to statements about age.

Ancestry estimation continues to represent an important contribution to the biological profile. Such estimations may prove pivotal, for example, in mass-disaster investigations in distinguishing local residents from tourists and other foreigners. However, with increasing migration and intermarrying increasing care is required to understand the potential problems associated with relying on physical features alone to attribute place of origin. Discussions in this volume make the important distinction between race and ancestry and recognize the importance of terminology in this complex issue. Methodologies involving measurements and visual assessment are available, but proper use of databases and recognition of the social factors involved remain critical. Such factors include, for example, the practitioner's need to understand the underlying assumptions inherent in the development of a dataset and the fact that physical skeletal manifestations do not always equate to the deceased individual's social identity in life.

Techniques of facial approximation and craniofacial superimposition are available to assist identification efforts. The former is utilized only in cases in which standard attempts at identification have failed and the need exists to reach out to the general public in search of leads aimed at identification. Superimposition techniques are used primarily for exclusion in cases for which both skulls of a deceased and photographs of the possible living individual represented are available. A diversity of approaches to these techniques exists with a continued need for additional research, testing, and evaluation.

Methodology aimed at the estimation of living stature can be traced back to the very beginnings of the field of forensic anthropology. Today, a variety of approaches are available involving formulae requiring measurements of individual as well as groups of bones. Contributors to this handbook discuss the caveats of utilizing antemortem stature records. Although formulae are now available for both sexes and different ancestral groups, additional research is needed on body proportions among different populations from around the world.

Techniques involved in estimating age at death, ancestry, and stature all have profited enormously from advances in quantitative methods. The large databases that can be accommodated with modern computer technology enable new types of research not possible only a few years ago. Geometric morphometrics conducted utilizing 3D methodology and advances in Bayesian statistics enable new approaches to traditional topics in forensic anthropology, enhancing accuracy.

New approaches in the study of forensic taphonomy facilitate greater understanding of the relationships of evidence to environment, particularly in reference to the postmortem history of human remains. Taphonomic indicators can provide key clues to time since death determination, trauma assessment, and reconstruction of postmortem history. An important component of taphonomic study consists of the study of burned bone. Although issues related to terminology abound in this area, research initiatives utilizing X-ray diffraction, small-angle X-ray scattering, and study of human albumin blood proteins all show promise in recognizing the evidence of burning and in teasing out related information on temperature, duration, and the timing of events within the perimortem/postmortem window.

Although forensic anthropologists usually do not make the call on cause and manner of death, they frequently find and interpret the evidence that allows such determinations to be made. Before interpretations of perimortem trauma can be advanced, antemortem and postmortem alterations must be evaluated. Features such as developmental foramina can look like a gunshot injury, for example, while postmortem animal tooth marks can mimic sharp force trauma. Trauma interpretation is complex and calls for the experience and techniques of forensic anthropology.

Identification of deceased individuals from skeletal remains represents the goal of much of the effort and methodology discussed earlier, yet discussions in this volume reveal considerable variation in definitions and degrees of identification. At one extreme, positive identification is accomplished when unique features found on the deceased are known to have existed on a missing person. Such identifications are most likely to occur in cases for which the antemortem information includes medical and/or dental records, fingerprints, and/or suitable DNA samples. At the other extreme, “presumptive” identifications are made through family recognition, clothing comparisons, and general attributes shared with a missing person. These three types of identification are all that may be possible in cases for which prints are not preserved, medical and dental records are not available, and DNA technology does not exist or samples are not sufficiently preserved. Clearly, molecular technology has revolutionized the identification process, but issues of preservation and contamination remain. Technological advances promise to increase the accuracy even with severely degraded samples. For example, the polymerase chain reaction (PCR) methodology has enabled identifications of very small samples, including relatively ancient ones.

Professional Conduct

Who is qualified to work as a forensic anthropologist in cases such as those presented in this book? Clearly, forensic science continues to struggle with this issue—individuals with widely varying academic degrees, training, and experience are involved. Although accreditation efforts have been made, no worldwide standard yet exists for the field. The American Board of Forensic Anthropology, sponsored by the American Academy of Forensic Sciences, is frequently cited as

being noteworthy in this regard. This Board grants certification to those who have the necessary qualifications, experience, and letters of recommendation and who pass an examination. Such certification has been awarded mostly to residents of the United States and Canada.

The Forensic Anthropology Society of Europe (FASE), a subsection of the International Academy of Legal Medicine, was formed in 2003, and in 2016 there are more than 200 members from 40 countries. This relatively new organization offers training, communication, and academic advancement of the practice of forensic anthropology in Europe. FASE, along with the United Kingdom now offers certification.

In September 2007 the Senior Managers of Australian and New Zealand Forensic Laboratories (SMANZFL) agreed to support the formation of a Medical Sciences Specialist Advisory Group (SAG), which includes forensic anthropology, forensic odontology, forensic entomology, and mortuary managers.¹ The formation of a SAG, the aim of which is to promote science excellence, provides a forum for practitioners from across Australia and New Zealand to discuss and improve technical skills, undertake research and training, and develop quality issues (including proficiency tests/trials, development of standards, databases and reference collections, and validation studies). The formation of the Medical Sciences SAG is the first time that forensic anthropology has been formally recognized by forensic service providers in Australia, and the SAG provides the platform to work towards accreditation for Australian practitioners. Overall, the growth and development of these societies and groups across the world reflect the increasing interest in forensic anthropology/archaeology and the accompanying need for improved standards. Their formation provides an excellent opportunity for the development of the discipline.

Forensic anthropologists work closely with practitioners from other disciplines, especially forensic pathologists and forensic odontologists. As indicated, forensic anthropologists leave determinations of cause and manner and death to the pathologists but frequently find and interpret the evidence that underlies the opinions expressed. Forensic anthropologists do not interpret dental restorations but overlap with forensic odontologists regarding interpretations of age at death and ancestry from dental evidence and the interpretation of craniofacial features in regard to identification and trauma.

Forensic applications continue to entice students and professionals alike in anthropology. Many who become involved in forensic endeavors are not prepared for some of the complex new situations they encounter, such as court testimony. Advice offered in this volume to tell the truth, to stay within professional expertise, to answer questions directly, and to avoid the natural tendency to lecture is well founded. Those practicing forensic anthropology not only have to follow courtroom procedures but also must pay attention to ethical issues as well. Such issues include being informed of appropriate laws and sociopolitical concerns, maintaining appropriate standards of training and accreditation, using reliable, accepted methodologies, writing concise readable reports that are objective and not speculative, receiving appropriate permissions for research attempted, and respecting the rights and concerns of families and descendants.

Clearly, forensic anthropology represents a diverse, complex, challenging, and rapidly expanding field. Practitioners (both up and coming and established) have a number of responsibilities, including the need to be

- *Technically competent*: knowledgeable in human and nonhuman anatomy, have experience working with a range of differentially preserved human and nonhuman remains, and fully versed in the advantages and limitations of the appropriate methodologies;
- *Inquiring*: mindful of the potentially different approaches to a casework problem;
- *Innovative*: developing research questions that address the problems raised by casework; and
- *Socially aware*: both in terms of working with other practitioners from other disciplines and in terms of the responsibility to the families of victims, the courts, and the media.

The combination of these responsibilities makes the professions of forensic anthropology and forensic archaeology exciting disciplines to be part of. The methodologies summarized in this handbook are state of the art but hardly the last word. As this volume goes to press, innovative research is being pursued in all of the areas within the field. Much of this research involves applications of new technology and/or new applications of existing technology. However, many of the most significant advances will likely not involve new technology but rather the acquisition of samples from around the world in areas not currently well represented. Such samples are needed for a more complete understanding of how human variation affects analyses and conclusions in forensic anthropology. Clearly, forensic anthropology/archaeology will continue to be practiced worldwide; our science needs to reflect all humanity to meet that challenge.

Note

- 1 Other established SAGs include Biology, Chemical Criminalistics, Document Examination, Field and Identification Sciences, Toxicology, Illicit Drugs, and Electronic Evidence.

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