CHAPTER 1

Forensic Anthropology: Embracing the New Paradigm

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Introduction: The Entity

It seems only natural that a volume devoted to a particular area of scientific expertise would start with a chapter aimed at providing some sort of general overview and definition of the field. This requirement would appear even more relevant in the present volume, as many experienced forensic anthropologists may have trouble identifying some of the areas covered in the book as part of their everyday work, or even as remotely related to the discipline that went by the name of *forensic anthropology* when they were growing their academic or professional teeth. Just a few decades ago, most practicing forensic anthropologists would likely have protested even the suggestion of including in the picture many of the subjects that are presented in this volume as well-established, integral parts of forensic anthropology.

These differences in the conception of the field go beyond the methodological discrepancies derived from the logical substitution of old with new techniques. The 1970s forensic anthropologist traveling forward in time would most likely realize right out of the time machine the relevance of gaining a better understanding of DNA analysis, for example, as the subject directly relates to victim identification, the classical goal of forensic anthropology. But forensic archaeology? Really? How does that relate to victim identification, and wouldn't it be a job for the police anyway? And what about trauma analysis? Didn't we grow up reciting every night in our bedtime prayers that

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"the forensic anthropologist cannot discuss the cause and manner of death"? And they even want to look at the weapon too, as if you did not have tool-mark analysts for that.

Some modern physical anthropologists equally may be troubled by the view of the field presented in this book. Wasn't forensic anthropology supposed to be just a direct application of physical anthropology techniques and, hence, once you knew your human osteology and general physical anthropology, you were ready to take on forensic cases? What is all this nonsense about soft tissue, postmortem intervals, scene investigation, or (brace yourself) paleopathology not providing a valid foundation for trauma analysis?

It is not possible to make sense of these apparent betrayals of the sacred principles and teachings of our forensic forefathers without taking a look back at the origins and development of the discipline of forensic anthropology. As Dickensian heroes, scientific fields usually rise from humble origins and goals, often even from necessity, gaining momentum, complexity, and scope as the pages are turned, before we can come to meet the wise, mature, and successful individuals who greet us from the closing paragraphs of the novel. The character cannot be encapsulated in any single snapshot, taken at a particular moment in time, or by its current state, but we can understand it fully only as its personality unfolds during personal encounters and acquaintances, traumatic or enlightening episodes, obstacles, successes, and setbacks. In other words, scientific disciplines do not evolve from their definition, but are defined by their evolution.

As a matter of fact, if we had to look for a Fagin or an Ebenezer Scrooge in our story, it would probably be some stubborn, almost religious historical adherence to a self-inflicted, very restrictive, and initial definition of forensic anthropology: to wit, as a strictly applied laboratory field, devoted solely to aiding in victim identification. In a sense, the story that we will uncover in the remaining pages of this chapter (and we may even dare say in the remaining chapters of this book) is mainly that of the struggle to grow beyond this classic definition, climbing the conceptual ladder from the humble origins as a technical, applied field, to the heights of a fully grown scientific discipline, with interests far more diverse than just victim identification. In our view, also as with Dickens' novels, this story is fortunately one of success, even if (spoiler alert) it doesn't exactly end with our 2 m, 100 kg Tiny Tim ice skating along the streets of old London.

It could not be any other way as, to a large extent, ours is also mostly an American story, and we all know that those always end happily. Although modern forensic anthropology definitely is not just an American enterprise, given that Europe and other areas of the world have made very important contributions to the history of the field, it is in the USA where the story has presented a more linear, consistent narrative. The story of American forensic anthropology is not based only on somehow isolated individual contributions, but rather characterized by an actual continuity along a well-defined tradition of research and professional practice. It can be stated rather confidently that forensic anthropology was born and took its first and more important steps in the United States of America; maybe not necessarily as a concept, but at least as an actual professional field, with a cohesive, constant, and independent body of practitioners, rather than as an additional task for other professionals, such as forensic pathologists. Forensic anthropology, though often presented as a relatively young discipline given its formal configuration and recognition in the 1970s, has a rich history in the USA, spanning most of the twentieth century.

And here is where the Dickensian parallels end. We might talk of humble origins in relation to the initial scope of the field but, as will be discussed below, when it comes to practical terms, our hero, like Darwin in Dickens' time, was born into a quite healthy and wealthy intellectual household. The participants in the early development of the field were some of the premier physical anthropologists of the day. Much of what we know about human skeletal variation and how to determine all aspects of the biological profile (age, sex, stature, ancestry) for physical anthropological purposes arose from the initial consideration of human bones from forensic contexts by these pioneers and their direct descendants, in their efforts to solve forensic identification issues (Kerley 1978). Thus, forensic anthropology is no stunted child (neither *ignorance* nor *want*) crusted with scabs and stooped with rickets, taking arms against a sea of troubles with a stomach bloated from malnutrition. Ours would be more of a *coming-of-age* story, starring the wealthy kid who becomes a somewhat spoiled and self-centered teenager, lounges through college and, in the end, recovering from alcoholism, becomes a leader of men: once again, an American story.

Because we must admit that there was actually quite a bit of lounging after formally defining the field in the 1970s, and a period of relative stasis in which minimal research was conducted that was directly applicable to the analysis of skeletal remains in forensic contexts (Snow 1973). Few cases were referred to the forensic anthropologist, and the answers proposed to most forensically relevant questions relied on old analytical methods derived from outdated skeletal samples. Career and state were at stake, and change was required. In the late eighties İşcan even warned that "this entity can stagnate or even self-destruct if the direction of future research is not carefully planned" (İşcan 1988a: 222)

In the following sections, the history of the field will be reviewed, mostly from an American perspective. As the story unfolds, you will see the character grow and mature, shiver as outrageous fortune throws new slings and arrows in its path, mostly in the shape of legal rulings and the development of other fields, and rejoice when characters like forensic taphonomy, forensic archaeology, or trauma analysis come to the rescue. It is clear now that forensic anthropology is moving away from fulfilling İşcan's prophecies of stagnation and self-destruction. In fact, the discipline is witnessing a revitalization derived from a "new conceptual framework" (Little and Sussman 2010: 31) in philosophy, composition, and practice.

This shift transpired because of a variety of factors, but primarily resulted from: (1) a critical self-evaluation of discipline definitions and best practices; and (2) strong outside influences from DNA, federal court rulings, and Congress-mandated assessments of the forensic sciences. At one time faced with extinction because of the "threat" posed by the ability of DNA to provide quick and precise personal identifications of unknown skeletons, the field has re-emerged in the last 10 years as a robust scientific discipline, able to stand on its own because of the realization of unique strengths, perspectives, and research goals. In other words, by looking outside the (packaging) box, a stronger forensic anthropology was developed. Of course, the job is not finished completely and our hero still is to face many new challenges in the future, but it is good just to be alive.

First, A Bit of History: The Early Years

It is suggested that forensic anthropology gained notoriety and acquired a face as a scientific discipline in the late 1930s, with the publication of Wilton Krogman's series of articles in the *FBI Law Enforcement Bulletin* (Krogman 1939a, 1943; Krogman et al. 1948). Krogman can be considered as the first renowned practitioner of endeavors with police that became known as "forensic anthropology." He was a brilliant scholar, researcher, and academician who trained with the likes of Sir Arthur Keith, in Great Britain, and T. Wingate Todd, at Western Reserve University in Cleveland, Ohio (Haviland 1994; Johnston 1989). Krogman later taught at the universities of Chicago and Pennsylvania. His research work was devoted largely to child growth and development, although he cultivated many other interests in human biology during his career. Even though a recognized expert on human identification, he was not contacted very frequently by police to assist in the construction of a biological profile for the unknown human skeletal remains that were brought to his laboratory (Haviland 1994). In this laboratory-based and episodic involvement in forensic cases, his profile is very similar to most of the other "practitioners" of the day, prior to the 1970s. Before Krogman's time, the history of the field had been written mostly by the contributions of diverse "anatomists-morphologists-anthropologists" (Kerley 1978: 160), who conducted research on variation in the human skeleton, which aimed at answering questions that at times arose in forensic settings (Pearson and Bell 1919).

Although he might have attained higher celebrity status, Krogman was not alone. The aforementioned T. Wingate Todd, as well as Aleš Hrdlička, Earnest Hooton, and a few other renowned physical anthropologists of the first half of the twentieth century also provided human identification services intermittently for the police (Kerley 1978); Hrdlička perhaps more than any other physical anthropologist of the day. Working out of the Smithsonian Institution, in Washington DC, he published little on the issue of human identification but consulted with police and, especially, the Federal Bureau of Investigation (FBI) on a large number of cases, from 1936 until his death in 1943 (Ubelaker 1999). This relationship was continued by Hrdlička's hand-picked successor, T.D. Stewart, although Stewart's interest in medicolegal issues resulted in a number of important articles (Stewart 1948, 1951). Todd, on the other hand, found his forensic line of work promising enough to realize the value of constructing a significant collection of human skeletal remains, aimed at studying human variation and answering basic research questions. With this purpose, Todd started expanding a small collection that had been started by Carl A. Hamann, his predecessor at the Case Western Reserve Medical School. The results of Todd's efforts came to form the basis of the *Hamann–Todd Collection*, the largest assemblage of modern human remains in the world, comprising more than 3300 individuals. Todd and his coworkers (including Montague Cobb and Krogman) used this collection to conduct basic research in human skeletal biology, notably that including age-related changes in the cranial sutures (Todd and Lyon 1924, 1925a, 1925b) and the pubic symphysis (Todd 1920, 1921a, 1921b). These studies have served as basic references and a starting point for the work of scores of researchers in many fields of anthropology, from forensic anthropology through bioarchaeology, and even paleoanthropology. The collection is housed currently at the Cleveland Museum of Natural History, in Cleveland, Ohio, where it attracts a multitude of researchers from throughout the USA and beyond. Apart from its large sample size, the Hamann–Todd collection, under the wise supervision of Lyman M. Jellema, also may be considered one of the better-curated comparative samples of human skeletons in the world. Krogman worked in Todd's laboratory from 1931 until 1938 (İşcan 1988b; Krogman 1939b; Haviland 1994) and the forensic cases that came to the lab likely provided the stimulus for Krogman to start considering the broader applications of human skeletal biology to other disciplines, including medicolegal investigation.

As the Hamann–Todd collection was being amassed, William Terry, of Washington University, St. Louis, Missouri, was collecting unclaimed and donated bodies used in anatomy classes at their medical school and other Missouri institutions. In 1941, Mildred Trotter took over from Terry and further increased the size of the collections. In 1967, the 1728 individuals that comprised the collection at that time were sent to the Smithsonian Institution for their continued curation and availability for research (Hunt and Albanese 2005).

Wars have helped to keep 'forensic' anthropologists employed and busy during the following decades. During World War II, Charles Snow, Mildred Trotter, and Harry Shapiro assisted in the identification of US war dead and even started collecting basic biological data from these war casualties (Stewart and Trotter 1954, 1955; Trotter and Gleser 1952). T. Dale Stewart, Thomas McKern, Ellis Kerley, and Charles Warren did the same during the Korean War (McKern and Stewart 1957; Klepinger 2006) and the Vietnam War (Stewart 1970; Ubelaker 2001). This eventually led to the formation of the US federal government's Central Identification Laboratory in Hawaii (CILHI) and Thailand (in the early and mid-1970s), renamed the Joint POW/MAI Accounting Command (JPAC) in 2003. Kerley (1978) suggests that it was this work for the US Armed Forces in the 1950s that legitimatized forensic anthropology as a scientific discipline. As an example of the quality of research produced, it was at this time that new standards for determining adult stature were presented by Mildred Trotter (Trotter and Gleser 1952, 1958; Trotter 1970), finally revising the turn-of-the-century European standards. Most of the publications from these times dealt with age-related changes in a few parts of the body (McKern and Stewart 1957), although, since the vast majority of individuals involved in the conflicts were white males between the ages of 17 to 30, the sample was slightly skewed.

In times of peace the job of helping the police identify the dead in the USA remained rather sporadic, infrequent, and limited. The few anthropologists who did this work all had similar curricula vitae: essentially academicians or museum specialists who were better known for their basic research in the field of physical anthropology, whereas their forensic anthropology work was conducted on the side. In the typical scenario of the day, after collection by the police, the remains were brought back to the morgue for possible identification, hopefully through soft tissue comparisons, including tattoos and medical interventions. Dental comparison was attempted next. If this proved fruitless, often the remains were taken to artists for facial reproduction, usually via molding of clay over the cranial remains. Only as a last resort were anthropologists sought, often by calling the local university for someone familiar with human osteology, to reevaluate components of the biological profile to help narrow down the missing person list. Perhaps the age, sex, stature, or ancestry determined by the police, pathologist, dentist, or sculptor was wrong! By the time of the analysis, the remains had passed through many hands and likely had been altered in some way, either by the police during recovery or transport, the pathologist during autopsy, the dentists during the all-too-common practice of "resecting" the jaw from the cranium, or by the sculptor putting clay on bone. Unfortunately, this description still remains a fairly accurate portrayal of the current situation.

The More Recent Years

Another important turning point in the field can be attributed to Krogman and the publication of his book, *The Human Skeleton in Forensic Medicine* (1962), after which the field was visible and well presented to a much wider forensic and medicolegal audience. During the 1960s and early 1970s police began to rely more and more on physical anthropologists to provide important information for their investigations regarding skeletal remains. As a result of this interest, an increase in basic research ensued that related to the identification of the recently deceased. This research often was described in physical anthropology journals and provided better methods to determine age, sex, stature, and ancestry (e.g., Bennett 1987; Fazekas and Kosa 1978; Phenice 1969; Gilbert and McKern 1973; Giles 1970; Giles and Elliot 1964; El-Najjar and McWilliams 1978; İşcan 1989; İşcan and Kennedy 1989; Stewart 1970, 1972). Bass (1969, 1978, 1979), Kerley (1978), İşcan (1988a), Stewart (1976), and others provide a rather comprehensive list of important articles and topics in the field over the last 30 years.

Academically, a few institutions arose that focused on skeletal biology contributions to medicolegal contexts and offered training and casework experience (Ubelaker 1997). The first institution of the sort was the University of Kansas in the 1960s. Many of the key forensic anthropologists were either on the faculty, including William Bass, Kerley, and McKern, or were graduate students, including Walter Birkby, Ted Rathbun, Richard Jantz, George Gill, Judy Suchey, and Doug Ubelaker (Rhine 1998; Bass 2001). However, after a brief time the department broke up as Bass left for the University of Tennessee in 1971, Kerley for Maryland, and McKern for Simon Fraser in 1972 (Ubelaker and Hunt 1995; Rhine 1998). Birkby, one of Bass' first students, later established a program at the University of Arizona in 1983. These departments, along with the University of Florida program established by William Maples in 1968, provided the focus of forensic anthropology research and training in the USA through the 1980s and 1990s (Falsetti 1999; Maples and Browning 1994).

In addition to academia-based training centers, Clyde Snow became a training center by himself with his work with what came to be termed "human rights" in Argentina in the 1980s, on cases involving historical figures (Josef Mengele), Custer battlefield participants, mummies, victims of John Wayne Gacy, and plane crash victims (Joyce and Stover 1991). It may be suggested that he was the first individual to conduct forensic anthropology casework on a full-time basis.

By the 1970s Krogman, Snow, Kerley, and a few other physical anthropologists had been attending the American Academy of Forensic Sciences meetings in the General Section on a regular basis (Kerley 1978). More and more of their time was taken up with forensic cases, conducting research, and teaching until they decided that it was time for some recognition of this particular specialty. In 1972, the Physical Anthropology section was created within the Academy (Kerley 1978; Snow 1982). Shortly thereafter, in 1977, the American Board of Forensic Anthropology was created and certification for forensic anthropologists in North America was in place.

This core group of "forensic anthropologists" also settled on a name – forensic anthropology – for the work done with the police which attempted to provide clues to the identity of the unknown deceased found in unusual circumstances.

Apparently they were unconcerned that the Germans had originally used the term in the 1940s and 1950s after World War II to describe a field of endeavor to determine ancestry and familial relationships of kids orphaned by the war (Schwidetsky 1954; Stewart 1984).

With the construction of a new name for the medicolegal work completed by these physical anthropologists, definitions were needed. One of the key publications that served to provide a basic working outline for the discipline was Stewart's *Essentials of Forensic Anthropology* published in 1979. T. Dale Stewart was a curator at the Smithsonian who was best known for his work with the Neanderthal (*Homo neandertalensis*) remains recovered from Shanidar Cave in Iran (Stewart 1977). As described above, the common scenario was that remains were brought to Stewart in a box by the police, especially the FBI, from their primary headquarters across the street from the Smithsonian in Washington DC, for which he provided a biological profile of the unidentified individual. Nonetheless, his full-time job remained as a physical anthropologist.

Stewart's *modus operandi* with respect to forensic casework (part-time, infrequent, and after the remains had passed through many hands) formed his definition of the field, which served as a guideline to the discipline since that time:

> Forensic anthropology is 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. Beyond the elimination of nonhuman elements, the identification process undertakes to provide opinions regarding sex, age, race, stature, and such other characteristics of each individual involved as may lead to his or her recognition. (Stewart 1979: ix)

Other definitions by active practitioners followed, which were along the same vein:

> Forensic Anthropology encompasses the application of the physical anthropologist's specialized knowledge of human sexual, racial, age, and individual variation to problems of medical jurisprudence. (Snow 1973: 4)
>
> Forensic Anthropology is the specialized subdiscipline of physical anthropology that applies the techniques of osteology and skeletal identification to problems of legal and public concern. (Kerley 1978: 160)
>
> Forensic Anthropology is that branch of applied physical anthropology concerned with the identification of human remains in a legal context. (Reichs 1986: xv)
>
> Forensic Anthropology is the field of study that deals with the analysis of human skeletal remains resulting from unexplained deaths. (Byers 2002: 1)

Forensic anthropology was experiencing renewed recognition within the forensic sciences and law enforcement as a field that could provide an important and reliable role in medicolegal investigation (Bass 2006; Rathbun and Buikstra 1984; Krogman and İşcan 1986). As a result of this renewed interest, new research in human skeletal biology arose. During the 1980s and 1990s, forensic anthropology began addressing some of the more pressing issues related to modernizing the determination of a biological profile of the recently deceased: reevaluation of chronological age markers, including the pubic symphysis (Brooks and Suchey 1990; Suchey et al. 1986), cranial sutures (Meindl and Lovejoy 1985), auricular surface (Lovejoy et al. 1985), and rib ends (İşcan and Loth 1986, 1989); reconsidering assessing ancestry in modern individuals (Gill and Rhine 1990); stature estimation (Ousley 1995); and trauma (Maples 1986; Merbs 1989), to name but a few important studies. It could be argued that modern human skeletal biology experienced a renaissance in research unseen since the 1920s, because of the rise of forensic anthropology (İşcan 1988a).

By the end of the twentieth century, forensic anthropology, though now proudly with a name, definitions, and better analytical methods, still was not too dissimilar to what had been practiced throughout the previous 50 years. Forensic anthropology has been considered a subfield of physical anthropology, almost exclusively laboratory-based (Wolf 1986), and done only occasionally on an as-needed basis by academia-based consulting physical anthropologists. Still, by the turn of the new century, considering its relatively short formal history, forensic anthropology was experiencing what could be termed the "salad days," probably best exemplified by Kerley's colorfully enthusiastic endorsement of the field: "The delightful days of early summer will probably continue to disclose to the adventurous the decomposed harvest of winter's crimes, and the forensic anthropologist is still the person best trained to reconstruct the biological nature of such skeletal remains at the time of death" (Kerley 1978: 170).

Chinks in the Armor: Considering Best Practices

As part of the reevaluation during the 1990s of forensic anthropology in general, and human skeletal biology in particular, the old reliable skeletal analytical methods and their applicability to modern forensic cases came under scrutiny. Many of the tried and true methods were developed in the first half of the twentieth century,and the samples were possibly inappropriate for comparison with modern humans. As a result, two significant developments with respect to the analysis of modern human skeletal samples derived from forensic cases occurred: (i) modern samples of human skeletal tissue and information upon which new or reevaluated analytical methods could be based were sought and (ii) better analytical statistics to interpret human skeletal variation were employed.

Seeking modern human skeletal samples

Many of the forensic anthropology or physical anthropology methods used in the 1970s and 1980s to determine biological parameters (chronological age, sex, and stature) of unknown individuals were based on studies that drew upon samples of individuals from the turn of the century – usually of lower socioeconomic status – and even from prehistoric Native American samples (Johnston 1962), consisting of individuals of unknown age. This is fine when working with historical cemeteries, individuals who died during that time period, or prehistoric Native Americans; however, it has been shown clearly that the effects of better nutrition, better health care, etc. have led to significant secular changes in many of these biological parameters (Meadows and Jantz 1995). In addition, factors of immigration, emigration, genetic mixing, hybridization, and others on the modern North American population have altered the genetic landscape rather dramatically, suggesting strongly that samples of modern humans were required to properly interpret the bones of the recently deceased from modern forensic cases (Ousley and Jantz 1998). However, the major problem with this solution is that creating large modern human skeletal collections like the Todd and

Terry Collections is rather difficult. Hamann seems to have altered the Ohio mortuary laws in order to permit the collection of unclaimed bodies, and Terry simply placed individuals from the medical dissecting room into the collections at Washington University Medical Center in St. Louis, Missouri (Hunt and Albanese 2005). In the early 1980s, Bass of the University of Tennessee, Knoxville, addressed this pressing need by starting to collect complete human skeletons of known individuals who donated their bodies to the Department of Anthropology. Initially in an attempt to address issues related to postmortem interval (Bass and Jefferson 2003) and forensic taphonomy, Bass found space on university property to place donated human remains and study decomposition patterns (see below). A residual benefit of the "Body Farm" project, as it became to be known, was an ever-growing collection of human skeletal material of known individuals (Wilson et al. 2010). The William M. Bass Donated Skeletal Collection currently contains nearly 870 individuals although the population demographics are skewed somewhat toward older white males. Later, donated forensic cases formed the basis of the William Bass Forensic Skeletal Collection, which consisted of over 100 individuals from cases conducted by the University of Tennessee Department of Anthropology as of 2009 (http://web.utk.edu/~fac/facilities).

Judy Suchey and her colleagues were pioneers in the study of the skeletal biology of modern forensic populations when she was permitted to retain as evidence, skeletal samples (clavicles, pubic symphyses, superior iliac crests) of individuals that entered the Los Angeles County Coroner's morgue in the late 1970s. Her samples totaled 1225 individuals of all shapes, sizes, and types (Suchey and Katz 1998). Some casts and photographs were made for teaching purposes.

An ongoing project involves the collection of a virtual modern human skeletal database, primarily in the form of anthropometric data, while also containing demographic and skeletal biological information. This database, termed the Forensic Anthropology Databank (FDB), was developed by Dick Jantz in the 1980s at the University of Tennessee from a National Institute of Justice grant to create a Database for Forensic Anthropology in the USA (DFAUS) and originally included information from 1523 individuals (Wilson et al. 2010). The database consists of University of Tennessee cases and data submitted from cases completed by other forensic anthropologists across the country (Jantz and Moore-Jansen 1988; Ousley and Jantz 1998). The database had information from nearly 2900 forensic cases as of 2010 (http://web.utk.edu/~fac/databank).

Longitudinal studies of human growth and development, primarily through radiographic imaging, have been conducted in the last 20 to 30 years to replace or supplement older studies (Moorrees et al. 1963; Maresh 1943) and have yielded excellent results. The most important are dental studies (Sciulli and Pfau 1994; Harris and McKee 1990) and pediatric radiographic studies detailing long-bone growth and development (Hoffman 1979). In addition, recent efforts to collect data from the vast radiographic record of forensic case individuals from medical examiner's offices around the country have proved very fruitful (Fojas 2010).

Better Statistics

Of course, with updated collections and new databases came an enhanced ability to perform quantitative analyses. Quantitative statistical analyses are far from new in physical and forensic anthropology. Most of the key statistical techniques currently employed to estimate different components of the biological profile have not only been long known and widely applied by anthropologists, but in some cases were historically first utilized to address anthropological questions. For example, least squares linear regression (LSL regression), which today is the most popular method employed to estimate parameters such as adult stature or infant age, was first utilized to assess the correlation between parental and offspring stature by Francis Galton in 1886 (Galton 1886). As a matter of fact, the Anthropometric Laboratory funded by Galton (Galton 1882), as well Galton's collaboration with Karl Pearson, played a central role in the development of modern statistics.

This lead in statistical research in the natural sciences would soon vanish, however, engulfed by the descent to the abyss of social sciences or tragic excursions into pseudoscientific crazes such as eugenics; anthropologists would subsequently contribute little to the development of new statistical methods. Still, inferential and exploratory statistical techniques would remain an important component of the toolkit of physical anthropologists, if now mostly as borrowers of methods developed by other disciplines. The practitioner would obtain a sex, ancestry, stature, or age diagnosis simply by substituting individual case measurements into the corresponding discriminant function (DF) or regression equations, or by consulting tables of cut-off values or confidence intervals for observed traits, rather than by actually performing any statistical analysis. Whenever the comparative samples from which the published estimates had been obtained were appropriate for the particular case, these methods, if conceptually destitute, were fairly effective in providing simple estimates.

The use of these methods, however, imposed severe limitations: (i) it did not allow for multigroup comparisons in classification methods, for example, when trying to assess the probability of the victim belonging to one of several ancestry groups; and (ii) it severely limited the ability of the researcher to estimate the associated probabilities in most multivariate methods. For example, published cut-off values obtained from discriminant function analysis allowed only for the assessment of whether the individual was more likely to belong to one of two groups, which means that in their simplest application – sex determination – the analyst was able to predict that the individual had a higher or lower probability of being a male or a female, based on whether a single particular measurement was larger or smaller than the provided cut-off value (see France 1998 for a discussion and numerous examples of these methods). However, the analysis could not estimate the exact probabilities associated to this diagnosis (i.e., the posterior probabilities and typicalities), which require complex calculations obtained from the raw (measurement) data. In other words, the forensic anthropologist could not distinguish a case with a 51% to 49% relative probability from a 99% to 1% case.

Off the shelf and wrong: the example from regression equations

To make matters worse, even methods requiring simple calculations, easy to perform by hand or with a pocket calculator, were typically published in many textbooks devoid of the information necessary to properly calculate these estimates. The most striking example is probably that of the prediction intervals for the LSL regression equations for stature estimation. The basic assumption in LSL regression can be written as:

$$y_i \sim N(\hat{y}_i, S_R) \tag{1.1}$$

where

$$\hat{y}_i = a + bx_i \tag{1.2}$$

which means that the average height of individuals with a given long-bone length is the result of the regression equation when we substitute the value measured in our individual (x_i).

In other words, if we are trying to estimate stature (y) from a long-bone measurement (x), we can read equation 1.1 as the stature (y_i) of those individuals with the same long-bone length (x_i) as our individual follows a normal distribution with a mean equal to the result obtained when we enter that length (x_i) in the regression equation, and standard deviation equal to S_R. Note that x and y refer to the generic variables, while x_i and y_i refer to the values corresponding to the exact measurement of x in our particular individual.

Since we are just dealing with a univariate normal distribution, to construct a confidence interval for our estimate we only need to add and subtract the appropriate number of standard deviations (S_R) from the solution of the regression equation. For example, a common approximation to obtain a 95% confidence interval is multiplying S_R by two (the corresponding value in a Student t distribution under the large sample approximation), and adding and subtracting the resulting figure from our discrete stature estimate.

S_R is a standard error that accounts for the three main sources of error affecting the calculation of the regression equation: (i) normal variability in stature not depending on variable x, which is accounted for by the standard deviation of the residuals (the average square difference between the values predicted by the regression equation and those observed in the real sample), usually noted as $S_{y \cdot x}$; (ii) the error associated with the calculation of the mean of the dependent variable y (i.e., the standard error of y), which determines the height in the vertical axis at which the center of the regression line will be placed; and (iii) the error in the calculation of the slope of the regression (b in equation 1.2). That is, the uncertainty linked to our estimates of where the line is to be placed, its inclination, and how close the real statures are to the regression line on average.

Note that from the explanation above it follows that S_R, and thus the breadth of our interval, will depend on the value of x that we measure in our individual. Or, simply put, that S_R must be calculated case by case, and cannot have a single constant value along the regression line. This is mostly due to the error associated with the calculation of the regression slope (b). By definition (in particular, from the definition of the regression intercept, a), the regression line must pass through the point corresponding to the means of x and y [$(\bar{x}, \bar{y})$ in Cartesian coordinates]. Consequently, as we have the line anchored in this point (for large samples, with little variation from sample to sample), and there is also an error attached to the calculation of the slope, the latter will affect more severely values far from the mean of x than those which are close to it (imagine a ruler spinning around a central point: the tips of the rule cover much larger distances than do the points close to the center). The calculation of S_R is not complex, but requires the introduction of a few values, including the size of the sample employed to obtain the regression equation, as well as the sample mean and standard deviation of *x*, in a linear algebraic equation. The correct equation and a straightforward explanation of how to use it can be found in Giles and Klepinger (1988). Ousley (see Chapter 16 in this volume) discusses stature estimation in depth.

Most classic forensic and physical anthropology textbooks, however, usually provided *only* the value of $S_{y \cdot x}$ (i.e., the standard deviation of the residuals, which unlike S_R was assumed to be constant and independent of *x*), thus omitting most of the information necessary to calculate S_R, while also misguiding the reader by indicating that the corresponding 95% confidence intervals could be calculated simply by multiplying this constant $S_{y \cdot x}$ by two. This latter estimate, however, does not provide a confidence interval for the regression prediction, but for the residuals (in order to avoid confusion between both confidence intervals, it is common to refer to the confidence interval linked to S_R as the *prediction interval*). Although the difference between both estimates decreases with sample size, at the sample sizes for most classic regression equations in anthropology this difference can be in terms of centimeters in the case of very tall or very short individuals. Additionally, the confidence interval obtained from $S_{y \cdot x}$ is *always* smaller than the real intended one. The only goal of statistical analysis is to provide probability estimates, and you might think that we could at least provide the right ones.

Do it yourself: stats for the people!

Fortunately, these and other similar situations would change drastically with the collection of the samples and databases described in the previous section of this chapter, as well as with the development of personal computers. Suddenly, forensic anthropologists had in their hands both the comparative data and the tools to perform the analyses themselves, obtaining their own equations and detailed reports. Resources like the Forensic Data Bank (Jantz and Moore-Jansen 2000) allowed for the importation of standard measurements of contemporary individuals, from large samples of different groups, into conventional statistical software. This permitted comprehensive *a la carte* analyses, now with all the required correct information. Statistical analyses became part of the everyday practice of the profession, instead of a strictly research-oriented enterprise. This new emphasis and possibility for real statistical analysis, rather than the algebraic operation of existing equations, resulted in a steadily increased focus and improvement in the statistical literacy of forensic practitioners. On the other hand, the new and updated skeletal collections allowed for the refinement of already existing methods and estimates, as well as the testing of their validity and application in modern populations based on expanded sample sizes. This trend was further strengthened by court rulings that stressed the need to test and justify the validity of the methods applied in case investigations, as well as of attaching probability estimates to forensic diagnoses (see the section on court rulings below.)

The resulting expanded range of analyses and probability estimates that could now be obtained and presented in court had obvious advantages. Namely these were obtaining new, more relevant, and precise information from our set of skeletal human remains but also, as discussed above, simply getting the ones from classic analyses right. Yet, the new approach was not completely free of shortcomings. From a forensic point of view, the most important shortcoming was that the new approaches complicated the task of evaluating and presenting the results to end users (law enforcement, coroners, and medical examiners) and in court. Numerical results (and often qualitative diagnoses) depend heavily on the selection of samples, analytical methods, and even the exact computer algorithms used by different statistical packages. Analyses based on different samples, outlier-removal criteria, test method options (e.g., stepwise versus one-step selection criteria), or even different software packages will render different results, which can therefore be potentially contested in court. This forced forensic analysts to include lengthy and complex method and result justifications in their case reports, making them difficult to understand (and therefore appear as less reliable) for law enforcement, court officials, and juries.

This drawback was mostly eliminated by the development and popularization of comprehensive statistical packages like Fordisc (Jantz and Ousley 2005; Ousley and Jantz 1996). Fordisc is a statistical package that provides both the database and the statistical tools for the metric analysis of different components of the biological profile. The program offers different standard discriminant analysis methods for the assessment of sex and ancestry, as well as regression equations to obtain stature estimates, including the appropriate confidence intervals. Although the interpretation of Fordisc as a tool for strict taxonomic and systematic analysis (i.e., to infer phylogenetic group relationships, rather than to assign individuals into groups, when the problem individual belonged to one of the groups included in the analysis) has received some criticism (Elliot and Collard 2009, and references therein), its utility in forensic contexts, when properly understood and utilized, is indisputable, having become a standard in US courts and laboratories. Placing the statistical analyses most commonly utilized in forensic anthropology within a framework of standard software and common samples has enormously simplified court presentation, analysis interpretation by third parties, and analyst training. The program also serves to maintain updated comparative datasets, through the continuous addition of data from ongoing forensic cases.

Outside the black box: from naked outputs to systems and processes

Finally, the new resources and mindset also served to boost research and the introduction of new analytical methods. Most traditional analyses were based on parametric methods that could be approximated by rather simple linear algebra equations. A commonly stated goal was to allow the practitioner to obtain the estimate with paper and pencil, a goal that, sadly, was often extended to the researcher producing the method. This imposed severe constraints to the range of methods and, more importantly, perspectives from which a particular problem could be approached. For example, descriptive univariate or bivariate approaches based on raw variable scores were favored over more complex techniques requiring distribution assessments and variable transformations, or that target processes rather than variable frequencies. From a conceptual point of view, the classic line of attack limited the analytical options to basically just *black-box* approaches, in which the analyst only focuses on the inputs and outputs of the system (what enters the box and what exits it), ignoring processes (what happens inside the box).

We can probably better understand the differences between both approaches and their consequences with an example. One of the classic problems in physical and forensic anthropology is estimating the age of an individual based on a skeletal marker, which appears or changes as the individual develops or grows older. Due to the regular sequence of changes or *phases* that the marker undergoes as the individual ages, the methods in this family of age-estimation techniques are often referred to as *phase methods* (Chapter 10 in this volume provides a lengthy discussion of the different alternatives for adult age estimation, including the most widespread phase methods). Within the classic scope, the researcher would approach phase methods by first calculating the mean age of all the individuals that displayed a particular phase or trait. A confidence interval containing a particular portion of the population (typically 95%) around this mean age would then be calculated. In this way, the practitioner could say that the predicted age of an individual presenting the trait lay somewhere within a particular range with a 95% probability of being correct.

Estimate errors and, consequently, the breadth of confidence intervals, are expected to decrease as sample size increases. Thus, most of the efforts to improve classic techniques through the production of narrower (i.e., more precise) age ranges, were based on recalculating confidence intervals from new, and larger samples (which included a greater variety of more recent populations). Simply put, almost all the emphasis was placed on sampling issues, while little or no attention was placed on the nature and dynamics of the physiological processes that produced or altered the traits being utilized. As a matter of fact, if one thing has characterized forensic anthropology research during past few decades, it is that a disproportionate emphasis has been placed on sampling techniques and sample characteristics, while nearly completely ignoring organismal biology, physiology, and population structure issues. Consequently, although new useful age markers have been successfully identified and introduced since the 1970s, the results of the reappraisal of most of the classic, widely used and reliable aging methods were anything but impressive. Perhaps sample characteristics were not the only issue; perhaps the methods themselves were at fault.

As with least squares regression above, an example is probably the best way of understanding how some classic methods limited our estimates, as well as how new approaches can help us to improve both our estimates and our insight into the processes underlying them. Let's begin with an unknown individual represented by a skeleton. Imagine that we are focused on providing an age estimate based on a single trait (e.g., an ossification center) that first appears in *some* individuals at age *A*, and is present in *all* individuals at age *B*. Therefore, if the trait is absent the individual is almost certainly younger than age *B*, while the presence of the trait would indicate that our individual is most likely older than age *A*. As mentioned above, the first step in traditional phase methods would be calculating the average age of all individuals exhibiting the trait, which would be followed by constructing a confidence interval around it.

Imagine, however, that ages *A* and *B* are both less than 20 years. Also let's assume that the trait develops during the same age interval in all populations considered. This is not a far-fetched assumption, if our age markers are actually expressing normal developmental processes. Now imagine that we calculate the average age of all individuals displaying the trait in two populations with different age structures: our marker is behaving in exactly the same way in both populations, and is expressing exactly the same information and physiological changes; however, the mean age will be higher in the older population, simply because we have proportionally more individuals older than 20. In other words, the mean age will depend partly on the age range at which our marker appears, but also, very importantly, on the proportion of adults present in our sample. Therefore, the confidence intervals calculated around this parameter will be very imprecise and extremely dependent on sample characteristics, thus providing very limited information on the actual ranges for the age marker itself.

Hence, recent approaches have started focusing not on the mean age of *presence* of the trait, but on the mean age of its first *appearance*, taking advantage of more complex techniques that are based on *logit* or *probit* models, admittedly harder to estimate with paper and pencil, but that, in exchange, actually do address directly the process under study. These models are not based on the distribution of ages, but on the conditional distribution of trait presence and *absence* on age. This means that the confidence intervals are not constructed around the mean age, but around the age at which an individual taken at random from the population has a 50% chance of displaying the trait and a 50% chance of lacking it. The resulting confidence intervals will also be narrower, as they will not refer to the whole age range, but just the narrow range of ages at which all individuals either display or lack the character.

These analyses also allow for comparison and combining probabilities derived from similar analyses of other traits (see Chapter 11 in this volume). However, probably their main advantage is that they offer real insight into the physiological process under study: note how we can infer details such as when the physiological change expressed by the trait is triggered, its rate of development, and when it is completed in most of the population. Boldsen et al. (2002), Milner et al. (2008), Konigsberg et al. (2008), and Milner and Boldsen (Chapter 11 in this volume) provide excellent starting points for discussions of transition analysis, one of the most promising applications of this type of methods in a modern forensic context. Hefner and coauthors (Chapter 14 in this volume) also provide another excellent example of the new trends in the statistical analysis of discrete traits, with their assessment of ancestry, looking far more closely than in the past at trait definition, the exact distributions of the ancestry markers in different populations, and the conditional (posterior) probabilities resulting from them.

Future venues

Finally, the new approaches are also starting to benefit from enhanced data-acquisition methods, which allow one to introduce more powerful techniques like those generically known as *geometric morphometrics* (GM). Plainly put, GM is not based on the analysis of linear measurements, but rather on the exact spatial location (coordinates in an *n*-dimensional space) of the landmarks previously used to take the classic anthropometric measurements. This results in a tremendous gain of information, especially useful to define shapes. For example, in the past you could take three measurements from three anthropometric landmarks (*A*, *B*, and *C*) that form the vertices of an imaginary triangle. The classic measurements would be those of the sides of the triangle, separating each pair of landmarks. This is to say, the segments *A–B*, *B–C*, and *C–A*. What information were we missing with this approach? Basically that each landmark was part of two different measurements or, in plain Castilian, that the three points were forming a triangle. We were getting some information on dimensionality, but actually missing the most relevant information regarding the geometric shape of the object that we were examining. The information gain from using Cartesian coordinates (i.e., GM) in a multidimensional space, instead of distances between points, increases exponentially with the number of points (landmarks) that we are considering. In a nutshell, to approximate with linear dimensions the amount of information collected in a GM analysis, we would have to measure all possible distances between all pairs of landmarks, and we would be still losing some geometric information when entering them in standard statistical analyses. Collecting precise landmarks from photographs or, especially, real specimens, was a rather arduous and delicate task in the past, but modern three-dimensional digitizers allow for the collection of data as easily as we did with the distance measurements in the past. Thus, the common use of GM techniques is an emerging but clear trend in forensic anthropology. Zelditch et al. (2004) is probably the best general introduction to GM. Online resources like the Morphometrics at SUNY Stony Brook webpage (http://life.bio.sunysb.edu/morph) are also invaluable.

Finally, Adding Forensic Archaeology

As described above, significant steps have been taken to address skeletal biology, and even the statistical techniques to analyze the traits, of the recently deceased since the inception of forensic anthropology. Law enforcement professionals, coroners, and medical examiners in the 1980s and 1990s began to figure out that the best avenue for analyzing unidentified skeletal remains was through a forensic anthropologist (Snow 1982). And so following the recovery, postmortem examination, and analysis performed by the forensic odontologist, or sculptor, the box of still unidentified remains would be sent to a forensic anthropology laboratory. The focus of the request was to provide a more definitive biological profile that might provide hints of identity or, at the very least, narrow down the missing-person list. However, additional questions were being asked: How long have the remains been there?, Why are some bones missing?, Why are some bones out-of-place?, Why are some of the bones broken, when did that occur, and could that relate to the death of the individual? Answers to these questions based on one's credentials could be provided; however, careful scrutiny, both in and out of court, revealed that the answers rarely had real scientific backing and had no place in the testimony for they were pure conjecture and not Daubert-worthy, which will be discussed later in this chapter.

The answers to these questions do not reside in the bones alone, but require a careful analysis of where they came from, the spatial distribution of the remains at the scene, and a careful consideration of the condition of the remains at the time of discovery. These are issues that relate to the contextual setting of the remains and cannot be obtained solely from the analysis of the bones in the box sent to the forensic anthropologist, or from the pictures of bones at the scene. And so, in order to give reliable answers, the forensic anthropologist, in turn, must retort with questions of their own that relate to the recovery and the post-recovery handling of the remains. With respect to the recovery, some of the key questions asked would be: Were the bones buried or above ground?, Were the remains exposed to the elements?, Were they on a slope or flat ground?, Could flooding from a nearby creek have disturbed the remains?, Were the remains in the shade and for roughly how long?, What types of trees are in the immediate vicinity (deciduous, coniferous)?, What is the grass cover?, What is the leaf cover?, What is the elevation of the site?, What is the soil acidity?, What animals (carnivores, scavengers, rodents) may have impacted the remains?, Where exactly were the bones relative to one another?, Where was the main concentration of remains?, and Where was the body originally located before dispersal? These are only a few of the many, many other questions essential to the work of a forensic anthropologist.

Further, other questions must also be asked by the forensic anthropologist that relate to the removal and transport of the remains from the scene, the possible effects of the postmortem examination, and by subsequent forensic analyses: What role did recovery play in altering the remains?, Were they dug out of the ground with a shovel, backhoe, or pulled out by hand?, Were some bones dropped accidentally, stepped upon, or the skull picked up incorrectly?, How were the remains handled during transport (all in one bunch in a body bag?, with other evidence placed on top of the bones?), during the postmortem examination, and during examination by other forensic specialists? All of this activity and interaction with the human bones prior to their arrival in the forensic anthropologist's laboratory is critical to the final proper forensic anthropological analysis and interpretation. Attention, therefore, shifts back to the forensic investigator and a review of how outdoor forensic scene recoveries generally are conducted by law enforcement.

As described more fully in Chapter 2, evidence-documentation protocols at indoor scenes are well constructed and yield precise notation of exact location of all evidence to other evidence and to the surrounding scene which, in turn, leads to the establishment of proper chain of custody at the outset of evidence recovery. The same meticulous protocol, however, cannot be said of the outdoor scene where remains are often hastily removed from the scene with little or no documentation of provenience. A review of the literature and training regimen of law-enforcement officials at all levels reveals that *there are no law enforcement protocols available for the recovery of human remains from outdoor contexts*. When shovels and backhoes are employed as first-line recovery tools, problems persist. Ill-conceived or incomplete recovery methods do not yield scientific answers to the aforementioned questions. The other aspect of that revelation is that simply overlaying indoor crime scene documentation and recovery protocols onto outdoor scenes will not work. As has been argued in the past (Dirkmaat and Adovasio 1997; Dirkmaat et al. 2008; and Chapter 2 in this volume), the best protocols for the recovery of outdoor scenes, therefore, do not lie within law enforcement protocols but instead lie within forensic anthropology and specifically with the forensic archaeology component of the field.

Forensic anthropology as a discipline, however, in the USA has been slow both to realize the problem and to embrace the solution. Primarily the reason for this lethargic response relates to how forensic anthropology is perceived by law enforcement and most forensic anthropologists themselves. Definitions of the field still indicate that forensic anthropology is a laboratory-based discipline focused on providing clues with respect to the identity of the victim represented by their cleaned skeletal remains. Only after the remains are recovered from the scene, examined at an autopsy *and* if other victim identification avenues (odontology, forensic sculpture) have been exhausted, are the bones then forwarded to forensic anthropologists. As is clear from a review of the vast majority of definitions and descriptions of the field provided by practitioners, forensic anthropology is considered a laboratory-based discipline. Other individuals and disciplines are relied upon to provide background information, collect the remains, document context, and construct viable scene interpretations. In the past, forensic anthropologists seemed to be perfectly content to wait in the laboratory for the remains to be brought to them.

Some forensic anthropologists with training in archaeology began to see this as a problem. Krogman, who had worked as an archaeologist early in his career, actually suggested very early on that outdoor forensic scene recovery could benefit from an archaeological perspective (Krogman 1943). Kerley also pointed out that, "one long-neglected aspect of forensic anthropology, which is of very practical interest to homicide investigators, is the application of standard archaeological techniques to the search for and recovery of homicide victims, and examination of the site of discovery of the body" (Kerley 1978: 166). Some early advocates of using archaeology in efforts to recover human remains from outdoor medicolegal contexts included Dan Morse at Florida State (Morse et al. 1983, 1984), Mark Skinner of Simon Fraser (Skinner and Lazenby 1983), Sheilagh and Richard Brooks in Nevada (Brooks and Brooks 1984), and Doug Wolf of the Kentucky state medical examiner's office (Wolf 1986). Although Bass was certainly an advocate of taking forensic anthropology into the field during the processing of outdoor scenes (Bass and Birkby 1978), as were other practioners, including William Maples (Maples and Browning 1994) and Stanley Rhine (Rhine 1998), to name a few, forensic archaeology was used little and the vast majority of cases today still arrive at the forensic anthropology laboratory in a box after the police have collected the remains from the scene. Forensic archaeology remains a peripheral rather than an integral activity of forensic anthropology.

Forensic archaeology today

In the last few years, changes have been forthcoming. Recent research and literature have described forensic archaeology more fully as a robust discipline that does not begin and end at the buried body feature (Dirkmaat and Adovasio 1997; Dirkmaat et al. 2008; Hochrein 2002; Conner 2007; Dupras et al. 2006). Modern archaeological practices are applied to the full range of outdoor scene location, documentation, and recovery activities beginning with the search for the unlocated site. Here, shoulder-to-shoulder pedestrian searches are effective in examining 100% of the surface within search corridors. If the remains are located on the surface within the path of the searchers, they will be found! Another important role that forensic anthropologists perform uniquely during the search is the on-site, instantaneous determinations of significance of biological tissue, whether animal, human, or nonforensic (see Chapters 2 and 3 in this volume).

If forensically significant remains are discovered, forensic anthropologists will clean the surface of the scene of extraneous material, and expose and then map the remains and evidence *in situ* by hand, supplemented by electronic mapping instrumentation, such as total stations or global positioning system (GPS) units (Dirkmaat and Adovasio 1997; Dirkmaat and Cabo 2006; Dirkmaat et al. 2008; see also Chapters 2, 5, 6, and 7 of this volume). As noted by Snow, the "spatial distribution of bones, teeth, and other items recovered in surface finds can help in determining the original location and position of the body" (Snow 1982: 118).

If the remains are buried, it is a much more difficult task to find the feature and remains, especially if a few weeks or months have passed. In these cases, cadaver dogs are particularly helpful, especially in the spring when new plants are emerging (Rebmann et al. 2000). More sophisticated subsurface examination techniques, and equipment such as ground-penetrating radar (GPR), may be used in confined or well-defined areas (see Chapter 4 in this volume). Obviously, forensic archaeology is especially well suited for these recoveries. Standard excavation methods, drawn nearly unmodified from archaeology protocols, serve to provide guidelines of how to delimit backdirt piles, carefully excavate burial fill to expose the remains within, and document the stratification found within the burial feature (Dirkmaat and Cabo 2006). These methods are well defined, well refined, and well practiced (Hochrein 1997, 2002; Hochrein et al. 2000; Chapter 5 in this volume). In turn, the same guiding principles that work at the small grave feature work during the recovery of much larger grave features, such as those encountered in human-rights work (Dirkmaat et al. 2005; Tuller et al. 2008; Chapter 8 in this volume).

Processing unique outdoor forensic scenes

Recently, the forensic processing of unique outdoor scenes has benefited from forensic archaeological recoveries, in particular fatal-fire scenes and large-scale mass disaster scenes. With respect to fire scenes that contain human victims, new techniques and new technologies (described in Chapter 6), used in conjunction with standard fire investigation methods, have resulted in more efficient *in situ* documentation and recovery efforts of human remains. Damage to biological tissue, resulting from modification of the scene in order to find the body (e.g., practices such as "overhauling") is dramatically minimized. Better transport methods that further minimize damage to the fragile and friable burned remains, in conjunction with better on-site documentation of bone fracture and damage patterns, benefit subsequent forensic anthropological analyses, especially human skeletal trauma interpretation (see Chapter 17 in this volume).

Finally, archaeological recovery methods have served to make recovery efforts at plane crashes and bomb blast sites much more efficient and effective (see Chapter 7 in this volume). New recovery protocols (Dirkmaat and Hefner 2001) were developed and employed in 2000 during the recovery of the crash of Missouri governor Carnahan (Reineke and Hochrein 2008), and during the initial scene documentation efforts at the crash of United Flight 93 on September 11, 2001 in Shanksville, Pennsylvania (Dirkmaat and Miller 2003). The forensic excavation of the victims of Colgan Air Flight 3407 in Buffalo in February 2009 represents the first recovery of mass fatality victims associated with a commercial airliner crash directed and conducted by a team of trained forensic archaeologists. The search efforts, careful excavation, and screening of all excavated material resulted in the near 100% retrieval of all recoverable human tissue. Furthermore, the documentation of provenience of each set of remains (via an electronic total station) permitted a scientific explanation for the inability to recover any identifiable remains (including DNA) of one the victims (Dirkmaat et al. 2010; Chapter 7 in this volume).

Primary Benefits of Forensic Archaeology

In addition to ensuring the comprehensive recovery of all human remains at the outdoor scene and ensuring that nonhuman biological tissue does not enter the evidence chain, forensic archaeological principles and practices employed during the recovery of the outdoor scene provide other significant benefits for the forensic investigation: establishing chain of custody early, providing a baseline for forensic trauma analysis, and permitting the construction of scientific arguments leading to reconstruction of past events (forensic taphonomy).

Chain of custody at the outdoor scene

The National Institute of Justice has recently set out clear guidelines with regard to the handling of evidence (National Institute of Justice 2005). One of the key aspects of proper crime scene processing they note is the early establishment of chain of custody. This is defined as the chronological log of the travels of evidence from the scene to the courtroom (where, when, how, and by whom was evidence touched). The important first step in the chain is the careful and thorough documentation of evidence *in situ* (in context) at the crime scene. Protocols are in place to accomplish this task very well at the indoor scene (Saferstein 2007, 2009; James and Nordby 2003). However, when the processing of an outdoor crime scene involves picking up bones that are visible on the surface and putting them in one bag, after a few pictures are taken, then it can be stated confidently that the first step in the chain of custody is not done well and could be questioned in court. As discussed above, forensic archaeological recovery practice and the comprehensive documentation of context provides the perfect solution for establishing the first step of the chain-of-custody sequence at the outdoor crime scene. Particularly important here are the detailed plan-view maps showing the exact location and orientation of each bit of evidence.

Human skeletal trauma analysis

In the early 1990s Hugh Berryman and Steve Symes began working in the Medical Examiner's Office in Memphis, Tennessee, as forensic anthropologists (Dirkmaat et al. 2008; see also Chapter 26). This is significant because it represented a shift in perspective by a progressive-minded forensic pathologist (in this case, Dr J.T. Francisco). Forensic pathologists usually work alone during the postmortem examination and base much of their interpretations of the cause of death of the victim on analysis of the soft tissue during the short-term autopsy. If bone damage is considered it is usually only a cursory examination such as attempting to put cranial bone fragments covered in blood and tissue together during the autopsy at the morgue table in order to better understand gunshot wounds. Francisco realized that much information could be gathered from a more in-depth analysis of the cleaned, damaged bones of the victim in addition to the study of the soft tissue. This is especially true with respect to human skeletal trauma. And so, osteological samples exhibiting evidence of trauma were culled during the postmortem examinations and retained *as evidence*. Soft tissue was removed to thoroughly study the bone specimens. Macroscopic and microscopic analysis was undertaken to understand the biomechanics of the forces upon the bone, better differentiate types of trauma (blunt force versus sharp force, versus ballistics force), and document tool marks (identifying unique characteristics of tools including teeth per centimeter of serrated knives and saws) on the bones (Berryman and Symes 1998; Symes et al. 1998; Chapter 17 in this volume). As a result of these simple protocols, the study of human skeletal trauma has advanced significantly. Previously, information regarding human skeletal trauma was derived primarily from the field of paleopathology and vertebral faunal analysis (Aufderheide and Rodriguez-Martin 1998; Brothwell 1981; Ortner 2003; Potts and Shipman 1981; Shipman 1981) and perhaps many of these interpretations essentially were based on educated guesses and a whole lot of faith since the real cause of the damage was unknown. On the other hand, forensic anthropology analyses conducted in the morgue setting provide a perfect testing laboratory because of the presence of both soft and hard tissue, and, in some cases, reliable witness accounts of the sequence and timing of events, instruments used, and actors involved. Now, add experimental studies on bone material by engineers and biomechanics in the laboratory (Kroman 2010; Baumer et al. 2010; see also Chapter 19) and the field of human skeletal trauma has become a robust scientific endeavor.

It was soon realized, however, that broken bones arriving in a box after recovery, autopsy, dental examination, and clay emplacement activities were hard to interpret with respect to the *timing* of the trauma. Was the damage to the bone the result of *perimortem* (at the time of death) activities – and thus very significant with respect to determining cause and manner of death – or the result of postmortem factors related to animal activity, tumbles down cliffs, rock falls, etc? Add to these factors the potential for bone damage resulting from mishandling of bones during recovery (especially critical for fatal-fire victims, and juvenile remains), or damage occurring during transport to the morgue, during the autopsy, during handling by other forensic specialists, or during the placement of clay, and "Houston, we have a problem."

Forensic archaeology methods again aid significantly in the determination of timing of trauma because: (i) scene information (e.g., base of cliff) and other contextual information is carefully noted, (ii) standard practice requires detailed and careful notation of the condition of the remains *in situ* at the time of recovery (broken bones are carefully described and photographed prior to moving them into collection containers), and (iii) forensic anthropologists know how to handle bones without inflicting damage. As a result of employing forensic archeological methods to the recover the remains, the trauma analyst is now confident that they better understand *when* the bones were broken and they can focus on the *how* and *why* they were broken.

Forensic taphonomy

With the implementation of forensic archaeological practices and the routine collection of information related to context, another important new advance within the field of forensic anthropology could develop; the subdiscipline of forensic taphonomy.

Again, we return to the questions being asked by law enforcement along with the box of bones brought to the laboratory: Why are some of the bones missing, damaged or modified?, Was any of this bone modification done by humans at the time of death or later to hide evidence?, How long has the body been at the scene?, and Is there any evidence in the position and orientation of the body that would provide clues to cause and manner of death? The answers to these and many other questions cannot be drawn solely from the analysis of the bones pulled from the box sent by police. It requires a thorough analysis of the bones and the contextual setting from which they are derived.

Earlier in the twentieth century another scientific discipline attempted to better understand the death event and what happened to the body afterwards: geology and specifically paleontology. Questions surrounding vertebrate faunal assemblages from the standpoint of where had the animals died and what factors led to the movement, dispersion, and removal of their bone elements arose. Efremov (1940) was one of the first researchers to link bone assemblage composition (species and specific bones) with analysis of surface modification and bone chemistry changes, and with the geological site formation analysis (Lyman 1994; Gifford 1981; see also Chapters 24 and 25). He termed the field of study "taphonomy" which can be defined simply as the study of what happens to biological tissue following the death of an individual. The central concepts, methods, and techniques have been applied widely within the fields of vertebrate paleontology (Lyman 1994), fossil hominid research (Brain 1981), and bioarchaeology (Grayson 1984) to answer many different questions.

William Bass saw early on that the principles of taphonomy were applicable to the study of human remains from forensic contexts. Initially as a result of a misinterpretation of the postmortem interval on a nonforensic case (Bass 1979), he and others (Kerley 1978) realized that very little was known about human decomposition in terms of sequence of decomposition, rates of decomposition, and how that rate is affected by a variety of factors, including temperature, exposure on the surface, burial, emplacement in water, carnivore activity, and insect activity. Shortly thereafter he established the (Bass) Anthropological Research Facility, affectionately known today as the "Body Farm," at the University of Tennessee, devoted almost exclusively to the study of human tissue decomposition, in the hopes of establishing more scientific estimates of postmortem interval (Bass and Jefferson 2003).

A thorough consideration of how taphonomic principles, methods, and practices could be applied to medicolegal contexts (especially outdoor scenes) led to two tomes on the subject of what came to be more formally termed forensic taphonomy (Haglund and Sorg 1997, 2002). As currently configured, forensic taphonomy requires a careful consideration of the factors (taphonomic agents) related to: (i) the removing of soft and hard tissue from the scene, (ii) altering the spatial distribution of the remains within the scene, (iii) modifying the surface of the bones, and (iv) modifying the chemical-mineral composition of the bones. The systematic collection of data related to these issues then permits the consideration of the primary foci of a forensic taphonomic analysis: (i) whether humans, as taphonomic agents, had a role to play in modifying the remains after death and (ii) what has been the postmortem interval since emplacement of the body on the scene?

Forensic taphonomic analysis begins at the outdoor forensic scene with the careful notation of the environs of the immediate area including floral distribution (ground cover, tree cover), fauna (carnivores, scavengers, rodents), insects (flesh-eating), geology (soils, slope, water), and climate (rain, snow), among other factors. This list of potential taphonomic agents that might impact the biological tissue next is linked to the pattern of distribution of the human remains at the scene via the careful three-dimensional mapping of all of the pieces of evidence relative to one another and to the scene itself. Obviously, by far, the best way to collect data at an outdoor crime scene that allows for a taphonomic analysis of the remains is to recover it using archaeological methods, techniques, and principles (see Chapter 2 in this volume). The final piece of the puzzle in the forensic taphonomic analysis is the careful notation of bone modification patterns in the laboratory.

And so, forensic archaeology adds another dimension to the unique skills that forensic anthropologists can bring to the forensic investigation table. It will be argued here that forensic archaeology is not just a supplemental activity to be applied to the investigation of the outdoor scene, only if so inclined and if not too inconvenient, but an absolutely integral part of outdoor forensic scene processing and the subsequent proper interpretation of the activities at these scenes at a level already attained by indoor scene recoveries conducted by law enforcement.

Outside Influences

As described above, a critical review of current practices in the field of forensic anthropology in the 1980s and 1990s eventually led to much better human skeletal biology and even the initial consideration of the role of forensic archaeology. At the turn of the twenty-first century, influences from beyond the field of forensic anthropology have forced renewed evaluations and considerations of best practices. These external influences have come in the form of advances in DNA analysis; federal court rulings related to the science behind the collection, analysis, interpretations, and presentation of forensic evidence; and recent governmental oversight of the forensic sciences.

Outside influence 1: DNA

Very few practitioners would dispute the relevance of the development of DNA analysis to forensic anthropology. This importance is largely the product of a common goal of both disciplines: positive identification. The question immediately arising from this coincidence in objectives is whether both disciplines can still be compatible or whether DNA might be called upon to completely supplant forensic anthropology, rendering it irrelevant for identification purposes. Why bother assessing the biological profile of the victim if we can easily identify her through DNA?

In our view, the answer to this question will not depend so much on future developments in genetics, but rather on the ability of forensic anthropology, first, to acknowledge the question and, secondly, to diversify its goals, techniques, and intellectual framework in order to adapt to these developments.

Curiously enough, it may be the first of these conditions (i.e., the realization that DNA advances pose a real threat to the viability of forensic anthropology as originally conceived) that represents a bigger challenge. As a matter of fact, up to the present, forensic DNA analysis has been a staunch ally, rather than a rival, of forensic anthropology. The introduction and popularization of forensic DNA analysis as a routine technique dramatically increased the probability of identifying unknown individuals. Just a couple of decades ago, the possibility of positively identifying a John or Jane Doe decreased dramatically if the victim could not be matched with the short list of missing persons in the area during the initial steps of the investigation. This possibility further decreased as time went by and consultations with other neighboring or overlapping law-enforcement offices were also fruitless. Then came the introduction of genetic tests and the possibility of comparing the victim's DNA with millions of profiles contained in comprehensive databases such as Combined DNA Index System (CODIS; see Dale et al. 2006 for a clear and comprehensive description of the system) or the *ad hoc* databases compiled in human-rights or mass disaster investigations. The accuracy of DNA matches also allowed forensic practitioners to obtain positive identifications even in the absence of fingerprints or dental or medical records, through comparison with the DNA profiles of potential victim relatives.

The first consequence of these developments was stimulating investigative agencies to further their identification goals and efforts: the budget and time devoted to the identification of unmatched John Does or of the myriad fragments of human tissue present at a mass fatality scene were now much more likely to render positive results. During this time, the contribution of forensic anthropology probably became more important than at any time previously. The biological profiles provided by the anthropologist served to reduce the number of DNA comparisons to be performed in each case by limiting the list of potential matches to the subsample of individuals sharing the same sex, age range, ancestry, and/or stature of the victim. This reduction of potential matches consequently served to exponentially reduce the time requirements and cost of DNA analysis.

Within this framework, many practicing forensic anthropologists may tend to dismiss the notion that forensic DNA analysis might represent any kind of threat for the profession. If anything, the collaboration with DNA analysts has done nothing but increase their casework and enhance both their results and their importance within the forensic community. This perception, however, may be based on a flawed assumption that the relevance of reducing the list of comparisons *before* genetic analysis is derived from inherent limitations of DNA analysis and, therefore, that the relevance of pre-sorting tasks will be permanent.

As discussed more in depth by Cabo (Chapter 22 in this volume), the development of DNA analysis in recent decades has not been marked by a mere increase in the number of forensic DNA laboratories or by a superficial refinement of basic techniques and equipment. On the contrary, the evolution of DNA analysis has been characterized by a frantic development of new techniques resulting in the rapid and systematic elimination of most key obstacles hampering its development. In approximately four decades, the limiting steps of DNA analysis progressed from replication (amplification) to subcloning to sequencing and to comparison, as successive issues were resolved and each step was automated. At present, massive parallel sequencing methods allow for the sequencing of millions of bases per hour, making it potentially possible to sequence the complete genome of an individual in just a few days (Rogers and Venter 2005). In the last two decades, the time required to sequence a full human genome has been reduced by thousands of percent and the costs by hundreds of thousands percent (see Chapter 22), and the key technical limitations for forensic DNA analysis now probably lie more in the completeness of profile databases than in genetic techniques themselves.

Conversely, governments and law-enforcement agencies have also done their homework, making large investments to create the appropriate resources by which to take advantage of these developments in genetics. In the USA, the National DNA Index System (NDIS) and CODIS, of the FBI, currently contain more than 9 million profiles, and the agency is focusing now on increasing the database of missing-person profiles (www.fbi.gov/about-us/lab/codis/codis_future). If an imposing case backlog still exists, technical improvements and the investment in the modernization of forensic laboratories are already resulting in a backlog reduction, in spite of the simultaneous increase in the number of samples submitted for DNA analysis.

Thus, the near future outlined by these developments is one in which analyzing a DNA sample will be both very cheap and very quick (at present it can be argued that it is already either cheap or quick), while comprehensive databases containing profiles for the identification of virtually any missing person will be readily available. How will this affect the work of forensic anthropologists?

We can probably get an idea by looking at other competing identification techniques that are already available. We could think of fingerprints or dental records, and ask ourselves how often are bodies submitted to us just for identification purposes when any of these items are available; however, the best comparison would probably be with fresh, fully fleshed bodies. In these cases most of the components of the biological profile (save for, perhaps, the exact age range) can be directly and rather unequivocally assessed by the pathologist, and thus are not commonly submitted to the forensic anthropologist for identification purposes. With the appropriate comparative databases, DNA would have a similar quality, but could also be extracted from skeletonized or fragmentary remains.

In this scenario, the biological profile would probably still be useful as a safeguard or double-check to identify laboratory or family record errors, but its utility as a pre-sorting method, aimed at reducing the list of potential matches, would be fundamentally diminished. It would represent an analysis sometimes useful to perform *in addition* to DNA analysis, but no longer something required *before* the latter.

We could also ask what would be the parameters marking the point of no return or, in other words, the amount of time and the costs to be reached by DNA analysis in order to become a closed alternative to the forensic anthropological profile, rather than its sister technique. The answer is rather simple: to reach that point, DNA techniques must simply become cheaper and faster than forensic anthropological analyses.

Fortunately, due to the development of forensic anthropology in recent decades, the solution to the problem and the future of the discipline will not depend on progressive salary cuts and modification of anthropological report production. We do believe that the primitive, exclusive goal of helping with identification issues will lose importance with the further development of forensic DNA techniques. Still, as discussed throughout this chapter, the evolution of forensic anthropology in the last few decades has been characterized by a diversification of its goals, objectives, and techniques, paralleled by a decisive refinement and deepening of its conceptual framework and entrenchment in the natural sciences. Nowadays, forensic anthropologists do receive and deal with identified and even fully fleshed bodies in their everyday practice. They do so in tasks such as forensic archaeological recoveries and trauma analysis.

Outside influence 2: recent federal rulings related to science in the courtroom

In the last 40 years, forensic anthropologists have testified rather infrequently in court. The primary reason for this lies with the definition of the role that forensic anthropology plays in forensic investigation: forensic anthropological analysis of the skeleton can produce a biological profile that *helps* determine identity of the victim by providing circumstantial evidence of identity, which in turn helps narrow the missing-person list. Positive identification is most often provided by other disciplines (dental and DNA). And since the identity of the victim is usually not in question at the time of trial, why then would forensic anthropologists be called to testify?

Another reason for the infrequency of courtroom testimony is that the results of the forensic anthropological investigation are always turned over to the police, forensic pathologist and/or medical examiner. The primary responsibility for determining cause and manner of death belongs to the forensic pathologist (cause of death) and the coroner/medical examiner (manner of death). Law-enforcement officials generally process the crime scene and are responsible for providing reconstructions of past events that occurred at these scenes. If a case goes to trial, it is these individuals who will provide commentary and expert testimony over the whole sweep of analyses and investigations that led to the rulings.

However, with the addition of forensic archaeology at outdoor scenes and ramifications to providing unique determinations of postmortem interval, circumstances surrounding the death event and placement at the scene, and especially, skeletal trauma, testifying opportunities for forensic anthropologists will become more frequent. With the responsibility of handling evidence as one of the leads at the outdoor scene recovery, there is a need for forensic anthropologists to better understand how to properly handle evidence, establish chain of custody, and prepare court testimony as an expert witness.

As with all other forensic scientific investigators, forensic anthropologists must document, analyze, and interpret evidence according to a certain level of standards in order for it to be admissible in court. Since the 1920s, the Frye decision has provided the guideline by which trial judges determine the validity of courtroom expert witness testimony (*Frye v. United States* 1923). Frye required that the science, upon which the findings of a particular expert witness are based, must be generally accepted in the expert's particular field if it is to be presented in court (*Frye v. United States* 1923: 1014). This ruling was amended in 1975 by the Federal Rules of Evidence (FRE) 702, which read: "If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise" (FRE 702, 1975). With this ruling it thus appeared that the "general acceptance" guide was replaced by the ability of testimony to assist the trier (the judge) of fact. This often led to reliance on experts who would provide the most forceful testimony and opinions. The "weight" of their expert opinion often resided on the length of their curriculum vitae and years of experience with little concern focused on the scientific basis of their interpretations.

In a 1993 ruling, *Daubert v. Merrell Dow Pharmaceuticals*, the Supreme Court attempted to alter this state of expert testimony by emphasizing that testimony related to scientific matters had to rely on the science behind the court presentation, rather than the presentation (*Daubert v. Merrell Dow Pharmaceuticals* 1993). The research and studies upon which conclusions were reached in a report should be testable, previously tested, previously presented in peer-reviewed publications that included appropriate consideration of potential error rate, and represent generally accepted scientific methods. Frye's "general acceptance" test was rejected and replaced by a new requirement that the "trial judge serve the role as gatekeeper" and "ensure that any and all scientific testimony or evidence admitted is not only relevant, but reliable" (*Daubert v. Merrell Dow Pharmaceuticals* 1993). It was hoped that focus would shift from the expert to the expert's testimony.

First, a bit of clarification

Additional clarifications, however, were needed and were presented in the form of additional court rulings, including *General Electric Co. v. Joiner* (1997) and *Kumho*

Tire Co. v. Carmichael (1999). Kuhmo, in particular, instructed that standards comparable to Daubert should apply to all expert testimony (*Kuhmo Tire Co. v. Carmichael* 1999). Even though most trial judges are not science experts and are generally limited in their ability to judge the scientific merit of much of the technical aspects of the forensic sciences, the US Supreme Court was confident that the adversarial nature of the judicial system – that is, "vigorous cross-examination, presentation of contrary evidence and careful instruction on the burden of proof" (*Daubert v. Merrell Dow Pharmaceuticals* 1993), would eventually lead to best-solutions science entering the courtroom, and suggested that the judge's inquiry remain flexible.

Finally, FRE rule 702 was amended in 2000 to read that a witness did not have to be a scientist to testify as an expert, but could also be qualified as an expert by "knowledge, skill, experience, training, or education" (FRE 702, 2000) if these findings were based on good scientific principles and best practices. The apparent wiggle room, perhaps, is necessary in many forensic sciences, including forensic anthropology. Ubelaker suggests "much of diverse anthropological analysis and interpretation must call upon experience and observation if it is indeed to maximize the information retrieved" (Ubelaker 2010: 416).

The bottom line

Most of forensic science evidence relates to crimes of violence, the vast majority of which are tried in state courts not federal courts (200 times more criminal cases are presented in state courts than federal courts). As currently constructed, Daubert applies to all federal cases and individual states adhere to their own standards (Frye, or versions of Daubert). Forensic scientists, including anthropologists, therefore, may see very little effect on their testimony in court in the near future. However, perhaps the potential for testimony to be disallowed and the case even thrown out, provides enough of a threat to raise standards across the board.

On the other hand, since Daubert attempts to get the best science into the courtroom and to diminish anecdotal accounts and years of experience arguments that focus on the status of the expert witness, it should serve as a standard-bearer and goal for all forensic scientists, including forensic anthropologists. It should not be considered a "threat" hanging over the heads of expert witnesses, but a way to level the playing field and get rid of "junk" science. With recent reevaluations of the forensic science (see the National Academy of Sciences report described below), change is afoot. The highest of standards should always be sought and Daubert provides a useable playbook. The effect of Daubert on the forensic sciences and forensic anthropology in particular is explored in greater detail in Chapter 32.

Outside influence 3: the US federal government

National Institute of Justice

As a result of the 1993 Daubert ruling, and likely a big slice of humble pie served as a result of the botched handling of forensic evidence in the O.J. Simpson case, the federal government set about to reevaluate best practices and try to improve a number of areas in the forensic sciences. To some degree the National Institute of Justice, the research, development, and evaluation arm of the US Department of Justice, has taken the lead in attempts to upgrade aspects of forensic sciences. This has been accomplished through research initiatives, funding opportunities, specialized training, and discipline-specific publications. In addition to these activities, one of the most tangible results of their activities was the formation of "working groups," assemblages of professionals from specific forensic specialties that are brought together to formulate standards for their particular discipline. Since the 1990s the National Institute of Justice has created what they call Technical Working Groups (TWGs), peer-review panels of experts (25 to 30 practioners from local, state, tribal, and federal agencies and laboratories) who were tasked with evaluating the problems and needs of participants in the forensic sciences and criminal justice community, and constructing potential solutions. Currently, 19 active TWGs are listed on the National Institute of Justice website. The direct result of many of these TWGs, are publications that present "best practices" in the form of Crime Scene Guides. They are typically widely disseminated and relatively influential. They include free publications (and pdf files) on *Fire and Arson Scene Evidence*, *Crime Scene Investigation*, *Death Investigation*, *Guide for Explosion and Bombing Scene Investigation*, and even *Electronic Crime Scene Investigation* (www.ojp.gov/nij/topics/law-enforcement/investigations/crime-scene/guides/twgs.htm).

FBI

In a similar vein and similarly constructed to the National Institute of Justice TWGs, the FBI created what they termed Scientific Working Groups (SWGs). There are currently 20 SWGs at various stages of development of guidelines (visit www.fbi.gov and follow links). Two of them include forensic anthropologists as key members: the Scientific Working Group for Forensic Anthropology (SWGANTH) assembled in 2008 (www.swganth.org) and the Scientific Working Group on Disaster Victim Identification (SWGDVI) created in 2010 (www.swgdvi.org). The SWGANTH includes 18 subcommittees that are attempting to provide guidelines that cover topics as diverse as ethics and conduct (see Chapter 33) to detection and recovery, as well as all of the standard forensic anthropology categories (e.g., age, sex, stature, trauma). The SWGDVI includes anthropologists at many levels of administration and subcommittees membership. Although these committees will not produce standards or guidelines to be followed under threat of retribution, they may prove relatively influential as ways to: (i) advertise the discipline and depth of "services" available to other disciplines, (ii) provide guides for new recruits to the field, (iii) provide fodder for defense lawyers upon which to cogitate and ruminate, and (iv) may serve to cause some current practitioners (unreconstructed whelps of true physical anthropologists) to pause and reconsider the quality of their efforts.

National Academy of Sciences

Probably the most influential document to effect the forensic sciences in recent years is the National Academy of Sciences' (NAS) report of the state of the forensic sciences in the USA that was published in February 2009 (NAS 2009). The appointed committee consisted of experts in many forensic disciplines and found problems in many areas, including:

1. with the *practices* within the varying forensic science disciplines themselves: "… operational principles and procedures … are not standardized or embraced, either

between or within jurisdictions. There is no uniformity in the certification of forensic practitioners, or in the accreditation of crime laboratories" (NAS 2009: 6);

2. with the underlying *principles* of individual forensic methods: "with the exception of nuclear DNA analysis, … no forensic method has been rigorously shown to have the capacity to consistently, and with a high degree of certainty, demonstrate a connection between evidence and a specific individual or source" (NAS 2009: 7);
3. with the *handling of evidence* at the crime scene and in the laboratory: "The depth, reliability, and overall quality of substantive information arising from the forensic examination of evidence available to the legal system" (NAS 2009: 6) also varied significantly according to jurisdictional levels, regions of the country, and state versus municipal versus federal agencies;
4. with the *training* of forensic specialists: "…there remains great variability in crime scene investigation practices, along with persistent concerns that the lack of standards and proper training at the crime scene can contribute to the difficulties of drawing accurate conclusions once evidence is subjected to forensic laboratory methods" (NAS 2009: 57).

One significant recommendation was the creation of an entirely new federal agency with oversight capabilities, and opportunities for funding research. The committee saw a critical need to conduct much more basic scientific research in order to: (i) "establish the scientific bases demonstrating the validity of forensic methods" (NAS 2009: 22); (ii) develop and establish "quantifiable measures of reliability and accuracy of forensic analysis" (NAS 2009: 23); (iii) develop "quantifiable measures of uncertainty in the conclusions of forensic analysis" (NAS 2009: 23); and (iv) conduct research into "human observer bias and sources of human error in forensic examinations" (NAS 2009: 24).

These findings could potentially have a significant effect on the state of forensic sciences, especially if a new federal department is created. Impacts will be felt in many areas including funding for research opportunities, especially validation of methods studies; accreditation of laboratories that handle and analyze evidence, and certification of those who handle evidence. As we have discussed above, forensic anthropology has already started improving the way that it does business: validation studies of both old and new methodologies have been conducted; much better comparative samples are used, and the statistics used to analyze the data are state-of-the-field. These efforts have improved the scientific worth of these methods and their applicability to modern forensic cases. In addition to improvements to the laboratory aspect of the field, forensic archaeology has been able to fill the investigative gap long missing in forensic investigations of outdoor scenes by dramatically improving how evidence is found, documented, and processed at outdoor scenes. The depth of interpretations of past events now rivals those drawn from indoor scenes. Forensic anthropology, it could be argued, therefore, is in good shape and would welcome any changes for the better in the forensic sciences.

Summary

Forensic anthropology has gone through a number of growth spurts in the last 80 or so years. Springing from sporadic and infrequent requests in the early twentieth century for assistance to provide a biological profile from skeletal remains, a few prominent academic and museum-based physical anthropologists such as Hrdlička, Todd, Krogman, and Hooten maintained a passing interest in the medicolegal applications of human skeletal biology. With very few exceptions, professional literature on the subject was not produced.

By the mid portion of the last century, more formalized relationships with law enforcement (in this case, the FBI) arose, especially at the Smithsonian Institution with T. Dale Stewart, Larry Angel, and Doug Ubelaker, which brought more attention to the field. This interest continued to grow with the work of Clyde Snow in early human-rights work, the creation of academic programs with a strong forensic anthropology component (Kansas, Tennessee, Arizona, Florida), professional literature, and especially with the formal creation of a separate section of the American Academy of Forensic Science and Board certification in the early 1970s. Throughout this period, forensic anthropology operated primarily as a laboratory-based discipline that sprang into action when called upon by law enforcement, coroners, and medical examiners to provide a biological profile after "standard" forensic avenues to provide victim identification had been exhausted.

The classic definition of the field, as proposed by T. Dale Stewart (1979) and as understood by İşcan (1988a), thus indicated that the primary, if almost exclusive goal of forensic anthropology was aiding in the identification of human remains in forensic contexts. This goal was attained through the estimation of biological profiles (chronological age, sex, ancestry, stature, and antemortem bone modification), which served to reduce the list of potential victim identities. A quantum shift in identification possibilities occurred in the 1980s and 1990s with the amplification of DNA through the PCR, which allowed for the sequencing of DNA even from trace samples. What is more important is that it permitted researchers the ability to perform a virtually infinite number of DNA comparisons, rendering match probabilities several orders of magnitude higher than can be attained through biological profiles derived from forensic anthropological analyses.

At first glance, it may appear that DNA analysis does not necessarily imply a fundamental change from past conditions regarding the goals, functions, and perspective of forensic anthropology. After all, providing positive identification from the bones has not commonly been one of the primary court-accepted tasks of forensic anthropologists, which instead has fallen to other forensic specialists such as forensic pathologists and forensic odontologists. In addition, DNA analysis is still regarded as a relatively expensive and slow procedure, and the number of DNA samples routinely submitted for analysis overwhelms forensic laboratories. From this perspective, the classic goal of biological profile estimation from bones within forensic anthropology still remains a unique and significant role in simplifying the task of narrowing down the missing person list.

When the current trends in DNA analysis are closely examined, however, it soon becomes clear that the current state of affairs is inevitably bound to change. In the last two decades, the limiting steps of DNA analysis have rapidly shifted from DNA amplification to DNA sequencing, and thence to sample comparison and matching, resulting in a rapid decrease in DNA processing times and costs. PCR has become an almost routine procedure, available in most biomedical research and practice centers. Visual comparison from electrophoresis in agarose and polyacrylamide gels has been replaced by automated capillary electrophoresis in the modern DNA sequencers, allowing the processing and sequencing of a large number of samples simultaneously. More importantly, robust DNA databases for sample comparison have been created and made available to the forensic community, with the reference samples growing at an astounding rate.

At present, the only issues preventing routine and widespread victim identification solely based on DNA comparisons are the costs and time required for amplification, sequencing, and comparison, as well as the need to provide potential matches, currently based on samples collected *ad hoc* from the family members of the potential victims. Overcoming these limitations only requires an improvement in sequencing techniques to an extent much smaller than what has transpired during the last two decades, and the inclusion of the DNA sequences of family members of all missing persons in CODIS or equivalent databases. The question is not whether this will happen, but when. When this point is reached, if positive identification remains as the main and almost exclusive goal of forensic anthropology, forensic anthropologists (and odontologists) may become mostly superfluous in most cases, other than those involving commingled remains, where element matching will still result in a significant decrease of sampling, amplification and sequencing efforts.

Therefore, if forensic anthropology is to remain a useful, vibrant scientific discipline, it is necessary to shift the scope of the field from mere identification to a larger range of problems. Through introspection, and the pressure of outside influences, forensic anthropologists were forced to look outside of the box for answers to pressing issues. First came the call to action to produce better scientific research in forensic anthropology, starting with the identification (that is, creation) of better, more appropriate modern skeletal samples (e.g., the Bass Skeletal Collection at the University of Tennessee, the Forensic Data Bank), and computer programs (Fordisc) to analyze the date. Naturally, better research samples yielded better research.

Next came the realization that forensic archaeology could provide, for the first time, detailed information on context at outdoor scenes not provided by law enforcement. Only after scene context and notation of evidence distribution and location via detailed maps were obtained could forensic taphonomic analyses be conducted, which in turn then permitted scientific (nonconjectural) determinations of postmortem interval, past events reconstruction, and even significantly better skeletal trauma analysis.

Recent court rulings regarding the role of science in the courtroom, as well as critical review of the science behind the forensic sciences, have emphasized that the old ways of conducting forensic science, including forensic anthropology, need to be updated. In many ways, forensic anthropology has anticipated these findings and preemptively embraced scientific improvements to forensic anthropology practices. Recent considerations of "best practices," therefore, did not result in a diminution of the field, but rather a strengthening, reconfiguring it as a vibrant, robust, scientific discipline.

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