EXPLORATIONS: AN OPEN INVITATION TO BIOLOGICAL ANTHROPOLOGY

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15. Bioarchaeology and Forensic Anthropology

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Learning Objectives

- Define and differentiate bioarchaeology and forensic anthropology as subfields of biological anthropology
- Describe the seven steps carried out during skeletal analysis
- Outline the four major components of the biological profile
- Contrast the four categories of trauma
- Explain how to identify the different taphonomic agents that alter bone
- Discuss ethical considerations for both bioarchaeology and forensic anthropology

Bioarchaeology and forensic anthropology are both subfields of biological anthropology. While the goals of each subfield are different, each relies on skeletal analysis to gain information about humans, both past and present. This chapter will provide a general overview of the analysis of human skeletal remains, as it applies to both bioarchaeology and forensic anthropology.

BIOARCHAEOLOGY

In 2010 Hurricane Earl reached the Caribbean Island of Antigua. The storm brought strong winds and heavy rainfall to the island. After the storm calmed, accumulated water drained back out to the ocean, carving a channel through one of the beaches at English Harbor as it went. Out of the newly created channel, human bones were exposed. Although they had been buried for many years, the remains belonged to 18th‾century British sailors who had died from Yellow Fever while stationed in the Caribbean. While no headstones were present to divulge information about each person buried on the beach, a large amount of evidence was still accessible through the analysis of each skeleton as well as the information garnered from the **burial context**. To gather more information about each of the individuals buried on the beach, the bones were examined, and a detailed analysis was carried out of the positions of the skeletons, the burial depth, whether clothing material such as buttons were found with each set of remains, and whether it appeared that the sailors were buried in coffins. In addition, the sex, age, and other individualizing characteristics were estimated through careful analysis of the bones themselves.

The remains uncovered by Hurricane Earl in Antigua became part of a bioarchaeological study. **Bioarchaeology** is the study of human remains excavated from archaeological sites. Bioarchaeologists glean information about each set of human remains by examining the skeleton and by considering the archaeological context in which the skeleton was recovered. Through this type of detailed skeletal analysis, bioarchaeologists obtain information about each individual skeleton, which can include age, sex, height, ancestry, disease, diet, and behavior. For a broader understanding of past peoples, bioarchaeologists look at skeletal trends on a population level. They gather data on groups of individuals to reveal both biological and cultural patterns within and between samples. In this way, bioarchaeological samples can contribute to our knowledge of the demographics and lifeways of past populations.

In the example of the buried remains on the beach in Antigua, Dr. Matthew Brown, a bioarchaeologist, examined the historic remains individually and then was able to combine the information from each individual to discern patterns within the entire sample of burials. For example, all of the skeletons belonged to males, not surprising considering that the beach was a burial site for British sailors. Dr. Brown also discovered that not all of the sailors were buried in the same manner. During the excavation, degraded wood fragments and rusted nails were uncovered in some of the burials. The wood and metal materials were consistent with those used to make coffins, leading him to suspect some of the sailors were buried in coffins. In other instances, no wood or nails were found but, instead, the bodies were positioned with their arms and legs tucked in close to the torso, with their hands positioned tightly together in the area of the pelvis. This was likely indicative of a hammock burial. A hammock burial would have served as a relatively easy way to inter a sailor who died in his hammock on board the ship. The hammock could be removed from the ship, carried onto the beach, and placed in a grave with minimal effort.

Bioarchaeologists like Dr. Brown help us understand information about past populations and the degree of social complexity found within each society. This information can help determine what types of food were consumed and how consumption patterns changed over time in one area. Or it may help us ascertain the scale of interpersonal violence that occurred during culture contact. Other research questions that bioarchaeology addresses revolve around physiological stress from disease or from malnutrition, daily activity, injuries, or growth patterns of individuals.

SPECIAL TOPIC: BIOARCHAEOLOGY IN ACTION

In this short clip, an excerpt from the BBC documentary Nelson's Caribbean Hell-hole: An Eighteenth-Century Navy Graveyard Uncovered (2013), Dr. Brown discusses the excavation of a skeleton of a British sailor: https://www.bbc.co.uk/programmes/p0187q6r.

FORENSIC ANTHROPOLOGY

Much like bioarchaeologist Dr. Brown in Antigua examined the skeletons of the British sailors, forensic anthropologists analyze the human skeleton to gain information regarding an individual who is deceased. However, one of the major differences between the two subfields of biological anthropology is that in **forensic anthropology** researchers specifically conduct their analysis on recently deceased individuals (typically within the last 50 years) and within the context of the law—in other words, as part of a criminal investigation. This means that forensic anthropologists can assist law enforcement agencies in several different ways, including aiding in the identification of human remains whether they are complete, fragmentary, burned, scattered, or decomposed. Additionally, forensic anthropologists can help determine what happened to the deceased at or around the time of death as well as what processes acted on the body after death (for example, whether the remains were scattered by animals, whether they were buried in the ground, or whether they remained on the surface as the soft tissue decomposed).

Many times, because of their expertise in identifying human skeletal remains, forensic anthropologists are called to help with outdoor search-and-recovery efforts, such as locating remains scattered across the surface or carefully excavating and documenting buried remains. In other cases, forensic anthropologists recover remains after natural disasters or accidents, such as fire scenes, and can help identify whether each bone belongs to a human or an animal. Forensic anthropology spans a wide scope of contexts involving the law, including incidences of mass disasters, genocide, and war crimes.

A point that can be somewhat confusing for students is that although the term *forensic* is included in this subfield of biological anthropology, there are many forensic techniques that are not included in the subfield. Almost exclusively, forensic anthropology deals with skeletal analysis. While this can include the comparison of antemortem (before death) and postmortem (after death) radiographs to identify whether remains belong to a specific person, or using photographic superimposition of the cranium, it does not include analyses beyond the skeleton. For example, blood spatter analysis, DNA analysis, fingerprints, and material evidence collection do not fall under the scope of forensic anthropology.

So, what can forensic anthropologists glean from bones alone? Forensic anthropologists can address a number of questions about a human individual based on their skeletal remains. Some of those questions include: How old was the person? Was the person biologically male or female? How tall was the person? What happened to the person at or around their time of death? Were they sick? The information from the skeletal analysis can then be matched with missing persons records, medical records, or dental records, aiding law enforcement agencies with identifications and investigations.

INITIAL SKELETAL ANALYSIS

While bioarchaeology and forensic anthropology have different goals and purposes, they both rely on skeletal analysis to reveal information about the deceased. Whether they aim to determine more information regarding an individual deceased for thousands of years (bioarchaeologists) or one who died within the last year (forensic anthropologists), they carry out the same basic steps as part of their analysis. They begin with seven steps or questions:

- Is it bone?
- Is it human?
- Is it modern or archeological?
- How many individuals are present or what is the minimum number of individuals (MNI)?
- Who is it?
- Is there evidence of trauma before or around the time of death?
- What happened to the remains after death?

Is It Bone?

One of the most important steps in any skeletal analysis starts with determining whether or not material suspected to be bone is in fact bone. Though it goes without saying that a forensic anthropologist or bioarchaeologist would only carry out analysis on bone, this step is not always straightforward. Whole bones are relatively easy to identify, determining whether or not something is bone becomes more challenging once it becomes fragmentary. For example, at high heat such as that seen on fire scenes, bone can break into pieces. During a house fire with fatalities, firefighters watered down the burning home. After the fire was extinguished, the sheetrock (used to construct the walls of the home) was drenched and crumbled. The crumbled sheetrock was similar in color and form to burned, fragmented bone, therefore mistakable for human remains (Figure 15.1). Forensic anthropologists on scene were able to separate the bones from the construction material, helping to confirm the presence of bone and hence the presence of individual victims of the fire. In this case, forensic anthropologists were able to recognize the anatomical and layered structure of bone and were able to distinguish it from the uniform and unlayered structure of sheetrock.

Figure 15.1 Example of burned sheetrock. Burned sheetrock used as building material appears similar to human bone but can be differentiated by the fact that it is the same density throughout.

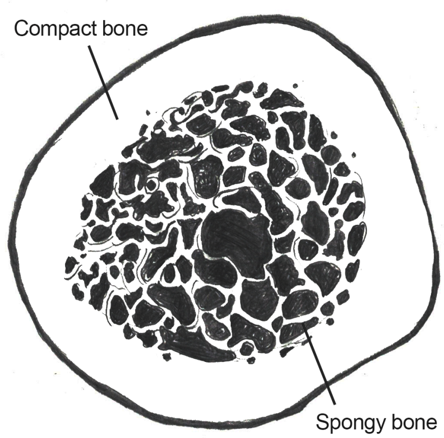

Figure 15.2 caption: Cross section of human long bone with compact and spongy bone layers visible.

As demonstrated by the example above, both the macrostructure (visible with the naked eye) and microstructure (visible with a microscope) of bone are helpful in bone identification. Bones are organs in the body made up of connective tissue. The connective tissue is hardened by a mineral deposition, which is why bone is rigid in comparison to other connective tissues such as cartilage (Tersigni-Tarrant and Langley 2017, 82–83; White and Folkens 2005, 31). In a living body, the mineralized tissue does not make up the only component of bone—there is also blood, bone marrow, cartilage, and other types of tissues. However, in dry bone, two distinct layers of the bone are the most helpful for identification. The outer layer is made up of densely arranged osseous (bone) tissue called **compact (cortical) bone**. The inner layer is comprised of much more loosely organized, porous bone tissue whose appearance resembles that of a sponge, hence the name **spongy (trabecular) bone**. Knowing that most bone contains both layers helps with the macroscopic identification of bone (Figures 15.2, 15.3). For example, a piece of coconut shell might look a lot like a fragment of a human skull bone. However, closer inspection will demonstrate that coconut shell only has one very dense layer, while bone has both the compact and spongy layers.

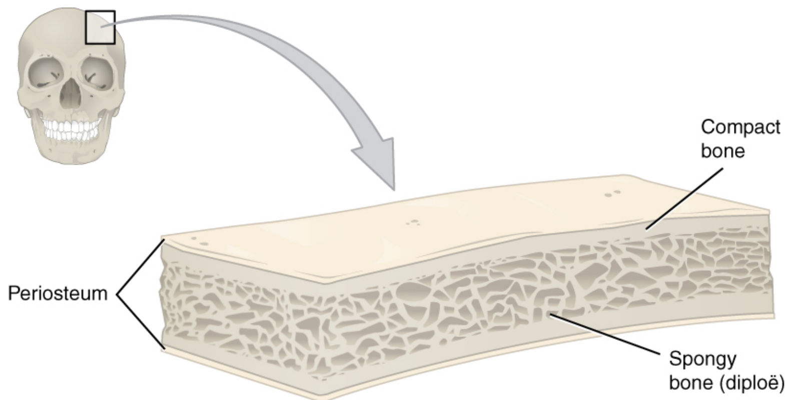

Figure 15.3 Cross-section of human cranial bone.

Cranial anatomy is slightly different as compared to that of a long bone in cross section. The compact (cortical) bone layers sandwich the spongy (trabecular) bone. One layer of compact bone forms the very outer surface of the skull and the other lines the internal surface of the skull.

The microscopic identification of bone relies on knowledge of **osteons**, or bone cells (Figure 15.4). Under magnification, bone cells are visible in the outer, compact layer of bone. The bone cells are arranged in a concentric pattern around blood vessels for blood supply. The specific shape of the cells can help differentiate, for example, a small piece of PVC (white plastic) pipe from a human bone fragment (Figure 15.5).

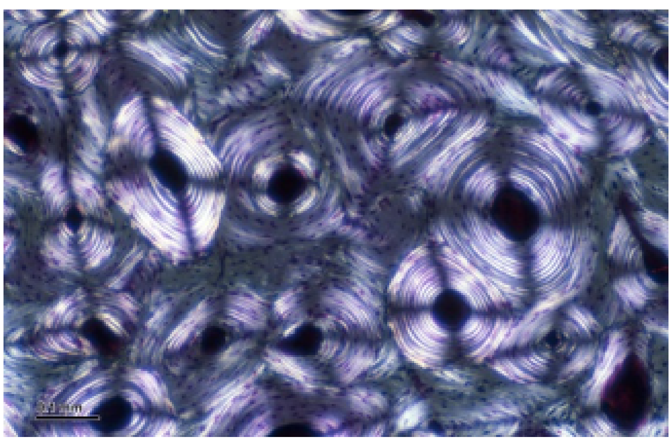

Figure 15.4 Bone microstructure (osteons).

Figure 15.5 Fragments of plastic PVC pipe, such as those seen in this photo, may be mistaken for human bone.

Is It Human?

Once it can be determined that an object is bone, the next logical step is to identify whether the bone belongs to a human or an animal. Bioarchaeologists must make this determination each time they come across remains at an archaeological site. Forensic anthropologists are faced with this question in everyday practice because human versus nonhuman bone identification is one of the most frequent requests they receive from law enforcement agencies.

There are many different ways to distinguish human versus nonhuman bone. The morphology (the shape/form) of human bone is a good place for students to start. Identifying the 206 bones in the adult human skeleton and each bone's distinguishing features (muscle attachment sites, openings and grooves for nerves and blood vessels, etc.) is fundamental to skeletal analysis.

Nevertheless, there are many animal bones and human bones that look similar. For example, the declawed skeleton of a bear paw looks a lot like a human hand, pig molars appear similar to human molars, and some smaller animal bones might be mistaken for those of an infant. To add to the confusion, fragmentary bone may be even more difficult to identify as human or nonhuman. However, several major differences between human and nonhuman vertebrate bone help distinguish the two.

Bioarchaeologists and forensic anthropologists pay special attention to the density of the outer, compact layer of bone in both the cranium and in the long bones. Human cranial bone has three distinctive layers. The spongy bone is sandwiched between the outer (ectocranial) and inner (endocranial) compact layers. In most other mammals, the distinction between the spongy and compact layers is not always so definite. Secondly, the compact layer in nonhuman mammal long bones can be much thicker than observed in human bone. Due to the increased density of the compact layer, nonhuman bone tends to be heavier than human bone (Figure 15.6).

Figure 15.6 The compact layer of this animal bone is very thick with almost no spongy bone visible.

Figure 15.7 In this x-ray of a subadult's ankle with the epiphyses of the tibia and fibula visible. The gap between the shaft of the bone and the end of the bone (epiphysis) is the location of the growth plate. Therefore, the growth plate gap is what separates the shafts from the epiphyses in the image.

The size of a bone helps determine whether it belongs to a human. Adult human bones are larger than subadult or infant bones. However, another major difference between human adult bones and those of a young individual or infant human can be attributed to development and growth of the **epiphyses** (ends of the bone). The epiphyses of human subadult bones are not fused to the shaft (Figure 15.7). Therefore, if a bone is small and it is suspected to belong to a human subadult or infant, the epiphyses would not be fused. Many small animal bones appear very similar in form compared to adult human bone, but they are much too small to belong to an adult human. Yet they can be eliminated as subadult or infant bones if the epiphyses are fused to the shaft.

Is It Modern or Archaeological?

As discussed earlier, bioarchaeologists are concerned with human remains from archaeological contexts, while forensic anthropologists work with modern cases that fall within the scope of law enforcement investigations. Accordingly, it is important to determine whether discovered human remains are archaeological or forensic in nature.

In many instances, bioarchaeologists work at known archaeological sites. Nevertheless, every bioarchaeologist and forensic anthropologist should begin their analysis by reviewing the context in which the remains were discovered. This will help them understand a great deal about the remains, including determining whether they are bioarchaeological or forensic in nature as well as considering legal and ethical issues associated with the collection, analysis, and storage of human remains (see "Ethics and Human Rights" section of this chapter for more information).

The "context" refers to the relationship the remains have to the immediate area in which they were found. The context includes the specific place where the remains were found, the soil or other organic matter immediately surrounding the remains, and any other objects or artifacts in close proximity to the body. For example, imagine that a set of remains has been located during a house renovation. The remains are discovered below the foundation. Do the remains belong to a murder victim? Or was the house built on top of an ancient burial ground? Observing information from the surroundings can help determine whether the remains are archaeological or modern. How long ago was the foundation of the house erected? Are there artifacts in close proximity to the body, such as clothing or stone tools? These are questions about the surroundings that will help determine the relative age of the remains.

Clues directly from the skeleton may also indicate whether the remains are archaeological or modern. For example, tooth fillings can suggest that the individual was alive recently (Figure 15.8). In fact, filling material has changed over the decades, and the specific type of material used to fix a cavity can be matched with specific time periods. Gold was used in dental work in the past, but more recently composite (a mixture of plastic and fine glass) fillings have become more common.

Figure 15.8 A human tooth with a filling.

How Many Individuals Are Present?

What Is MNI?

Another assessment that an anthropologist can perform is the calculation of the number of individuals in a mixed burial assemblage. Because not all burials consist of a single individual, it is important to be able to estimate the number of individuals in both an archaeological and forensic context. Quantification of the number of individuals in a **burial assemblage** can be done through the application of a number of methods, including the following: the Minimum Number of Individuals (MNI), the Most Likely Number of Individuals (MLNI), and the Lincoln Index (LI). The most commonly used method in physical anthropology, and the focus of this section, is determination of the MNI.

The MNI presents “the minimum estimate for the number of individuals that contributed to the sample” (Adams and Konigsberg 2008, 243). Many methods of calculating MNI were originally developed within the field of zooarchaeology for use on calculating the number of individuals in faunal or animal assemblages (Adams and Konigsberg 2008, 241). What MNI calculations provide is a lowest possible count for the total number of individuals contributing to a skeletal assemblage. Traditional methods of calculating MNI include separating a skeletal assemblage into categories according to the individual bone and the side the bone comes from and then taking the highest count per category and assigning that as the minimum number.

Before beginning MNI calculations, however, it is important to make sure that all elements in the assemblage belong to the same species. If an assemblage contains both human and faunal (animal) elements, the assemblage should be divided into two separate groups. In a forensic context, it is likely that an MNI calculation is only necessary for the human skeletal remains. However, in an archaeological assemblage, it may be useful to calculate MNI for both the human and faunal remains. Faunal remains can contribute to a greater understanding of lifeways in past populations. For example, the age and sex profile of the animals at a site might be indicative of domestication. Large numbers of young male cattle bones and adult female cattle bones may indicate that the males were killed young while females were kept into adulthood. This pattern is consistent with cattle selection for captivity: adult males can be dangerous and aggressive, so they are killed young. On the other hand, females produce milk and are kept into adulthood.

Why Calculate MNI?

The determination of MNI is critical in both bioarchaeological and forensic contexts, as it allows anthropologists to establish an approximate number of deceased individuals within a burial assemblage (Adams and Konigsberg 2008). However, it must be recognized that unless a skeletal assemblage has a near-100% recovery rate for at least one type of skeletal element, the MNI will not provide an accurate estimate for the original number of individuals contributing to the burial assemblage (Adams and Konigsberg 2008, 243).

Determination of MNI is most applicable in cases of mass graves or **commingled burials** (Figure 15.9). The term *commingled* is applied to any burial assemblage in which individual skeletons are not separated into separate burials. Commingled assemblages occur in cases of familial burials (e.g., multiple family members buried in a single grave plot) and mass graves, possibly the result of genocide. However, it is important to remember that in any forensic context, MNI should be referenced and an MNI of one should be substantiated by the fact that there was no repetition of elements associated with the case.

Figure 15.9 Commingled human remains.

CONSTRUCTING THE BIOLOGICAL PROFILE

Who Is It?

"Who is it?" is one of the first questions that law enforcement officers ask when they are faced with a set of skeletal remains. Likewise, when human bones are found as part of archaeological fieldwork, the remains present the opportunity to learn more about the individuals who lived in the past. In order to answer this question, "who is it?", bioarchaeologists and forensic anthropologists construct a biological profile (White and Folkens 2005, 405). A **biological profile** is an individual's identifying characteristics, or biological information, which include the following: sex, age, stature, ancestry, skeletal variation, trauma, and pathology.

Although the biological profile is constructed by forensic anthropologists and bioarchaeologists using the same methodology, the estimations of these skeletal characteristics, or attributes, form the framework for different kinds of questions. Forensic anthropologists typically construct a biological profile to help positively identify a deceased person. In some cases, bioarchaeologists match information about a known individual in the past to remains found in an archaeological context, but they generally construct a biological profile to learn more about people's everyday lives. For example, bioarchaeologists may focus on indicators of pathological conditions in bone to assess the level of stress or disease that affected a particular individual or population. Likewise, bioarchaeologists might assess ancestry to understand more about migration patterns, population history, or relatedness among groups. For an additional example, see the search for, excavation, and analysis of King Richard III's remains in the box below.

SPECIAL TOPIC: THE SEARCH FOR THE LOST GRAVE OF KING RICHARD III

For an interesting overview of the search for the grave of the English King Richard III, as well as the discovery of the skeletal remains and the subsequent osteological analysis to help identify the remains as King Richard III's, see *The Discovery of Richard III* at: https://www.le.ac.uk/richardiii/.

The following section will lay out each component of the biological profile and briefly review standard methodology used for each.

Estimating Sex

Estimation of sex is often one of the first things considered when establishing a biological profile because several other parts, such as age and stature estimations, rely on an estimation of sex to make the calculations more accurate.

Estimations of sex look at differences in both morphological (form or structure) and metric (measured) traits in individuals. When assessing morphological traits, the skull and the pelvis are the most commonly used areas of the skeleton for estimations. These differences are related to sexual dimorphism usually varying in the amount of robusticity seen between males and females. **Robusticity** deals with strength and size; it is frequently used as a term to describe a large size or thickness. In general, males will show a greater degree of robusticity than females. For example, the length and width of the mastoid process, a bony projection located behind the opening for the ear, is typically larger in males. The mastoid process is an attachment point for muscles of the neck, and this bony projection tends to be wider and longer in males. In general, cranial features tend to be more robust in males (Figure 15.10).

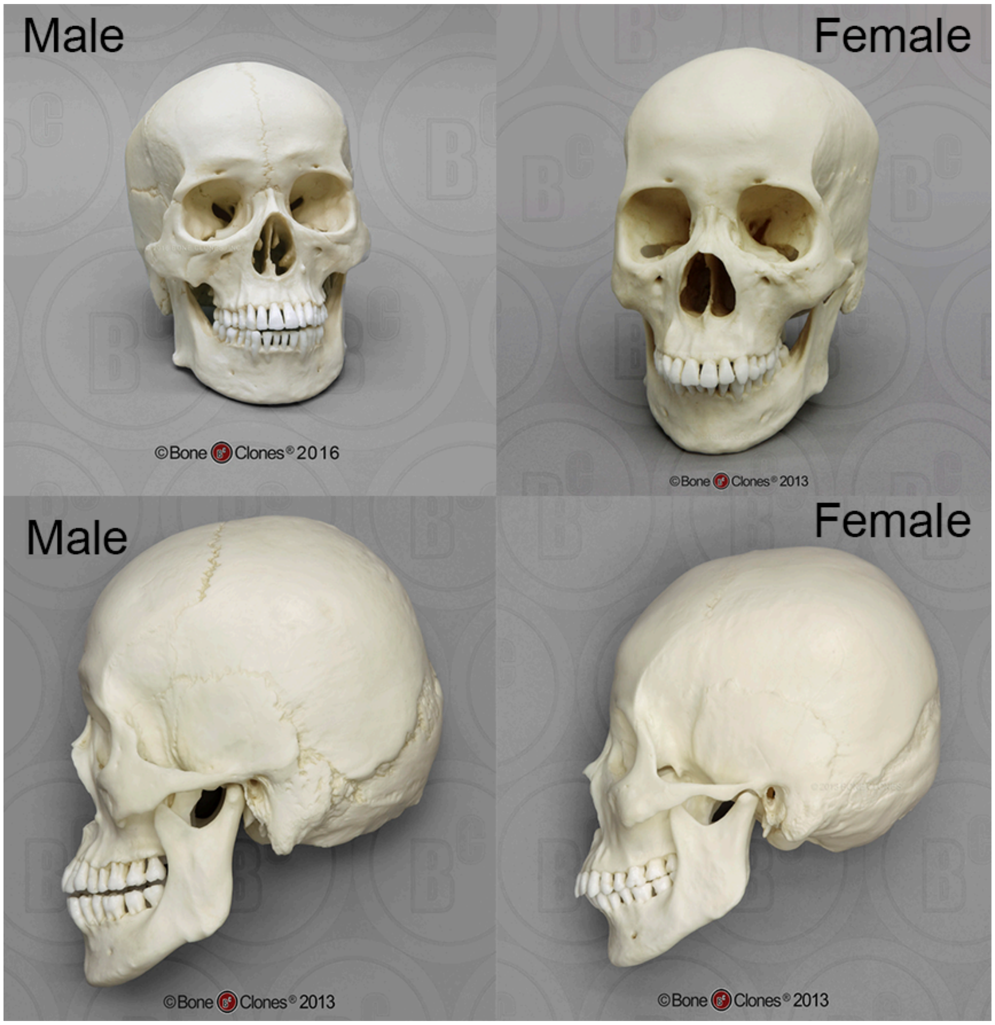

Figure 15.10 Anterior and lateral view of a male and female cranium.

When considering the pelvis, the features associated with the ability to give birth help distinguish females from males. During puberty, estrogen causes a widening of the female pelvis to allow for the passage of a baby. Several studies have identified specific features or bony landmarks associated with the widening of the hips, and this section will discuss one such method. The Phenice Method (Phenice 1969) is traditionally the most common reference used to assess morphological characteristics associated with sex. The Phenice Method specifically looks at the presence or absence of (1) a ventral arc, (2) the presence or absence of a sub-pubic concavity, and (3) the width of the medial aspect of the ischiopubic ramus (Figure 15.11). When present, the ventral arc, a ridge of bone located on the ventral surface of the pubic bone, is indicative of female remains. Likewise the presence of a sub-pubic concavity and a narrow medial aspect of the ischiopubic ramus is associated with a female sex estimation. Assessments of these features, as well as those of the skull (when both the pelvis and skull are present), are combined for an overall estimation of sex.

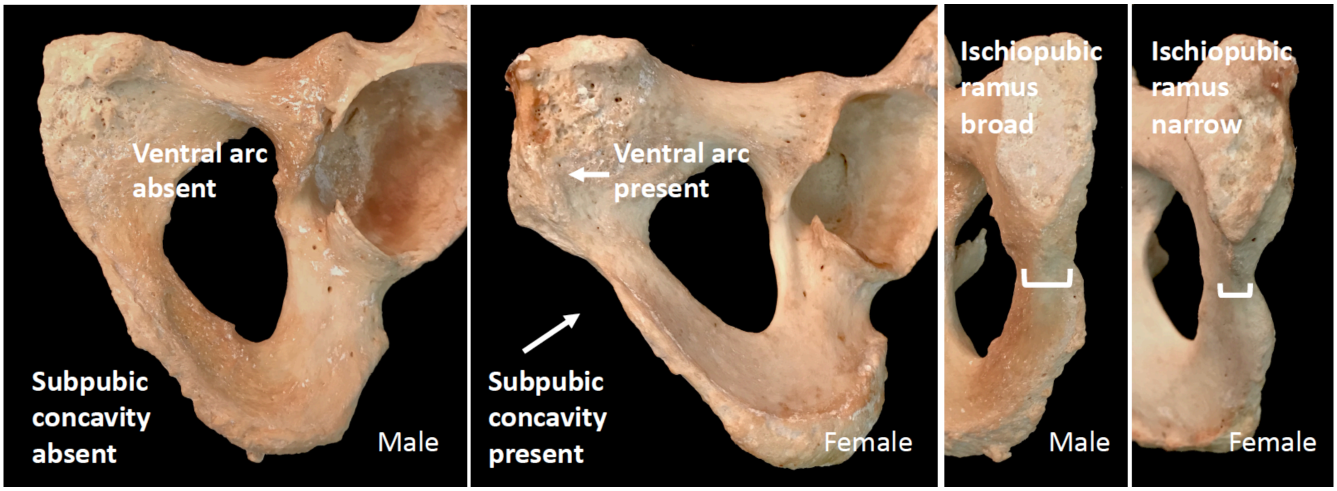

Figure 15.11 Features associated with the Phenice Method.

Metric analyses are also used in the estimation of sex. Measurements taken from every region of the body can contribute to estimating sex through statistical approaches that assign a predictive value of sex. These approaches can include multiple measurements from several skeletal elements in what is called multivariate (multiple variables) statistics. Other approaches consider a single measurement, such as the diameter of the head of the femur, of a specific element in a univariate (single variable) analysis (Berg 2017, 152–156).

It is important to note that, although forensic anthropologists and bioarchaeologists usually begin assessment of biological profile with sex, there is one major instance in which this is not appropriate. The case of two individuals found near Willits, California, on July 8, 1979, is one example that demonstrates the effect age has on the estimation of sex. The identities of the two individuals found in Willits were unknown; therefore, law enforcement sent them to a lab for identification. A skeletal analysis determined that the remains represented one adolescent male and one adolescent female, both younger than 18 years of age. This information did not match with any known missing children at the time.

In 2015, the cold case was reanalyzed, and DNA samples were extracted. The results indicated that the remains were actually those of two girls who went missing in 1978. The girls were 15 years old and 14 years old at the time of death. It is clear that the 1979 results were incorrect, but this mistake also provides the opportunity to discuss the limitations of assessing sex from a subadult skeleton.

Assessing sex from the human skeleton is based on biological and genetic traits associated with females and males. These traits are linked to differences in sexual dimorphism and reproductive characteristics between females and males. The link to reproductive characteristics means that most indicators of biological sex do not fully manifest in prepubescent individuals, making estimations of sex unreliable in younger individuals (SWGANTH 2010b). This was the case in the example of the 14-year-old girl. When examined in 1979, her remains were misidentified as male because she had not yet fully developed female pelvic traits.

Sex vs. Gender

Biological sex is a different concept than **gender**. While biological anthropologists can estimate sex from the skeleton, estimating an individual's gender would require a greater context as gender is culturally defined rather than biologically defined. Take for example an individual who identifies as transgender. This is an individual who has a gender identity that is different from their biological sex. The gender identity of any individual depends on factors related to self-identification, situation, or context, and cultural factors. While in the U.S. we have historically thought of sex and gender as binary concepts (male or female), many cultures throughout the world recognize several possible gender identities. In this sense, gender is seen as a continuous or fluid variable rather than a fixed one.

Estimating Ancestry

Ancestry is another component of the biological profile. As noted previously, ancestry can aid law enforcement in their identification of missing persons and can help bioarchaeologists understand many different things about individuals and populations living in the past, such as migration patterns and population distance. Biological ancestry today is often incorrectly labeled as race and generally refers to the individual's **phenotype** (outward appearance). Within the field of anthropology, ancestry estimation has a contentious history, and early attempts at racial classification were largely based on the erroneous assumption that an individual's phenotype was correlated with their innate intelligence and abilities (see Chapter 13 for a more in-depth discussion of the history of the race concept). **Biological ancestry** refers to the underlying genetic differences between modern populations. In any other organism/living thing, groups divided according to the biological race concept would be defined as a separate species. The major issue with applying the biological race concept to humans is that there are not enough differences between any two populations to separate on a genetic basis. In other words, *biological races do not exist in human populations*. However, the concept of race has been perpetuated and upheld by sociocultural constructs of race (see Chapter 13).

The conundrum for forensic anthropologists is the fact that while races do not exist on a biological level, we still recognize and categorize others based on their phenotype. Clearly, our phenotype is an important factor in not only how we are viewed by others but also how we identify ourselves. Also, when a person is reported missing, the information that is collected by law enforcement and sometimes entered into a missing person's database includes age, biological sex, stature, and "race." Therefore, the more information a forensic anthropologist can provide regarding the individual's physical characteristics, the more he or she can help to narrow the search. As an exercise, create a list of all of the women you know who are between the ages of 18 and 24 and approximately 5´ 4 " to 5´ 9 " tall. You probably have several dozen people on the list. Now, consider how many females you know who are between the ages of 18 and 24, approximately 5´ 4 " to 5´ 9 " tall, and are Vietnamese. Your list is going to be significantly shorter. That's how missing persons searches go as well. The more information you can provide regarding a decedent's phenotype, the fewer possible matches law enforcement are left to investigate. This is how ancestry has become an indispensable part of the biological profile.

In an effort to combat the erroneous assumptions tied to the race concept, forensic anthropologists have attempted to reframe this component of the biological profile. The term *race* is no longer used in casework and teaching. Instead, employing the word *ancestry* is a more appropriate way to describe an individual's phenotype, because we are largely shaped by the environments surrounding our recent ancestral origins. In other words, our phenotype lends clues to the environment for which our ancestors were best adapted (for additional information, see Chapters 13 and 14).

Because human populations vary in their phenotype due to environmental forces, forensic anthropologists are able to use morphological traits to predict the ancestral origins of an unidentified individual. In general, anthropologists are able to divide humans into broad geographically discrete groups, including (but not limited to) the following: European, African, Asian, Native American, and Hispanic. Traditionally, ancestry assessment was accomplished through a visual inspection of morphological variants of the skull (morphoscopics), primarily focused on elements of the facial skeleton, including the nose, eyes, and cheek bones (Figure 15.12). However, in an effort to reduce subjectivity, nonmetric cranial traits are now assessed within a statistical framework to help anthropologists better interpret their distribution among living populations (Hefner and Linde 2018). Based on the observable traits, a macromorphoscopic analysis will allow the practitioner to create a statistically validated prediction of geographic origin. In essence, forensic anthropologists are using human variation in the estimation of geographic origin, by referencing documented frequencies of nonmetric skeletal indicators, or macromorphoscopic traits.

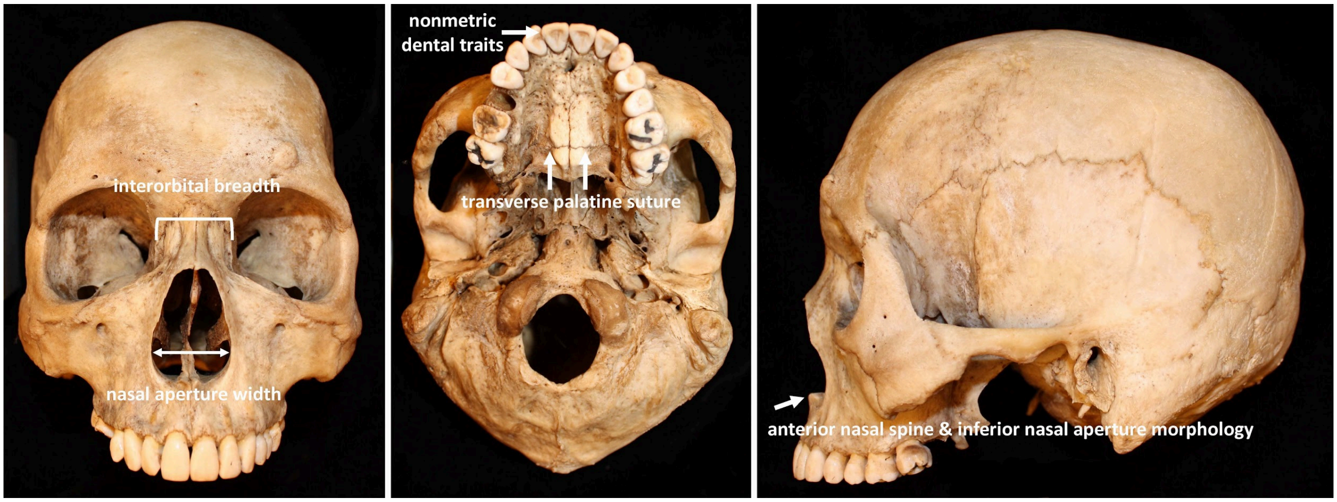

Figure 15.12 Skeletal traits commonly used in a morphological assessment of ancestry.

Finally, ancestry can also be determined through metric analyses. The computer program Fordisc is an anthropological tool used to estimate different components of the biological profile, including ancestry, sex, and stature. When using Fordisc, skeletal measurements are input into the computer software and the program employs multivariate statistical classification methods, including discriminant function analysis, to generate a statistically validated prediction for the geographic origin of unknown remains. Fordisc will also tell the analyst the likelihood of the prediction being correct, as well as how typical the metric data is for the assigned group.

Estimating Age

Estimating age from the skeleton relies on the measurement of two basic physiological processes: (1) growth and development and (2) degeneration (or aging). From fetal development on, our bones and teeth grow and change at a predictable rate. This provides for relatively accurate age estimates. After our bones and teeth cease to grow and develop, the bone begins to undergo structural changes, or degeneration, associated with aging. This does not happen at such predictable rates and, therefore, results in less accurate or larger age-range estimations.

During growth and development stages, two primary methods used for estimations of age of subadults (those under the age of 18) are **epiphyseal union** and **dental development**. **Epiphyseal union,** or **epiphyseal fusion,** refers to the appearance and closure of the epiphyseal plates between the primary centers of growth in a bone and the subsequent centers of growth (refer to Figure 15.7). Prior to complete union, the cartilaginous area between the primary and secondary centers of growth is also referred as the growth plates (Schaefer et al. 2009). Different areas of the skeleton have documented differences in the appearance and closure of epiphyses, making this a reliable method for aging subadult remains (SWGANTH 2013).

As an example of its utility in the identification process, epiphyseal development was used to identify two subadult victims of a fatal fire in Flint, Michigan, in February 2010. The remains represented two young girls, ages three and four. Due to the intensity of the fire, the subadult victims were differentiated from each other through the appearance of the patella, the kneecap. The patella is a bone that develops within the tendon of the quadriceps muscle at the knee joint. The patella begins to form around three to four years of age (Cunningham et al. 2016, 407–409). In the example above, radiographs of the knees showed the presence of a patella in the four-year-old girl and the absence of a clearly discernible patella in the three-year-old.

Figure 15.13 Dental development in a subadult.

Dental development begins during fetal stages of growth and continues until the complete formation and eruption of the adult third molars (if present). The first set of teeth to appear are called deciduous or baby teeth. Individuals develop a total of 20 deciduous teeth, including incisors, canines, and molars. These are generally replaced by adult dentition as an individual grows (Figure 15.13). A total of 32 teeth are represented in the adult dental arcade, including incisors, canines, premolars, and molars. When dental development is used for age estimations, researchers use both tooth-formation patterns and eruption schedules as determining evidence. For example, the crown of the tooth forms first followed by the formation of the tooth root. During development, an individual can exhibit a partially formed crown or a complete crown but a partially formed root. The teeth generally begin the eruption process once the crown of the tooth is complete. The developmental stages of dentition are one of the most reliable and consistent aging methods for subadults (Langley et al. 2017, 176–177).

Degenerative changes in the skeleton typically begin after 18 years of age, with more prominent changes developing after an individual reaches middle adulthood (commonly defined as after 35 years of age in osteology). These changes are most easily seen around joint surfaces of the pelvis, the cranial vault, and the ribs. In this chapter, we focus on the pubic symphysis surfaces of the pelvis and the sternal ends of the ribs, which show metamorphic changes from young adulthood to older adulthood. The **pubic symphysis** is a joint that unites the left and right halves of the pelvis. The surface of the pubic symphysis changes during adulthood, beginning as a surface with pronounced ridges (called billowing) and flattening with a more distinct rim to the pubic symphysis as an individual ages. As with all metamorphic age changes, older adults tend to develop lipping around the joint surfaces as well as a breakdown of the joint surfaces. The most commonly used method for aging adult skeletons from the pubic symphysis is the Suchey-Brooks method (Brooks and Suchey 1990; Katz and Suchey 1986). This method divides the changes seen with the pubic symphysis into six phases based on macroscopic age-related changes to the surface. Figure 15.14 provides a visual of the degenerative changes that typically occur on the pubic symphysis.

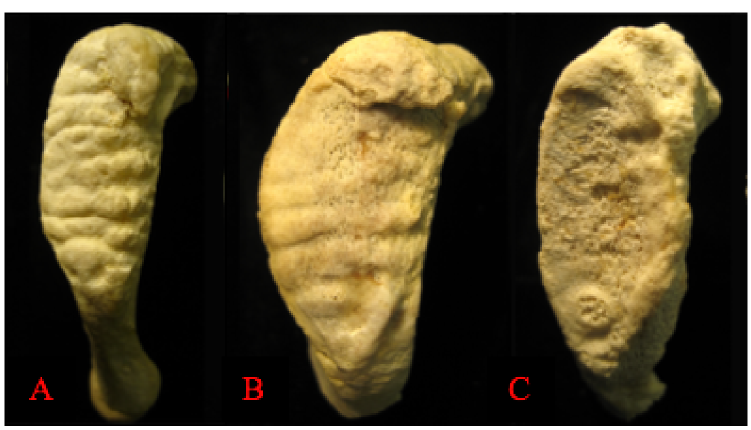

Figure 15.14 Examples of degenerative changes to the pubic symphysis: (A) young adult; (B) middle adult; (C) old adult.

The sternal end of the ribs, the **anterior** end of the rib that connects via cartilage to the sternum, is also used in age estimations of adults. This method, first developed by M. Y. İşcan and colleagues, looks at both the change in shape of the sternal end but also the quality of the bone (İşcan et al. 1984; İşcan et al. 1985). The sternal end first develops a billowing appearance in young adulthood. The bone typically develops a wider and deeper cupped end as an individual ages. Older adults tend to exhibit bony extensions of the sternal end rim as attaching cartilage ossifies. Figure 15.15 provides a visual of the degenerative changes that typically occur in sternal rib ends.

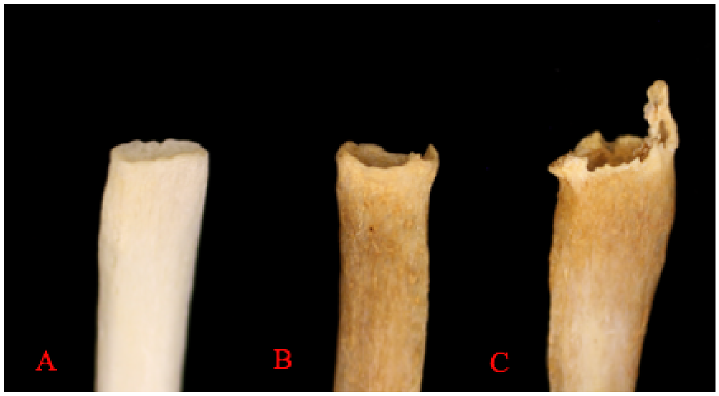

Figure 15.15 Examples of degenerative changes to the sternal rib end: (A) young adult; (B) middle adult; (C) old adult.

Estimating Stature

Stature, or height, is one of the most prominently recorded components of the biological profile. Our height is recorded from infancy through adulthood. Doctor's appointments, driver's license applications, and sports rosters all typically involve a measure of stature for an individual. As such, it is also a component of the biological profile nearly every individual will have on record. Bioarchaeologists and forensic anthropologists use stature estimation methods to provide a range within which an individual's biological height would fall. **Biological height** is a person's true anatomical height. However, the range created through these estimations is often compared to **reported stature**, which is typically self-reported and based on an approximation of an individual's true height (Ousley 1995).

In June 2015, two men were shot and killed in Granite Bay, California, in a double homicide. Investigators were able to locate surveillance camera footage from a gas station where the two victims were spotted in a car with another individual believed to be the perpetrator in the case. The suspect, sitting behind the victims in the car, hung his right arm out of the window as the car drove away. The search for the perpetrator was eventually narrowed down to two suspects. One suspect was 5´ 8" while the other suspect was 6´ 4", representing almost a foot difference in height between the two. Forensic anthropologists were given the dimensions of the car (for proportionality of the arm) and were asked to calculate the stature of the suspect in the car from measurements of the suspect's forearm hanging from the window. Approximate lengths of the bones of the forearm were established from the video footage and used to create a predicted stature range. Stature estimations from skeletal remains typically look at the correlation between the measurements of any individual bone and the overall measurement of body height. In the case above, the length of the right forearm pointed to the taller of the two suspects who was subsequently arrested for the homicide.

Certain bones, such as the long bones of the leg, contribute more to our overall height than others and can be used with mathematical equations known as regression equations. **Regression methods** examine the relationship between variables such as height and bone length and use the correlation between the variables to create a prediction interval (or range) for estimated stature. This method for calculating stature is the most commonly used method (SWGANTH 2012). Figure 15.16 shows the measurement of the bicondylar length of the femur for stature estimations.

Figure 15.16 Image of measurement of the bicondylar length of the femur, often used in the estimation of living stature.

Identification Using Individualizing Characteristics

One of the most frequently requested analyses within the forensic anthropology laboratory is assistance with the identification of unidentified remains. While all components of a biological profile, as discussed above, can assist law enforcement officers and medical examiners to narrow down the list of potential identifications, a biological profile will not lead to a **positive identification**. The term *positive identification* refers to a scientifically validated method of identifying previously unidentified remains. Presumptive identifications, however, are not scientifically validated; rather, they are based on circumstances or scene context. For example, if a decedent is found in a locked home with no evidence of forced entry but the body is no longer visually identifiable, it may be presumed that the remains belong to the homeowner. Hence, a presumptive identification.

The medicolegal system ultimately requires that a positive identification be made in such circumstances, and a presumptive identification is often a good way to narrow down the pool of possibilities. Biological profile information also assists with making a presumptive identification based on an individual's phenotype in life (e.g., what they looked like). As an example, a forensic anthropologist may establish the following components of a biological profile: white male, between the ages of 35 and 50, approximately 5′ 7″ to 5′ 11″. While this seems like a rather specific description of an individual, you can imagine that this description fits dozens, if not hundreds, of people in an urban area. Therefore, law enforcement can use the biological profile information to narrow their pool of possible identifications to include only white males who fit the age and height outlined above. Once a possible match is found, the decedent can be identified using a method of positive identification.

Positive identifications are based on what we refer to as individualizing traits or characteristics, which are traits that are unique at the individual level. For example, brown hair is not an individualizing trait as brown is the most common hair color in the U.S. But, a specific pattern of dental restorations or surgical implants can be individualizing, because it is unlikely that you will have an exact match on either of these traits when comparing two individuals.

A number of positive methods are available to forensic anthropologists, and for the remainder of this section we will discuss the following methods: comparative medical and dental radiography and identification of surgical implants.

Comparative medical and dental radiography is used to find consistency of traits when comparing antemortem records (medical and dental records taken during life) with images taken postmortem (after death). Comparative medical radiography focuses primarily on features associated with the skeletal system, including trabecular pattern (internal structure of bone that is honeycomb in appearance), bone shape or cortical density (compact outer layer of bone), and evidence of past trauma or skeletal pathology. Other individualizing traits include the shape of various bones or their features, such as the frontal sinuses (Figure 15.17).

Figure 15.17 Example of the unique shape of the frontal sinus.

Comparative dental radiography focuses on the number, shape, location, and orientation of dentition and dental restorations in antemortem and postmortem images. While there is not a minimum number of matching traits that need to be identified for an identification to be made, the antemortem and postmortem records should have enough skeletal or dental consistencies to conclude that the records did in fact come from the same individual (SWGANTH 2010a). Consideration should also be given to population-level frequencies of specific skeletal and dental traits. If a trait is particularly common within a given population, it may not be a good trait to utilize for positive identification.

Figure 15.18 Image of joint replacement in the right shoulder.

Surgical implants or devices can also be used for identification purposes (Figure 15.18). These implements are sometimes recovered with human remains. One of the ways forensic anthropologists can use surgical implants to assist in decedent identification is by providing a thorough analysis of the implant and noting any identifying information such as serial numbers, manufacturer symbols, and so forth. This information can then sometimes be tracked directly to the manufacturer or the place of surgical intervention, which may be used to identify unknown remains (SWGANTH 2010a).

TRAUMA ANALYSIS

Types of Trauma

Within the field of anthropology, **trauma** is defined as an injury to living tissue caused by an extrinsic force or mechanism (Lovell 1997:139). Forensic anthropologists can assist a forensic pathologist by providing an interpretation of the course of events that led to skeletal trauma. Within the field of bioarchaeology, trauma analyses may contribute to a deeper understanding of past lifeways and interpersonal relationships. Within this section, the different types of trauma will be briefly outlined. Next, the timing of the injury (e.g., did trauma occur before, at or around, or after the time of death) will be discussed. Finally, the section will conclude with a discussion of how trauma interpretation is performed in the forensic anthropology laboratory.

Typically, traumatic injury to bone is classified into one of four categories, defined by the trauma mechanism. A trauma mechanism refers to the force that produced the skeletal modification and can be classified as (1) sharp force, (2) blunt force, (3) projectile, or (4) thermal (burning). Each type of trauma, and the characteristic pattern(s) associated with that particular categorization, will be discussed below.

First, let's consider *sharp-force trauma*, which is caused by a tool that is edged, pointed, or beveled—for example, a knife, saw, or machete (SWGANTH 2011). The patterns of injury resulting from sharp-force trauma include linear incisions created by a sharp, straight edge; punctures; and chop marks (Figure 15.19; SWGANTH 2011). When observed under a microscope, an anthropologist can often determine what kind of tool created the bone trauma. For example, a power saw cut will be discernible from a manual saw cut.

Figure 15.19 Example of sharp-force trauma (sword wound) to the frontal bone.

Figure 15.20 Example of multiple blunt force impacts to the left parietal and frontal bones.

Second, *blunt-force trauma* is defined as "a relatively low-velocity impact over a relatively large surface area" (Galloway et al. 1999, 5). Blunt-force injuries can result from impacts from clubs, sticks, fists, and so forth. Blunt-force impacts typically leave an injury at the point of impact but can also lead to bending and deformation in other regions of the bone. Depressions, fractures, and deformation at and around the site of impact are all characteristics of blunt-force impacts (Figure 15.20). As with sharp-force trauma, an anthropologist attempts to interpret blunt-force injuries, providing information pertaining to the type of tool used, the direction of impact, the sequence of impacts, if more than one, and the amount of force applied.

Third, *projectile trauma* refers to high-velocity trauma, typically affecting a small surface area (Galloway et al. 1999, 6). Projectile trauma results from fast-moving objects such as bullets or shrapnel. It is typically characterized by penetrating defects or embedded materials (Figure 15.21). When interpreting injuries resulting from projectile trauma, an anthropologist can often offer information pertaining to the type of weapon used (e.g., rifle vs. handgun), relative size of the bullet (but not the caliber of the bullet), the direction the projectile was traveling, and the sequence of injuries if there are multiple present.

Figure 15.21 Example of projectile trauma with an entrance wound to the frontal bone and exit wound visible on the occipital.

Finally, *thermal trauma* is a bone alteration that results from bone exposure to extreme heat. Thermal trauma can result in cases of house or car fires, intentional disposal of a body in cases of homicidal violence, plane crashes, and so on. Thermal trauma is most often characterized by color changes to bone, ranging from yellow to black (charred) or white (calcined). Other bone alterations characteristic of thermal trauma include delamination (flaking or layering due to bone failure), shrinkage, fractures, and heat-specific burn patterning. When interpreting injuries resulting from thermal damage, an anthropologist can differentiate between thermal fractures and fractures that occurred before heat exposure, thereby contributing to the interpretation of burn patterning (e.g., was the individual bound or in a flexed position prior to the fire).

While there are characteristic patterns associated with the four categories of bone trauma, it is also important to note that these bone alterations do not always occur independently of different trauma types. An individual's skeleton may present with multiple different types of trauma, such as a projectile wound and thermal trauma. Therefore, it is important that the anthropologist recognize the different types of trauma and interpret them appropriately.

Timing of Injury

Another important component of any anthropological trauma analysis is the determination of the timing of injury (e.g., when did the injury occur). Timing of injury is traditionally split into one of three categories: **antemortem** (before death), **perimortem** (at or around the time of death), and **postmortem** (after death). This classification system differs slightly from the classification system used by the pathologist because it specifically references the qualities of bone tissue and bone response to external forces. Therefore, the perimortem interval (at or around the time of death) means that the bone is still fresh and has what is referred to as a green bone response, which can extend past death by several weeks or even months. For example, in cold or freezing temperatures a body can be preserved for extended periods of time increasing the perimortem interval, while in desert climates decomposition is accelerated, thereby significantly decreasing the postmortem interval (Galloway et al. 1999, 12). Antemortem injuries (occurring well before death and not related to the death incident) are typically characterized by some level of healing, in the form of a fracture callus or unification of fracture margins. Finally, postmortem injuries (occurring after death, while bone is no longer fresh) are characterized by jagged fracture margins, resulting from a loss of moisture content during the decomposition process (Galloway et al. 1999, 16). In general, all bone traumas should be classified according to the timing of injury, if possible. This information will help the medical examiner or pathologist better understand the circumstances surrounding the decedent's death, as well as events occurring during life and after the final disposition of the body.

The Role of the Forensic Anthropologist in Trauma Analysis

Within the medicolegal system, forensic anthropologists are often called upon by the medical examiner, forensic pathologist, or coroner to assist with an interpretation of trauma. The forensic anthropologist's main focus in any trauma analysis is the underlying skeletal system—as well as, sometimes, cartilage. Analysis and interpretation of soft tissue injuries fall within the purview of the medical examiner or pathologist. It is also important to note that the main role of the forensic anthropologist is to provide information pertaining to skeletal injury to assist the medical examiner/pathologist in their final interpretation of injury. Forensic anthropologists do not hypothesize as to the cause of death of an individual. Instead, a forensic anthropologist's report should include a description of the injury (e.g., trauma mechanism, number of injuries, location, timing of injury); documentation of the injury, which may be utilized in court testimony (e.g., photographs, radiographs, measurements); and, if applicable, a statement as to the condition of the body and state of decomposition, which may be useful for understanding the depositional context (e.g., how long has the body been exposed to the elements; was it moved or in its original location; are any of the alterations to bone due to environmental or faunal exposure instead of intentional human modification).

BONE PATHOLOGY

While there is a wide range of variation within the human skeletal system, bone development can also occur pathologically. Bone pathology can occur when there is excessive bone growth (osteoblastic activity or bone building) or bone is destroyed unnecessarily (osteoclastic activity or bone breakdown). Osteoblastic (bone building) and osteoclastic (bone destruction or breakdown) activities are normal processes of bone development, growth, and maintenance; however, when bone growth or breakdown exceeds what is necessary, the bony change can be classified as pathological, resulting in a bone pathology.

Types of Bone Pathology

For the purposes of this chapter, we will focus on both osteoblastic and osteoclastic pathologies of the human skeleton. In addition to considering whether a pathology is osteoclastic or osteoblastic, it is also important to classify a pathology according to its origin. Bone pathologies can be classified in a number of ways, including:

- congenital: occurring in the developmental period, often hereditary;
- traumatic: resulting from extrinsic factors and forces;
- degenerative: causing the degeneration or breakdown of bone tissue;
- infectious: resulting from bacterial, viral, or fungal agents;
- circulatory: resulting from a disruption in the relationship between the skeletal and circulatory system;
- metabolic: resulting from nutrient deficiencies;
- endocrinological: caused by hormonal imbalances; and
- neoplastic: related to abnormal growth, both benign and malignant, of bone tissue.

For the remainder of this section, we will focus on six different bone pathologies: (1) osteosarcoma, (2) osteogenesis imperfecta, (3) rickets, (4) achondroplasia, (5) Paget's disease of bone, and (6) diffuse idiopathic skeletal hyperostosis (DISH).

Osteosarcoma

Osteosarcoma is a type of neoplastic bone pathology. Characterized by malignant tumors that begin within bone tissues, osteosarcoma is a primary bone cancer (meaning it begins directly in bone tissue, rather than spreading to bone from other body tissues). Malignant tumors associated with osteosarcoma usually occur during growth and development and are observed most often in adolescents and young adults (Ortner and Putschar 1981, 384). Tumors are most frequently observed near the ends of long bones (Figure 15.22; Ortner and Putschar 1981, 384).

Osteogenesis Imperfecta

Figure 15.23 X-ray of the forearms of an individual with osteogenesis imperfecta (note the presence of multiple healing fractures).

Osteogenesis Imperfecta (OI) is a congenital bone pathology characterized by bones with low collagen content, leading to frequent fracturing (Ortner and Putschar 1981, 337). However, OI can also occur as a result of a spontaneous mutation. The disease is characterized by multiple fractures throughout the skeleton, particularly in the long bones (Figure 15.23). Depending on the type of OI, the disease is either manifest at birth or during childhood or adolescence (Ortner and Putschar 1981, 337). In addition to their susceptibility to easily fractured bones, individuals with OI are typically shorter in stature and may be subject to fracturing of tooth enamel and premature tooth loss (Ortner and Putschar 1981, 337).

Figure 15.22 Osteosarcoma on a left human femur.

Rickets

Figure 15.24 Example of Rickets in long bones of the leg.

Rickets is a metabolic bone pathology resulting from a Vitamin D deficiency in childhood (Ortner and Putschar 1982, 273). Vitamin D is essential to the mineralization of bone tissue and is characterized by a wide variety of cranial and postcranial changes, including the following: asymmetrical deformities of the skull, bowing of the long bones, vertebral compression fractures, and a smaller, thicker pelvis (Figure 15.24; Ortner and Putschar 1981, 273–278).

Achondroplasia

Figure 15.25 A cast of a complete skeleton of an adult female skeleton with achondroplasia.

Achondroplasia is a congenital bone pathology resulting from an abnormality in the conversion of cartilage to bone and is the most common form of dwarfism (Ortner and Putschar 1981, 329). The skeletal manifestations of achondroplasia are most apparent in the long bones comprising the arms and legs, while the trunk is of relatively normal proportions in individuals with achondroplasia (Figure 15.25). On average, males with achondroplasia are approximately 4´ 4" tall and females are approximately 4´ 1" tall (NIH 2019).

Paget's Disease of Bone

Paget's disease of bone is a disease of unknown origin that causes bones to grow larger and weaker over time (NIH 2019). The disease is marked by both osteoblastic and osteoclastic activity, with excessive osteoclastic resorption followed by osteoblastic proliferation leading to unnecessary amounts of new woven bone (Ortner and Putschar 1981, 309). The disease typically does not appear until the fourth or fifth decade of life and is more common in males than females (Ortner and Putschar 1981, 309). Paget's disease of bone can affect any bone, but the most commonly affected elements include the spine, pelvis, skull, and legs. The frequency of osteosarcoma is also higher among individuals with Paget's disease of bone (NIH 2019).

Diffuse Idiopathic Skeletal Hyperostosis (DISH)

DISH is a bone pathology characterized by a hardening (calcification or buildup of calcium salts) of the ligaments and tendons of the vertebral column. While DISH is observed in other areas of the skeleton, the vertebral column is the most frequently affected region. DISH is more prevalent in males than females and typically is observed in older adults (50-plus years) (NIH 2019). Recent medical research suggests that DISH results from abnormal osteoblastic activity in the spine, leading to excessive bone growth (NIH 2019).

TAPHONOMY

What Happened to the Remains After Death?

The majority of the skeletal analysis process revolves around the identity of the deceased individual. However, there is one last, very important question bioarchaeologists and forensic anthropologists should ask: What happened to the remains after death? Generally speaking, processes that alter the bone after death are referred to as taphonomic changes.

The term *taphonomy* was originally used to refer to the processes through which organic remains mineralize, also known as fossilization. Within the context of biological anthropology, the term *taphonomy* is better defined as the study of what happens to human remains after death. Initial factors affecting a body after death include processes such as decomposition and scavenging by animals. However, taphonomic processes encompass much more than the initial period after death. For example, plant root growth can leach minerals from bone, leaving a distinctive mark. Sunlight can bleach human remains, leaving exposed areas whiter than those which remained buried. Water can wear the surface of the bone until it becomes smooth.

Some taphonomic processes can help a forensic anthropologist estimate the relative amount of time human remains have been exposed to the elements. For example, root growth through a bone would certainly indicate a body was buried for more than a few days. Forensic anthropologists must be very careful when attempting to estimate time since death based on taphonomic processes as environmental conditions can greatly influence the rate at which taphonomic processes progress. For example, in cold environments, tissue may decay slower than in warm, moist environments.

The study of the decomposition and placement of an individual's body in the grave can also help bioarchaeologists understand more about how the body was placed and treated, and if there were any rituals that took place during the burial. For example, ochre, a mineral used as a pigment in paintings and dyes throughout human history, can stain bone and be an indication of ceremonial practice related to burial. Likewise, corrosion of different kinds of metals placed as grave goods or used as material in coffins can stain bone. For example, in a sample of medieval and post-medieval Spanish and Basque skeletons from the Cathedral of Santa Maria, Kimberly Hopkinson and colleagues (2008) noted a bright green to turquoise staining in some of the skeletons' teeth. The researchers believe that the staining was due to an ancient Greek practice of placing a coin in the mouth of the deceased to serve as the payment for the ferryman of Hades, Charon, who transported the deceased across the river that divided the world of the living from that of the dead. Hopkinson and colleagues determined that as the copper component of the bronze coins reacted with acid, it stained the teeth and surrounding bone, leaving evidence of the ancient Greek burial practice.

Both bioarchaeologists and forensic anthropologists must contend with taphonomic processes that affect the preservation of bones. For example, high acidity in the soil can break down human bone to the point of crumbling. In addition, when noting trauma, they must be very careful not to confuse postmortem (after death) bone damage with trauma.

A short description and photographic examples of several different types of taphonomic processes are shown below.

Figure 15.26 Rodent gnawing.

Rodent gnawing: When rodents, such as rats and mice, chew on bone, they leave sets of parallel grooves. The shallow grooves are etched by the rodent's incisors (Figure 15.26).

Figure 15.27 Carnivore damage.

Carnivore damage: Like rodents, carnivores leave destructive dental marks on bone. Tooth marks may be visible be in form of pit marks or punctures from the canines, as well as extensive gnawing or chewing of the ends of the bones to retrieve marrow (Figure 15.27).

Figure 15.28 Burned bone.

Burned bone: Fire causes observable damage to bone. Temperature and the amount of time bone is heated affect the appearance of the bone. Very high temperatures can crack bone and result in white coloration. Color gradients are visible in between high and lower temperatures, with lower temperatures resulting in black coloration from charring. Cracking can also reveal information about the directionality of the burn (Figure 15.28).

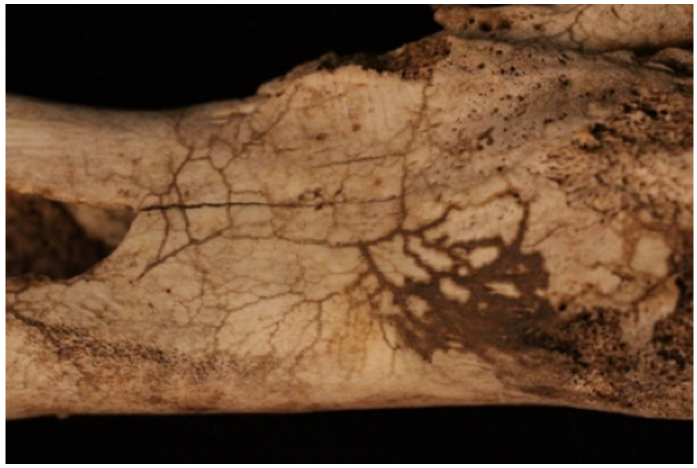

Figure 15.29 Root etching.

Root etching: Plants can alter bone. Specifically, plant roots can etch the outer surface of the bone, leaving grooves where the roots attached as they leached nutrients. During this process, the plant's roots secrete acid that breaks down the surface of the bone (Figure 15.29).

Figure 15.30 Weathering.

Weathering: Many different environmental conditions affect bone. River transport can smooth the surface of the bone due to water abrasion. Sunlight can bleach the exposed surface of bone. Dry and wet environments or the mixture of both types of environments can cause cracking and exfoliation of the surface. Burial in different types of soil can cause discoloration, and exposure can cause degreasing (Figure 15.30).

Figure 15.31 Cut marks.

Cut marks: Humans also alter bone by cutting, scraping, or sawing it directly or in the process of removing tissue. The groove pattern—that is, the depth and width of the cuts—can help identify the tool used in the cutting process (Figure 15.31).

ETHICS AND HUMAN RIGHTS

Working with human remains requires a great deal of consideration and respect for the dead. Forensic anthropologists and bioarchaeologists have to think about the ethics beyond our use of human remains for scientific purposes. How do we conduct casework in the most respectable manner possible? This section will discuss several ethical issues to consider when contemplating a career in forensic anthropology and bioarchaeology. While there are a wide range of ethical considerations within both subfields, this chapter will focus on two major categories: working with human remains and acting as an expert within the medicolegal system.

Working with Human Remains

Forensic anthropologists and bioarchaeologists work with human remains in a number of contexts, including casework, excavation, research, and teaching. When working with human remains, it is always important to use proper handling techniques. To prevent damage to skeletal remains, bones should be handled over padded surfaces. Skulls should never be picked up by placing fingers in the eye orbits, foramen magnum (hole at the base of the skull for entry of the spinal cord), or through the zygomatic arches (cheekbones). Human remains, whether related to casework, fieldwork, donated skeletal collections, or research, were once living human beings. It is important to always bear in mind that work with remains should be ingrained with respect for the individual and his or her relatives. In addition to fieldwork, casework, and teaching, anthropologists are often invited to work with remains that come from a bioarchaeological context or from a human rights violation. While this discussion of ethics is not comprehensive, two case examples will be provided below in which an anthropologist must consider the ethical standards outlined above.

NAGPRA

NAGPRA stands for the Native American Grave Protection and Repatriation Act, a federal law enacted in 1990 (NAGPRA 1990). NAGPRA provides protections and establishes repatriation procedures for Native American and Native Hawaiian remains, cultural items, and sacred objects. Human remains and associated artifacts, curated in museum collections and federally funded institutions, are subject to three primary provisions outlined by the NAGPRA statute: (1) protection for Native graves on federal and private land; (2) recognition of tribal authority on such lands; and (3) the requirement that all Native skeletal remains and associated artifacts be inventoried and culturally affiliated groups be consulted concerning decisions related to ownership and final disposition (Rose et al. 1996). NAGPRA legislation was enacted to ensure ethical consideration and treatment of Native remains and, in many cases, has improved dialogue between scientists and Native groups.

SPECIAL TOPIC: NATIVE AMERICAN GRAVES PROTECTION AND REPATRIATION ACT (NAGPRA)

- For more information on NAGPRA, visit:https://www.usbr.gov/nagpra/.
- For the text of the law, visit: https://www.nps.gov/history/local-law/FHPL_NAGPRA.pdf.

Modern Human Rights Violations

Forensic anthropologists may also be called to participate in criminal investigations involving human rights violations. Anthropological investigations may include assistance with identifications, determination of the number of victims, and trauma analyses. In this role, forensic anthropologists play an integral part in promoting human rights, preventing future human rights violations, and providing the evidence necessary to prosecute those responsible for past events. A few ethical considerations for the forensic anthropologist involved in human rights violations include the use of appropriate standards of identification, presenting reliable and unbiased testimony, and maintaining preservation of evidence. For a more comprehensive history of forensic anthropological contributions to human rights violation investigation, see Ubelaker 2018.

Acting as an Expert in the Medicolegal System

In addition to the ethical considerations involved with working with human skeletal remains, forensic anthropologists must abide by ethical standards when they act as experts within the medicolegal system. The role of the forensic anthropologist within the medicolegal system is primarily to provide information to the medical examiner or coroner that will aid in the identification process or determination of cause and manner of death. Forensic anthropologists also may be called to testify in a court of law. In this capacity, forensic anthropologists should always abide by a series of ethical guidelines that pertain to their interpretation, presentation, and preservation of evidence used in criminal investigations. First and foremost, practitioners should never misrepresent their training or education. When appropriate, outside opinions and assistance in casework should be requested (e.g., consulting a radiologist for radiological examinations or odontologist for dental exams). The best interest of the decedent should always take precedence. All casework should be conducted in an unbiased way, and financial compensation should never be accepted if it is incentive to take a biased stance regarding casework. All anthropological findings should be kept confidential, and release of information is best done by the medical examiner or coroner. Finally, while upholding ethical standards for oneself, a forensic anthropologist is also expected to report any perceived ethical violations committed by his or her peers.

Ethical standards for the field of forensic anthropology are outlined by the Organization of Scientific Area Committees (OSAC) for Forensic Science, administered by the National Institute of Standards and Technology (NIST). OSAC and NIST recently began an initiative to develop standards that would strengthen the practice of forensic science both in the United States and internationally. OSAC's main objective is to "strengthen the nation's use of forensic science by facilitating the development of technically sound forensic science standards and by promoting the adoption of those standards by the forensic science community" (NIST n.d.). Additionally, OSAC promotes the establishment of best practices and other guidelines to ensure that forensic science findings and their presentation are reliable and reproducible (OSAC 2018).

Review Questions

- What kinds of questions can bioarchaeologists answer from studying human skeletal remains?
- What is the main difference between bioarchaeology and forensic anthropology? (Hint: consider the age of the remains.)
- What are the seven primary steps involved in a skeletal analysis?
- What are the major components of a biological profile? Why are forensic anthropologists often tasked with creating biological profiles for unknown individuals?
- What are the four major types of skeletal trauma?
- What is taphonomy, and why is an understanding of taphonomy often critical in forensic anthropology analyses?
- What are some of the ethical considerations faced by forensic anthropologists and bioarchaeologists?

Key Terms

Antemortem trauma: Trauma occurring before death.

Anterior: Toward the front.

Bioarchaeology: The study of human remains excavated from archaeological sites .

Biological ancestry: Refers to the underlying genetic differences between modern populations.

Biological height: A person's true anatomical height.

Biological profile: An individual's identifying characteristics or biological information, commonly including sex, age, ancestry, and stature.

Burial assemblage: A set of human remains and associated artifacts associated with a single burial context.

Burial context: The circumstances surrounding the formation of a burial assemblage, an understanding of which can help inform our understanding and interpretation of the burial.

Commingled burials: Burial assemblages in which individual skeletons are not separated into discrete burials.

Compact (cortical) bone: The outer layer of bone, made up of densely arranged osseous (bone) tissue.

Dental development: The gradual replacement of deciduous (baby) teeth with adult teeth.

Epiphyseal union (or epiphyseal fusion): The appearance and closure of the epiphyseal plates between the primary centers of growth in a bone and the subsequent centers of growth.

Epiphyses: Ends of the bone, where growth occurs.

Forensic anthropology: The analysis of the skeletal remains of recently deceased individuals (typically within the last 50 years) within the context of the law—or, in other words, as part of a criminal investigation.

Gender: Culturally dependent identity of male or female.

Osteon: Primary structural unit of compact bone.

Perimortem trauma: Trauma occurring at or around the time of death.

Phenotype: A set of outwardly observable characteristics for an individual.

Positive identification: A scientifically validated method of identifying previously unidentified remains.

Postmortem trauma: Trauma occurring after death.

Pubic symphysis: A joint that joins the left and right halves of the pelvis anteriorly.

Regression methods: Mathematical analysis that examines the relationship between

dependent and independent variables.

Reported stature: Self-reported height.

Robusticity: Strength relative to size.

Spongy (trabecular) bone: The inner layer of bone comprised of loosely organized porous bone tissue whose appearance resembles that of a sponge.

Trauma: An injury to living tissue caused by an extrinsic force or mechanism. (See Lovell 1997, 139.)

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Dr. Ashley Kendell is currently an assistant professor and forensic anthropologist at Chico State. Prior to beginning her position at Chico State, she was a visiting professor at the University of Montana and the forensic anthropologist for the state of Montana. Dr. Kendell obtained her doctorate from Michigan State University, and her research interests include skeletal trauma analysis and digitization and curation methods for digital osteological data. She is also a Registry Diplomate of the American Board of Medicolegal Death Investigators. Throughout her doctoral program, she worked as a medicolegal death investigator for the greater Lansing, Michigan, area and was involved in the investigation of over 200 forensic cases.

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Alex Perrone is a lecturer in anthropology and biological sciences at California State University, Chico, and a lecturer in anthropology at Butte Community College. She is also the Supervisor of the Human Identification Laboratory in the Department of Anthropology at California State University, Chico. Her research interests include bioarchaeology, paleopathology, forensic anthropology, skeletal biology, California prehistory, and public health. She has worked on bioarchaeological and archaeological projects in Antigua, California, Hawaii, Greece, and the UK, and was an archaeological technician for the USDA Forest Service. She assists with training courses for local and federal law enforcement agencies and assists law enforcement agencies with the recovery and analysis of human remains.

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Dr. Colleen Milligan is a physical anthropologist with research interests in bioarchaeology, skeletal biology, and forensic anthropology. She has been a Fellow with the Department of Homeland Security and has assisted in forensic anthropology casework and recoveries in the State of Michigan and California. She has also assisted in community outreach programs in forensic anthropology and forensic science, as well as recovery training courses for local, state, and federal law enforcement officers. She is a certified instructor through Peace Officers Standards and Training (POST). Dr. Milligan serves as the current co-director of the Chico State Human Identification Laboratory.

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