Comparative Skeletal Anatomy

COMPARATIVE SKELETAL ANATOMY

A PHOTOGRAPHIC ATLAS FOR MEDICAL EXAMINERS, CORONERS, FORENSIC ANTHROPOLOGISTS, AND ARCHAEOLOGISTS

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PREFACE

Bones are frequently encountered in both archaeological and forensic contexts. In either situation it is critical that human remains are differentiated from non-human remains. In the realm of forensic investigations, this is usually the final determination. In the archaeological context, greater precision in identification may be warranted in order to draw conclusions about ancient diets, animal husbandry and hunting practices, and environmental reconstructions. This photographic atlas is designed to assist the archaeologist or forensic scientist (primarily zooarchaeologists and forensic anthropologists) in the recognition of various species that are commonly encountered in both contexts. Obviously the ability to differentiate between the bones of various species (let alone simply human vs non-human bones) is dependent upon the training of the analyst, but good reference material is also essential. While there are books dedicated to human osteology and books that focus on animal osteology, there is really nothing that brings the two together. It is our intent to fill this void with the compilation of photographs presented in this atlas. Greater attention is given to the postcranial remains, which are presented in standard anatomical orientations. In addition, "non-traditional" photographs of the various non-human species are also included in an attempt to bring together both anatomical and artistic images.

For this atlas, the large, non-human mammals include: horse (*Equus caballus*), cow (*Bos taurus*), black bear (*Ursus americanus*), white-tail deer (*Odocoileus virginianus*), pig (*Sus scrofa*), goat (*Capra hircus*), sheep (*Ovis aries*), and dog (*Canis familiaris*). All of these are compared to a modern adult male human skeleton.

The smaller non-human animals include: raccoon (*Procyon lotor*), opossum (*Didelphis virginiana*), cat (*Felis catus*), rabbit (*Oryctolagus cuniculus* and *Sylvilagus floridanus*), turkey (*Meleagris gallopavo*), duck (*Anas platyrhynchos*), chicken (*Gallus gallus*), rat (*Rattus norvegicus*), red fox (*Vulpes vulpes*), and snapping turtle (*Chelydra serpentina*). All of these are compared to a modern newborn human skeleton.

The first part of this book consists of a brief introduction followed by detailed black and white photographs of the key postcranial elements from the animals listed above. In order to show size and shape variations between the human and the non-human species selected for this atlas, scaled skeletal elements are pictured side-by-side. For example, a cow humerus and a human humerus are placed side-by-side in order for the reader to observe how they differ. Anterior (i.e., front or cranial in animals) and posterior (i.e., back or caudal in animals) views of each bone are presented. In some cases, medial or lateral views are also included.

The second part of the book consists of an overview of common butchering techniques used in traditional and commercial meat processing. This is followed by photographs of representative butchered bones. We have included a range of different butchery marks, including both prehistoric cut marks made with stone tools and historic cut marks made with cleavers and saws. We have also included examples of sawn human bones from a forensic case associated with intentional body dismemberment. Since bone was a common raw material throughout antiquity and up until the early 20th century, we have also illustrated a number of examples of worked bone artifacts.

Overall, we hope that this book will fill a void in the forensic science and archaeological literature, presenting comparisons between human and non-human bones that are useful to the archaeologist and forensic scientist. It is our goal that this book is frequently consulted as a laboratory and field reference guide...one that gets worn and discolored over the years from continued use and not a book that sits idle on a book shelf.

Bradley J. Adams
Pamela J. Crabtree

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About the Authors

Bradley J. Adams

Bradley J. Adams received his BA from the University of Kansas and his MA and PhD degrees from the University of Tennessee. He is currently the Director of the Forensic Anthropology Unit for the Office of Chief Medical Examiner (OCME) in New York City. He is also affiliated with numerous universities in the New York City area. In his present position with the OCME, Dr. Adams and his team are responsible for all forensic anthropology casework in the five boroughs of New York City (Manhattan, Brooklyn, Queens, the Bronx, and Staten Island). Prior to accepting the position in New York City, Dr. Adams was a forensic anthropologist and laboratory manager at the Central Identification Laboratory in Honolulu, Hawaii.

Pamela J. Crabtree

Pamela J. Crabtree is an associate professor of anthropology at New York University, where she has taught since 1990. Her area of specialization is zooarchaeology, and she has analyzed a wide variety of faunal collections from late prehistoric and early medieval Europe, the Middle East, and historic North America. Dr. Crabtree is co-author of *Exploring Prehistory: How Archaeology Reveals Our Past* (2006) and she is co-editor of *Ancient Europe: Encyclopedia of the Barbarian World 8000 BC–AD 1000*. She is currently a member of the archaeological team that is surveying the Iron Age site of Dún Ailinne in Ireland.

1 Introduction

Regardless of the context (forensic or archaeological), the correct identification of human and non-human remains is a very serious issue in osteological analyses. While the difference between various species is often very striking, it can also be quite subtle (Figure 1-01). Case studies and text books have highlighted similarities between some species, for example the hand and foot bones (metacarpals and metatarsals) of the human hand and the bear paw in the forensic realm (Byers 2005; Owsley and Mann 1990; Stewart 1979; Ubelaker 1989). These comparisons between the human and bear are also presented in Chapter 4 of this book. Sometimes the morphological similarity between species is quite unusual and counterintuitive. For example, there is a remarkable correspondence between an adult human clavicle and an adult alligator femur (Figure 1-02).

The goal of this book is to create a comprehensive photographic guide for use by experienced archaeologists and forensic scientists to distinguish human remains from a range of common animal species. The atlas illustrates the larger mammal species in comparison to adult human bones, while the smaller mammal, bird, and reptile species are compared to an infant human skeleton. We have chosen to photograph the Old World domesticates—cattle (*Bos taurus*) , sheep (*Ovis aries*) , goat (*Capra hircus*), horse (*Equus caballus*), and pig (*Sus scrofa*)—since these animals are frequently found on historic archaeological sites in North America, and they are commonly recovered from Neolithic and later sites in the Eastern Hemisphere. Furthermore, they are also common in modern contexts and could easily end up being submitted as a forensic case.

The atlas includes three domestic bird species; two of them, chicken (*Gallus gallus*) and duck (*Anas platyrhynchos*), were initially domesticated in the Eastern Hemisphere, while the third, turkey (*Meleagris gallopavo*), was first domesticated by Native Americans. We have also chosen to illustrate a range of North American wild mammals, including many that were frequently hunted by Native Americans in pre-Columbian and colonial times. These include black bear (*Ursus americanus*), white-tail deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), and opossum (*Didelphis virginiana*). We have also included two species of rabbits. The smaller rabbit is the native wild rabbit or cotton-tail (*Sylvilagus floridanus*), while the larger rabbit is a domestic rabbit (*Oryctolagus cuniculus*) which is originally of European origin. Commensal species are frequently found in historic-period archaeological sites, and we have illustrated two of the most common, dog (*Canis familiaris*) and cat (*Felis catus*). We have also included a chapter of miscellaneous photographs (Chapter 17). In this chapter various views are presented of infant and adult human skeletons, selected comparisons between human and red fox (*Vulpes vulpes*), bobcat (*Felis rufus*), rat (*Rattus norvegicus*), and snapping turtle (*Chelydra serpentina*). The snapping turtle is the only reptile that is included as many of the bones are distinctive is shape and they are commonly recovered from North American archaeological sites.

Fig. 1-01. Comparison from left to right of infant human, adult chicken, and adult cat right femora (anterior views).

Most archaeological faunal remains are the leftovers from prehistoric and historic meals. Many animal bones show traces of butchery that reveal the ways in which the carcass was dismembered. Furthermore, it is not unusual for food refuse to be mistaken for human remains and end up in the medical examiner or coroner system. In this atlas we have illustrated a range of different butchery marks and techniques (Chapter 18), including both prehistoric cut marks made with stone tools and historic cut marks made with cleavers and saws. We have also included examples of sawn and butchered faunal bones and have included schematic diagrams of modern, commercial butchery patterns. Since bone was a common raw material throughout antiquity and up until the early 20th century, we have also illustrated a number of examples of worked bone artifacts. Finally, knife cuts and saw marks in bone are not unique to non-human remains. There are numerous cases each year of intentional body mutilation using knifes and/or saws. In cases of human dismemberment (usually implying sawing through bones) or disarticulation (usually implying separation between joints) it is quite possible that a badly decomposed or skeletonized human body portion may

Fig. 1-02. Comparison of an adult human clavicle with alligator and crocodile femora; note the similar morphology between the human and nonhuman elements. Top is a left human clavicle, middle is a right *Crocodylus acutus* femur, bottom is a right *Alligator mississippiensis* femur.

appear non-human to the untrained eye. A forensic example of postmortem human dismemberment is also presented in Chapter 18 to show the similarity of tool mark evidence.

The ability to differentiate between complete or fragmentary human and non-human bones is dependent on the training of the analyst and the available reference and/or comparative material. It is truly a skill that requires years of training and experience and is not something that can be gleaned entirely from books. There is no substitute for coursework and training in osteology with actual skeletal material in order to appreciate the range of variation within all animal species. An experienced osteologist should always be consulted for confirmation of element type and species if there is any doubt.

ARCHAEOLOGICAL CONTEXT

Animal bones have played critical roles in archaeological interpretation for more than one hundred and fifty years of scientific endeavors. The discovery of the bones of extinct animals in association with simple chipped stone tools in sites in France and Britain helped to establish the antiquity of the human presence in Europe and to overthrow the traditional 6000-year biblical chronology for human life on earth. Faunal remains have also played a crucial role in the reconstruction of early human subsistence practices, in the study of animal domestication in both the Eastern Hemisphere and the Americas, and in the analysis of the ways in which historic cities were provisioned with food. Large numbers of animal bones are often recovered from archaeological sites, and these bones can be used to study past hunting practices, animal husbandry patterns, and diet. In order to use animal bones in archaeological interpretation, zooarchaeologists (archaeologists who specialize in the study of faunal remains) must be able to identify the bones, determine sex and age at death when possible, and examine the bones for evidence of butchery marks and traces of bone working.

While archaeologists expect to find human remains in cemeteries, human bones are often found in other contexts. For example, two adult human burials and the remains of several infants were unexpectedly recovered from the habitation area of the early Anglo-Saxon village site of West Stow in eastern England (West 1985: 58-59). This was the case even though the settlement site was associated with a nearby contemporary cemetery. In another example, at the late Neolithic site of Hougang near Anyang in China, burials of infants in pits or urns were associated with house construction activities (Chang 1986: 270). In short, zooarchaeologists and physical anthropologists must be able to confidently identify both animal bones and human remains in order to accurately interpret past cultures.

The first step in the analysis of animal bones recovered from archaeological sites is the careful identification of both body part and animal species. Precise identification requires a good comparative collection of modern specimens whose species, sex, and age are well-documented. However, a comparative collection must be supplemented by identification guides and atlases that can help the researcher distinguish between different species. Most zooarchaeological identification guides focus solely on non-human species, (e.g., Brown and Gustafson 1979; Cornwall 1956; Gilbert 1990; Gilbert, et al. 1981; Olsen 1964, 1968) even though human remains are commonly found in archaeological sites. One exception to this is Schmid (1972) who does illustrate human bones, but there is no comparison with subadult human bones.

FORENSIC CONTEXT

It is equally important for forensic scientists working with human skeletal remains to be able to differentiate between human and non-human bones. In the modern forensic context, it is quite common for non-human bones to be mistaken for human remains and end up in the medical examiner or coroner system. It is of obvious importance that they are correctly identified as such, or the consequences could be substantial. It is usually the role of a forensic anthropologist to make this assessment of "human vs. non-human" and generate the appropriate report. In most forensic scenarios, once a determination of non-human is made it is seldom of investigative significance to correctly identify the species. There are numerous skeletal anatomy books dedicated to human osteology (e.g., Bass 2005; Brothwell 1981; Scheuer and Black 2000; Steele and Bramblett 1988; White 2000; White and Folkens 2005). Some guides and textbooks on human osteology and forensic anthropology do include sections on differentiating between human and non-human remains (e.g., Bass 2005; Byers 2005; Ubelaker 1989) but these are more cursory discussions.

When attempting to differentiate between human and non-human skeletal remains, fragmentation only compounds the problem. If fragmentation is so extreme that gross identification of human versus non-human bone is not possible, microscopic (i.e., histological) techniques can be employed (e.g., Mulhern and Ubelaker 2001). Under magnification, the shape of the bone cells may be indicative of non-human bone, but this technique is not "fool proof" as some non-human animals (e.g., large dogs, bovines, and non-human primates) are nearly identical to humans microscopically. Our atlas will only focus on the gross assessment of bones.

BOOK TERMINOLOGY AND ORGANIZATION

In constructing this atlas, we have chosen to illustrate examples of both adult and juvenile animal bones, in addition to adult and infant human skeletons. Other guides to the identification of birds and mammals from archaeological sites illustrate only adult bones. However, many animal bones recovered from archaeological sites and within the forensic context are the remains of juvenile animals. Farmers who keep cattle for milk, for example, often slaughter excess male calves during their first year of life. In a meat-oriented economy, farmers frequently choose to slaughter adolescent animals, since these animals are nearly full-grown, and continuing to feed animals beyond adolescence results in only limited increases in meat output. We have included illustrations of both adult and juvenile pigs, and we have illustrated both an adult sheep and an immature goat. We have also photographed examples of immature chickens, since most chickens consumed today are quite young.

In general, the animals in this atlas are presented in the order of their size, progressing from largest to smallest. The corresponding human and non-human elements are presented alongside each other in order to fully appreciate the variation in size and shape between them. In order to add a scaled perspective, a metric ruler (centimeters) is present in each photograph along with a U.S. penny.

Bipedalism, upright walking on two legs, is one of the most important developments in all of human evolution. However, as a result of bipedalism, many human bones are oriented in somewhat different ways than comparable bones are in other mammals. In addition, the directional terms used to describe parts of the body differ somewhat between humans and other mammals (Figures 1-03 and 1-04). For example, in human osteology the term *anterior* is used to describe the front portion of a bone, while in quadrupeds the term *cranial* is used. Similarly, the back portion of the femur is described as *posterior* in humans, but it is described as *caudal* in other mammals. Different terms are also used for the lower portions of mammal limbs. For example, the surface of the forelimb (distal to the radius and ulna) that faces the ground is described as *palmar* (or *volar*), while the comparable surface in the hindlimb is described as *plantar*. The opposite surfaces of the bone are described as *dorsal*. The terms *proximal*, *distal*, *medial*, and *lateral* are used to describe surfaces in both human and non-human bones. For humans, we have used the directional terms as described in Bass (2005). For other mammals, they have used the terms as defined in Evans and de Lahunta (1980) and Getty (1975). In describing bird bones, we have followed the terminology used by Cohen and Sergeantson (1996).

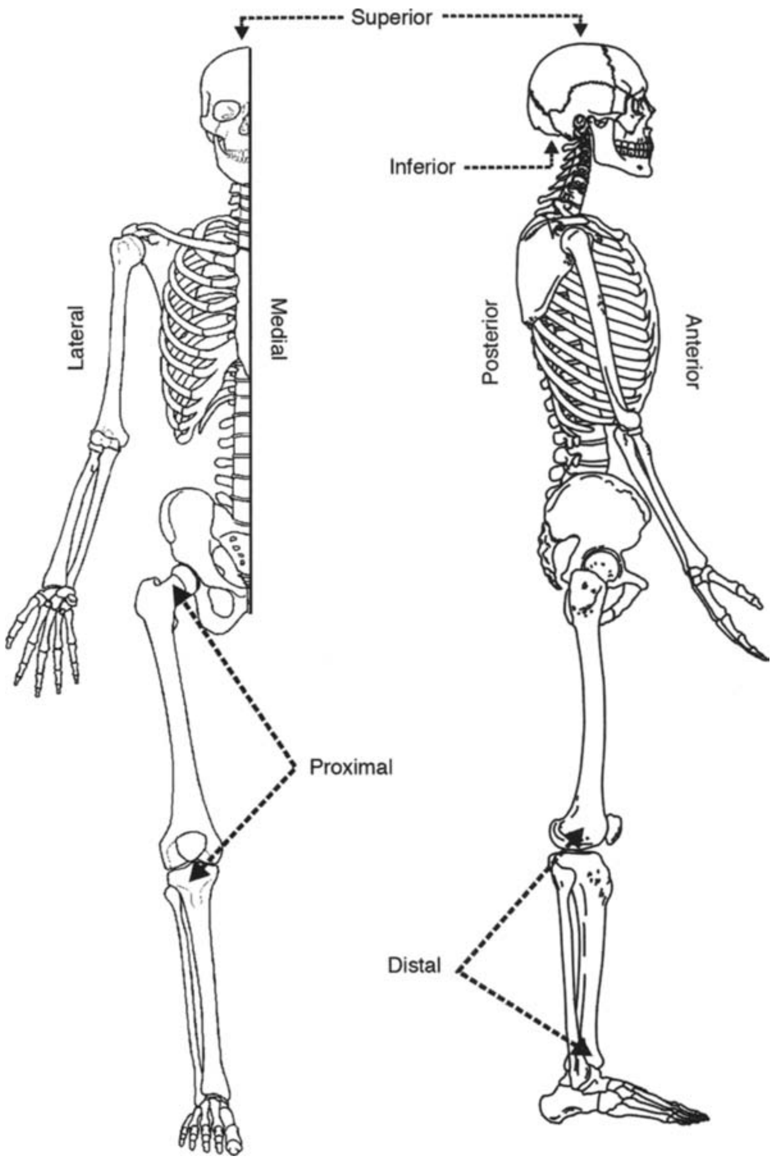

Fig. 1-03. Schematic diagram of human skeleton in standard anatomical position (i.e., standing with arms at the side and palms forward so that no bones are crossing) labeled with anatomical terminology.

BACKGROUND OF THE SPECIMENS INCLUDED IN THIS BOOK

Most of the non-human skeletons that are illustrated in this atlas come from the collections of the zooarchaeology laboratory in the Anthropology Department of New York University. The bear skeleton was borrowed from the Department of Mammology of the American Museum of Natural History. Most of the horse bones that are illustrated here are from a horse skeleton that was borrowed from the Museum Applied Science Center for Archaeology (MASCA) at the University of Pennsylvania Museum.

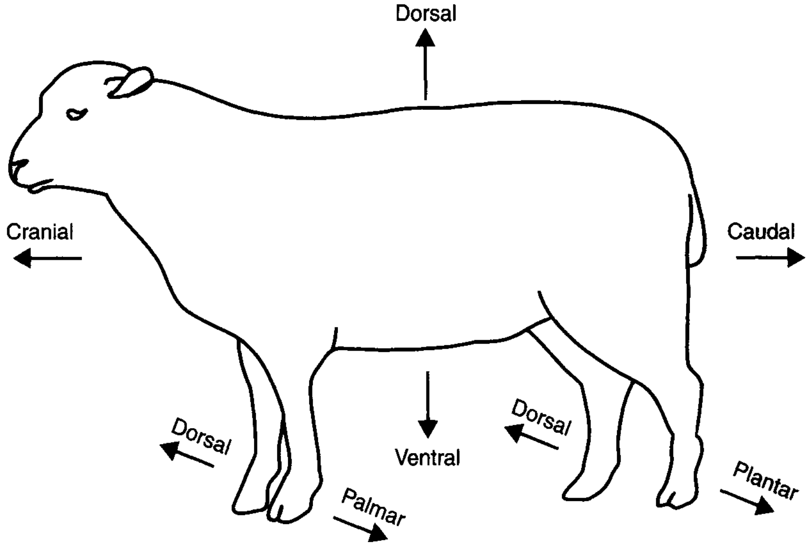

Fig. 1-04. Schematic Diagram of animal skeleton labeled with anatomical terminology.

The raccoon skeleton was borrowed from Susan Ant¢n. The alligator and crocodile femora were provided by the Herpetology Department at the American Museum of Natural History and were photographed by Ilana Solomon and Tam Nguyen. The original photograph of the turkey skull was provided courtesy of the National Wild Turkey Federation, while Gina Santucci performed the artistic modifications to the photograph. Seth Brewington provided the photograph of the antler comb from Iceland. The horse metacarpus and metatarsus were borrowed from the Zooarchaeology Laboratory in the Anthropology Department at Hunter College. Jeannette Fridie was a great help with many facets of this book. The human remains are from unidentified individuals that were analyzed at the Office of Chief Medical Examiner in New York City. We are grateful to everyone who loaned us specimens and assisted in this project.

2 Human vs Horse

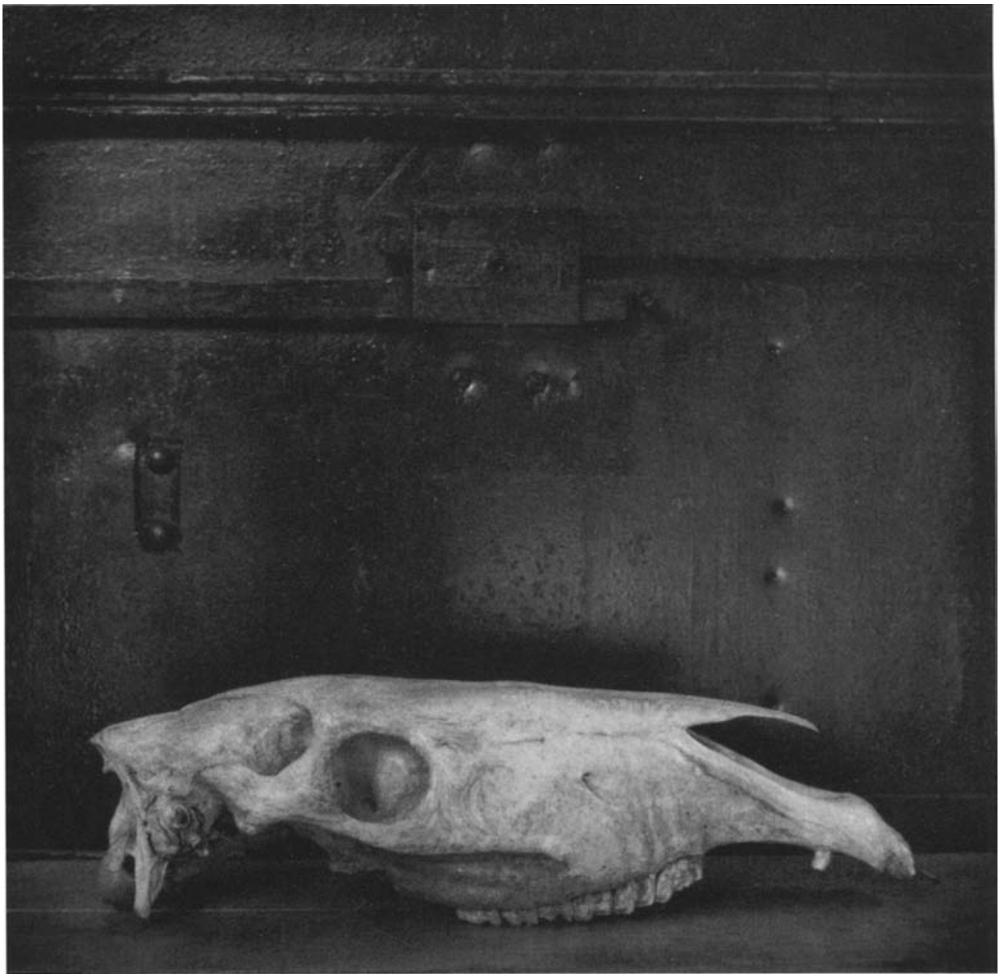

Fig. 2-00. A lateral view of the horse's cranium. The horse's dental formula is 3/3.0-1/0-1.3/3.3/3. Canines are usually seen only in males.

Fig. 2-01. A human right humerus (anterior view) is compared to a horse's right humerus (cranial view). The shaft of the horse's humerus has a large deltoid tuberosity. The proximal end of the horse's humerus includes an intermediate tubercle, which is not seen on the human humerus.

Fig. 2-02. A human right humerus (posterior view) is compared to a horse's right humerus (caudal view).

Fig. 2-03. A human right radius and ulna (anterior views) are compared to a horse's radius and ulna (cranial view). Note the large olecranon process on the horse's ulna.

Fig. 2-04. A human right radius and ulna (posterior views) are compared to a horse's radius and ulna (caudal view). Note that the horse's ulna tapers to a point about two-thirds of the way down the shaft of the radius.

Fig. 2-05. A human right radius and ulna (lateral views) are compared to a horse's radius and ulna (lateral view). The horse's ulna is partially fused to the radius in adults.

Fig. 2-06. A human right femur (anterior view) is compared to a horse's right femur (cranial view). The horse's femur shows a well developed third trochanter.

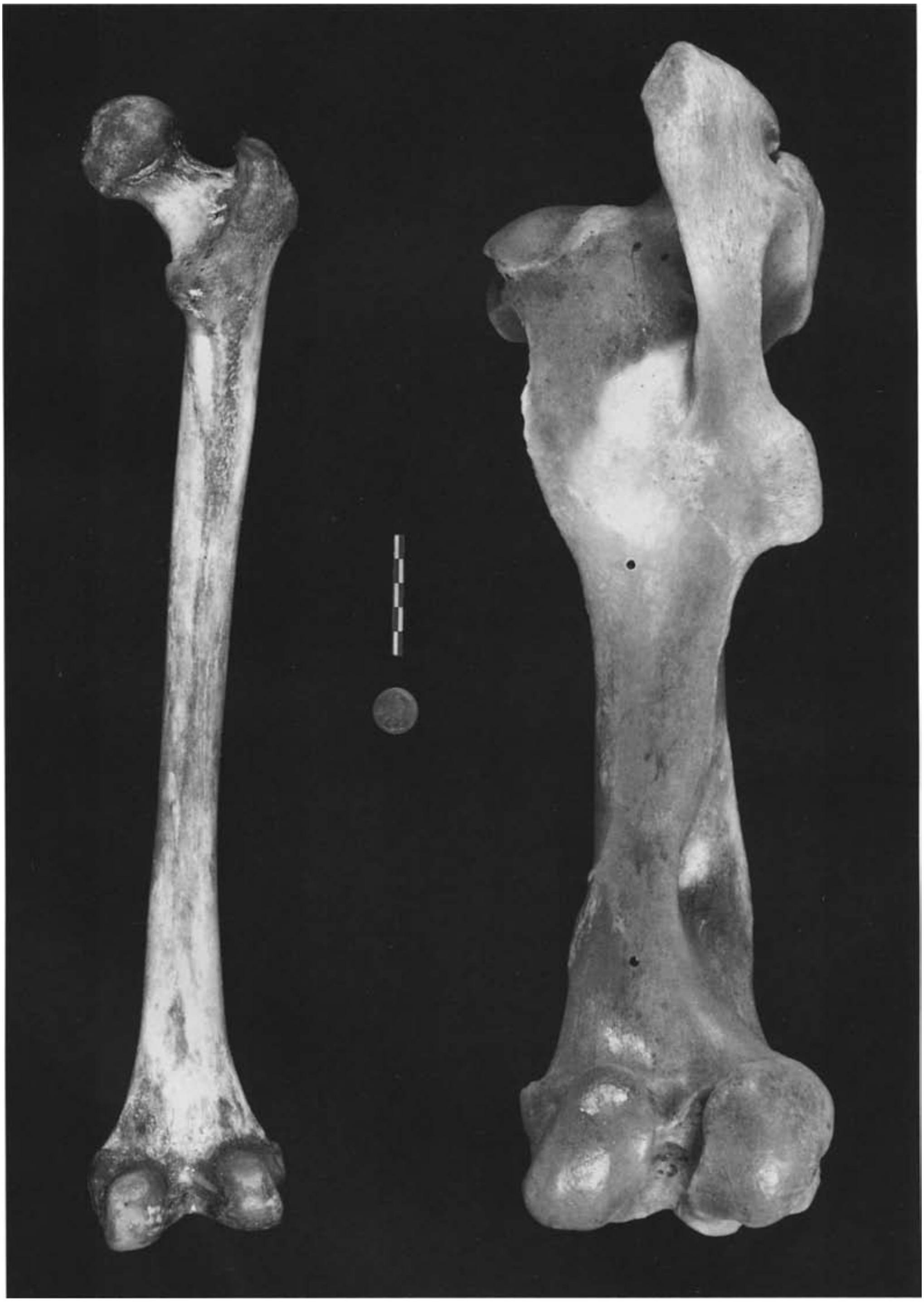

Fig. 2-07. A human right femur (posterior view) compared to a horse's right femur (caudal view).

Fig. 2-08. A human right tibia (anterior view) is compared to a horse's right tibia (cranial view). The horse distal tibia includes both a medial and a lateral malleolus. The lateral malleolus is the evolutionary remnant of the distal fibula.

Fig. 2-09. A human right tibia (posterior view) is compared to a horse's right tibia (caudal view).

Fig. 2-10. A human right tibia (lateral view) is compared to a horse's right tibia (lateral view).

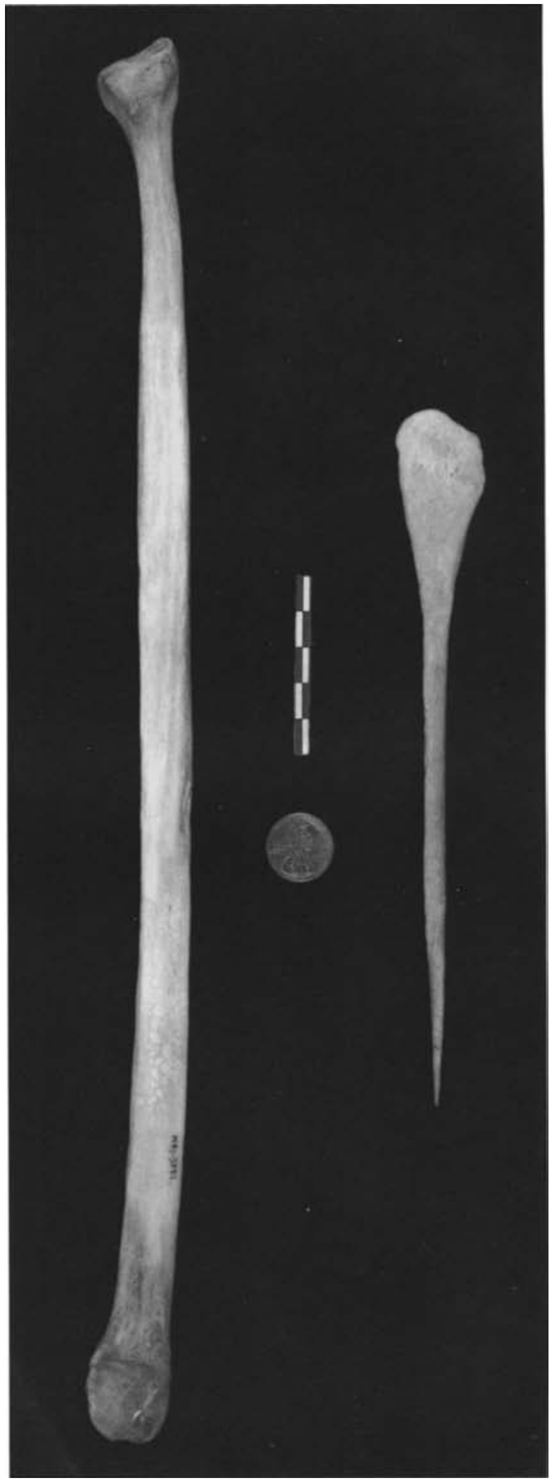

Fig. 2-11. A human right fibula (medial view) is compared to a horse's right fibula (lateral view). The horse's fibula is greatly reduced. The rounded head is transversely flattened, and the shaft tapers to a point.

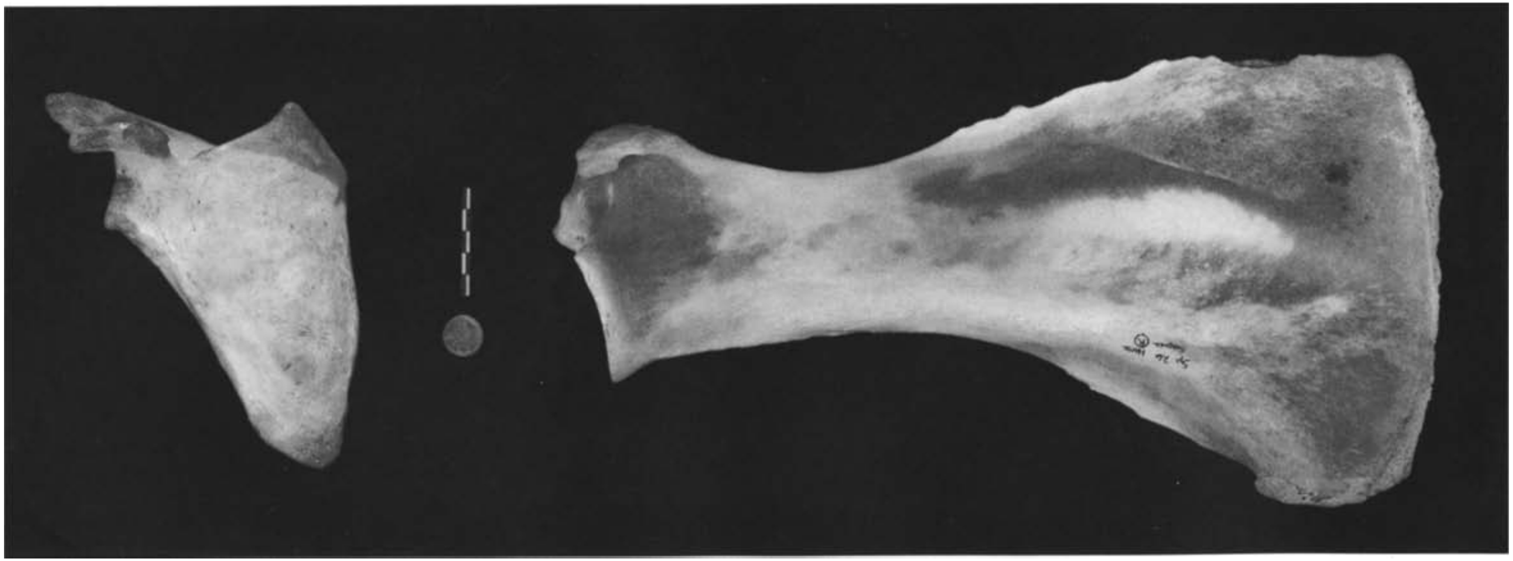

Fig. 2-12. A human right scapula (anterior view) is compared to a horse's right scapula (medial view). Both scapulae are oriented as they would be in a human.

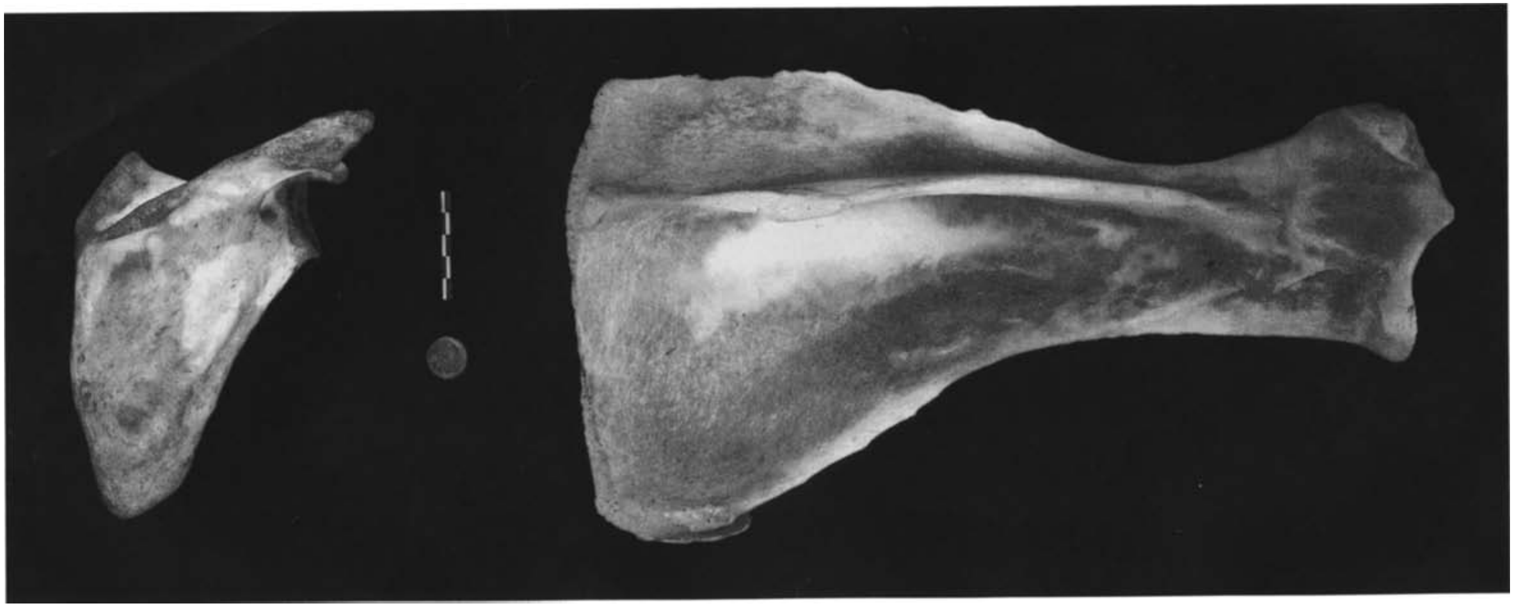

Fig. 2-13. A human right scapula (posterior view) is compared to a horse's right scapula (lateral view). Note that the spine of the horse's scapula rises from the scapular neck.

Fig. 2-14. A human right innominate (lateral view) is compared to a horse's right innominate (lateral view). The articular surface on the horse's acetabulum is crescent-shaped.

Fig. 2-15. A human right innominate (medial view) is compared to a horse's right innominate (dorsal view).