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## Survey of Comparative Human and Non-human Osteology: Common Florida Species

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SURVEY OF COMPARATIVE HUMAN AND NON-HUMAN OSTEOLOGY:  
COMMON FLORIDA SPECIES

by

JENNIFER DEWEY

A thesis submitted in partial fulfillment of the requirements  
for the Honors in the Major Program in Anthropology  
in the College of Sciences  
and in the Burnett Honors College  
at the University of Central Florida  
Orland, Florida

Fall Term, 2013

Thesis Chair: John J. Schultz, PhD

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## **Abstract**

Forensic anthropologists are tasked with the responsibility of identifying human remains in a forensic context. This includes differentiating between human and non-human osteological remains, and further determining a species-specific identification when presented with non-human material. Previous research has provided manuals that are typically limited to one class of animal and includes either photographs or descriptions of cranial or post-cranial skeletal elements. Further, the available resources generally cover a limited number of species from Florida's diverse habitat. Therefore, the intent of this thesis was to compile a comprehensive comparative osteological guide of local Florida species that addressed both cranial and postcranial skeletal elements. The first aspect of this research was to identify the most common Florida species typically analyzed in a medicolegal context. At the same time, represented examples were identified at the class level for birds, reptiles, and marine mammals. Next, the analysis consisted of detailed photographic documentation of cranial and post-cranial skeletal elements at three collections. The Anthropology Department teaching lab at UCF and the Biology Department Vertebrate Collection at UCF as well as the University of Florida's Zooarchaeology Comparative Collection. The images were then edited to highlight the most diagnostic features exhibited among the different taxonomic families. These results were then compiled into a series of guidelines to aid in a family and species-specific identification to be used during an investigation when presented with a whole skeleton, a single skeletal element, or fragmentary remains.



## **Dedication**

For Jenna

## **Acknowledgments**

I would like to express my deepest appreciation to my thesis chair Dr. John Schultz; without his guidance this honor's thesis would not have been possible. I would like to thank my committee member Mr. Frank Logiudice; whose dedication and enthusiasm for his subject provided a solid foundation that allowed my research to take on a depth that would not have been possible without him. I would also like to thank my committee member Dr. Sandra Wheeler; whose insight into the use of Adobe Photoshop proved to be invaluable. I would like to thank the University of Central Florida Department of Anthropology and Department of Biology for permission to utilize their skeletal collections. I would also like to thank the University of Florida for permission to utilize their zooarchaeological collection and a special thanks to the collection manager Mr. Irv Quitmyer for his assistance. I would like to thank my friend Lorraine Humbert for her considerable support and a special thanks to my family for keeping me grounded though the duration of this thesis.

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## **Chapter 1: Introduction and Literature Review**

### Tasks of the Forensic Anthropologist

A forensic anthropologist is tasked with the responsibility of identifying human remains in forensic contexts. The foundation of any forensic investigation is based on several key observations regarding skeletal remains. This skeletal analysis starts with questioning the material itself. Is it bone (Dupras et al., 2012)? If the answer is yes then the next question. Is it human (Dupras et al., 2012)? To meet this challenge the forensic anthropologist must be familiar with the comparison between human and various non-human osteological remains (Schultz 2012). They must be able to identify whole bones, large fragments, and possibly even small fragments; thus, they must have an understanding of the gross morphologies among various species. The primary method of identification includes a gross morphological osteological comparison. Nevertheless, when presented with highly fragmentary and eroded skeletal remains, a forensic anthropologist is required to know when gross comparisons are not feasible and be able to apply other identification methods appropriately. These cases might call for the use of microscopic analysis, biomolecular methods, and DNA analysis (Mulhern, 2009; Mulhern and Ubelaker, 2012; Byers, 2007).

A forensic anthropologist can make use of skeletal collections, either their own or that of a local museum, to make a species determination. Due to the scarcity of such collections most forensic anthropologists must use several different types of published resources: forensic anthropology book chapters, archaeology manuals, comparative human and non-human skeletal identification manuals, non-human atlases, or zooarchaeological texts to make these

determinations. Following is a detailed review of each of these available sources and the pros and cons of their use in a Florida setting when identifying bones from non-human species.

### Literature Review

#### Forensic Anthropology Book Chapters

Forensic anthropology textbooks are generally organized into chapters that focus on the techniques needed to recover human remains. Each chapter provides a brief overview of the subject matter. Differentiating human and non-human remains is generally not explored in detail. However, those that do focus on descriptive differences between the most common misidentified skeletal elements and contain limited photographic comparison between skeletal elements (Byers, 2007; Gilchrist et al., 2011; Klepinger, 2006; Komar and Buikstra, 2008; Mulbern, 2009; Dupras et al., 2012). The information provided is mostly in the form of case studies with emphasis towards laboratory techniques for differentiation. Also, these case studies generally focus on the single most common misidentified skeletal element, human and bear metacarpals.

While the previous resources use case studies to illustrate the difference between human and non-human remains, Byers (2007), Gilchrist et al. (2011), and Komar and Buiksta (2008) try to instruct on how to approach comparative anatomy by focusing instead on the maturity and architecture of the bone. Byers (2007) explains that when determining the maturity of a bone sample the presence of an unfused or missing epiphysis, and depending on the class of animal, can distinguish between small non-human mammals and human sub-adults. The architecture of a bone sample, referring to the overall shape of the bone, can help to distinguish between adult human remains and comparably large non-human remains. Others tend to focus on mammals,

with Dupras et al. (2012) being an exception which includes mammals, avian, reptilian, amphibian, and fish skeletons.

Forensic Anthropology textbooks occasionally provide photographic comparisons; unfortunately these skeletal elements are not always defleshed, which limits a visual comparison. Stewart (1979) provides a detailed explanation on the technique used for skinning bear paws and a photographic comparison between human and bear carpal and tarsal phalanges. A focus on fragmentary and juvenile skeletal elements is sometimes included, but few details are devoted to this issue. What is emphasized are the other methods of identification such as histology, protein analysis, and DNA analysis. These methods are most often utilized when a forensic anthropologist is presented with severely fragmentary remains with all diagnostic features either obliterated or simply not present.

#### Comparative Human and Non-human Skeletal Identification Manual

The most applicable comparative human and non-human skeletal identification manuals for forensic anthropologists are provided by Adams and Crabtree (2008), Adams and Crabtree (2012), France (2009), and France (2011). It is rare, even among these manuals, to have a comprehensive resource of information that compares not only all classes of species needed for one region, but also provides comparisons for each skeletal element.

The Adams and Crabtree (2008, 2012) manuals focus on the North Eastern American region; with representation of the most commonly found mammals, avians (i.e., chicken, turkey, and duck), and a human sub-adult comparison to a snapping turtle. Considering the range of wild and domesticated species in Florida this list would need to be expanded to include a wider range

of long legged birds (e.g., cranes, wood storks), a more diverse representation of both terrestrial and marine mammals (e.g., dog, coyote, fox, bobcat, Florida panther, manatee, bottlenose dolphin), and finally reptiles (e.g., alligator, sea turtle, gopher tortoise).

These manuals are intended to act as a visual photographic guide comparing either a single non-human skeletal element with a corresponding human element or a composite image showing the variation in size of a single skeletal element across several species. Illustrations are provided showing modern butchery marks used for the different types of animals, as well as photographs showing examples of butchery marks recovered from different archaeological sites. Comparisons for both cranial and postcranial skeletal elements are also provided.

One of the best advantages for these particular manuals is that sub-adult non-human and human bones are emphasized and contrasted with the same adult human and non-human comparable skeletal element. In Adams and Crabtree (2012), an entire chapter is devoted to the sub-adult human skeleton and is often used for comparison to smaller species. It is important to note that this level of detail is not often seen in these types of resources. The resources that do include a comparison to more than one class of animal unfortunately do not always include sub-adults.

A disadvantage of Adams and Crabtree (2008), which was later corrected in Adams and Crabtree (2012), is that while each species represented is contrasted with the corresponding human element, regrettably not every view is represented. For example, the superior and inferior views of the joints surfaces were not consistently presented, which is often a simple way to determine a species locomotion pattern. Adams and Crabtree (2008, 2012) respectively also has

not addressed how to identify fragmented remains but does include a detailed account of how to recognize the butchery marks left on non-human remains.

France (2009, 2011) does not specifically state the region that she focuses on; however, with the exception of the curious inclusion of a seal, we can infer from the species selected that she has concentrated her research to the Western North American region. This has resulted in a manual that includes a multitude of animals not found in the American southeast (e.g., moose, elk, bison, mountain sheep, mountain lion, and prairie dog). Although there is some degree of overlap between the species presented in this work and domesticated and wild species found in Florida, this manual unfortunately does not cover all of species encountered in a forensic context. Florida has diverse habitats that are quite different from the mountainous region of the American west. The inclusion of marine mammals (e.g., manatees and dolphins), long legged birds (e.g., cranes and storks), and reptiles (e.g., alligators, sea turtles, gopher tortoise) for a Florida reference would be essential due to Florida's abundant rivers, coastal waterways, and swamps.

France (2009, 2011) includes photographic comparisons of human and non-human mammals; however, the most recent edition has also included a brief chapter on avian osteology. Both editions provide comparisons of cranial and postcranial skeletal elements. France (2009) is organized by taxonomic order and then by bone type, highlighting the distinguishing features among species allowing for quick and accurate comparisons. One of the unique features of this edition is the use of color photographs.

France (2011) is comprised of black and white photographs and is a condensed field version of the previous edition. This edition is organized by skeletal element and species.

Unfortunately it does not provide consistent side by side comparison with the corresponding human skeletal element. The main advantage of these resources is the detailed diagnostic information included in each image; however, these manuals have not provided sub-adult comparisons or discussed identifying fragmented or butchered remains.

### Non-human Skeletal Atlases

#### *Photo-based*

Of all the non-human skeletal atlases, Elbroch (2006) has the most diverse collections of species for the North American region and is the best resource for cranial remains. Specifically for domesticated and wildlife species found in Florida, this manual still lacks long-legged water birds typically found in Florida (e.g., sandhill crane and wood stork) and some of the more common domesticated species (e.g., cattle). It has detailed computerized images and photographs of mammals, avians, reptiles, and amphibians. The only disadvantage to this resource is that it only covers cranial remains and unfortunately does not have side by side comparisons with the human equivalent skeletal elements. Notes are included on how to make close species determination based on measurements and overall species variations. Sub-adults and fragmented remains are not mentioned in this resource.

Wolniewicz (2004 a, b) is a field guide comparing terrestrial mammals of the Northeastern United States. The species selected do not include common domesticated species (e.g., pig, horse, cow, goat, and dog). Specifically in reference to the domesticated and wildlife species found in Florida, this manual is missing the Florida panther and representation from

other classes (e.g., avians and reptiles). It is divided into two volumes, the first is dedicated to cranial remains and the second to postcranial remains. The volumes are compiled of colored images, most of which are actual size; unfortunately if the length of the bone did not fit the determined page length the shaft was cut in half and each element was photographed side by side. The photos are arranged based on similar species size and photographed together for comparison; however, there are not any views that include adult or sub-adult human comparison or any mention of fragmented remains.

### *Illustrated Identification Keys*

The next several resources are diagnostic keys. Jones and Manning (1992) concentrate on North American terrestrial mammals with a focus on skulls. The terrestrial mammals found in Florida are represented in this manual with the exception of region-specific species (i.e., Florida panther and bobcat). The book is arranged by taxonomic order with differences in characteristics further dividing into families and sub-families. The key, unfortunately, does not taper down to a species classification and therefore is best only as a general type of guide. It has a combination of illustrations and photographs of different species but no mention is made of adult or sub-adult human comparison or fragmented remains.

Roest (1991) provides a similar type of key manual for the Northern United States and Southern Canadian region with a focus on terrestrial mammal skulls. As a result of the northern focus of this guide, certain species common to the American southeast region are not represented here (e.g., wild hog, bobcat, Florida panther, goat, armadillo, opossum, beaver, river otter, dog,

and cat). This manual is comprised of simple illustrations that provide helpful diagnostic comparison to similar species, but unfortunately there is no mention of adult or sub-adult human comparison or fragmented remains.

Glass and Thies (1997) also provides a key for North American terrestrial mammals found north of Mexico, with a focus on skulls. In comparison with what is needed for the southeastern region this manual excludes coyote, deer, Florida panther, otter, rabbit, skunks, various sea mammals, reptiles and avians. It is arranged with the original key differentiating between defining characteristics leading to different orders. These orders have detailed illustrations of each of the present families and information on how to determine a genus within each family. Due to this individual species characteristics have been generalized. Again there is no mention of adult or sub-adult human comparisons or fragmented remains.

### Zooarchaeology Manuals

Zooarchaeological references are generally devoted to identifying faunal remains from archaeological sites. As such their focus is not to determine whether skeletal remains are human or not but instead to make a species determination and further explore the implication of its presence. The general lack of preservation of non-human skeletal remains found at archaeological sites has led researchers to focus on identification of fragmented remains, analysis of butchery marks, and the determination of age and sex of non-human remains. Zooarchaeologists use this type of information to understand the relationship between humans and animals, to determine subsistence patterns and site formation processes, and to identify



physical and social environments by analyzing the oftentimes fragmentary and taphonomically modified remains (Reitz and Wing, 1999).

### *Process of Identification*

Zooarchaeology manuals approach these topics in different ways. Those that focus more on providing insight into the *process* needed to make species specific determination include Serjeantson, (2009), O' Conner (2000, 2003), Reitz and Wing (1999), Davis (1987), and Chaplin (1971). These text are typically without the precise details that a comparative photographic atlas would provide and instead employ illustrations and descriptions comparing major class differences.

Serjeantson (2009) is a volume devoted entirely to avians found at archaeological sites without a specific regional focus. Human and non-human comparisons are not made; instead a general description of the avian skeleton is provided with several distinctions being made between families. Photographs and illustrations accompany these descriptions. Most useful is the explanation of the different stages of bird bone identification, especially the chapter devoted to fragmented and butchered remains.

O'Conner (2000, 2003) provides insight into the process of identification of non-human skeletal remains. O'Conner (2000) does not focus on specific region, while O'Conner (2003) focuses on urban animal assemblages. Both resources provide a brief description of different class skeletal characteristic with illustrations; unfortunately, these illustrations do not have sufficient detail to make an accurate species specific determination. No attention is given to the

comparison of human remains, but instead non-human fragmentation, butchering, sex and age determination are addressed in an archaeological context.

Reitz and Wing (1999) provides a standard zooarchaeology textbook. Basic anatomy between the different classes is discussed with emphasis on differing locomotion patterns, growth rates, anatomical variation, size, and sex differences. Illustrations are provided for the different classes discussed within the text; however, no comparisons are made between human and non-human skeletal remains. Recording methods for modified remains due to fragmentation, weathering, or butchery are addressed without emphasis of species identification within these contexts.

Chaplin (1971) provides an account on the process of a species identification; however, no class specifics are mentioned. A limited number of photographs are provided but are not used to contrast different species. Focus was given to non-human techniques for age determination, sex, and bone pathologies. Overall this resource, much like the others, provides only information on the basic approach for non-human skeletal identification.

### *Description of Osteological Features*

The next type of zooarchaeological manuals provide the same type of information but with less emphasis on the process of identification and more on the description of skeletal elements to aid in species identification (Romer, 1997; Brothwell, 1981; Hesse and Wapnish, 1985). Romer (1997) provides a primarily descriptive osteological comparison within the reptile class, species ranging from the Triassic to modern age with no geographic distinction. Of the

three reptiles used to represent Florida's diverse population in this project (i.e., alligator, sea turtle, and gopher tortoise), all of their higher orders and families are described in detail. Unfortunately, specific genus and species details are not included. Illustrations of different skeletal elements are used to emphasize differences between families, however these are infrequently presented. A description of human remains or fragmented remains are not included in this manual.

Brothwell (1994) focuses on distinguishing human remains from other larger terrestrial mammals. Illustrations accompanied by brief descriptions are used to contrast select skeletal elements with species not restricted to a single region. These species include lion, hyena, bear, deer, reindeer, pig, wild boar, and human. Fragments, regrettably, are not mentioned. However, sub-adults are mentioned for age-determination but not in the context of species identification.

Hesse and Wapnish (1985) provide generalized descriptions of both cranial and post-cranial skeletal elements for mammals and avians. However, neither humans nor a specific geographical region are mentioned. Illustrations and photographs are used to primarily provide emphasis to skeletal characteristics among orders, but not to identify particular species. Specific species mentioned are gazelles, pig, horse, sheep and goat. The history of fragments and butchery patterns are discussed, but not with adequate detail to aid in a species identification.

#### *Atlas of Animal from Archaeological Sites*

The remaining group of zooarchaeological references (Olsen, 1964; Olsen, 1968; Olsen, 1972; Gilbert, 1990; Gilbert et al., 1996; Gilbert, 1973; Cohen and Serjeantson, 1999; Schmid,

1972) are used in the identification of non-human remains at archaeological sites. Illustrations are provided in combination with descriptive elements for a wide range of species typically focused on the area of interest.

Stanley Olsen provides three volumes (Olsen, 1964; Olsen, 1968; Olsen, 1972) with the first two focusing on southeastern and southwestern regions of the United States and the last on the entire North American region. Olsen (1968) focuses on fish, amphibian, and reptile cranial and postcranial remains. Of the species represented, only Florida's sea turtle does not overlap. This volume is organized with several views of the cranium and mandible of specific species. The views between different species are unfortunately not uniform in number or order, and the quality of the illustrations are poor. For post-cranial skeletal elements, only the anterior view has been used and despite obvious variation between each species, every illustration is the same size with a scale denoting the overall size. Human remains are not used in contrast to any of these skeletal elements and there is no mention of fragmented or butchered remains. Olsen (1972) provides much of the same details except for the cranial and post-cranial remains of avians (e.g., sand hill crane, wood stork, black vulture, and turkey are represented); similarly Olsen (1964) does the same for terrestrial mammals, with exception of the more common animals (i.e., cows). These are helpful resources but the use of illustrations instead of photographic comparisons limits the overall usefulness for identifying non-human skeletal remains from forensic contexts.

The remaining resources (Gilbert, 1990; Gilbert et al., 1996; Gilbert 1973) use a combination of key characteristics and illustrations to help make non-human identifications. Gilbert (1990, 1973) are both specific to North America and focus on mammals exclusively.

Overall the species represented are native to the western and southwestern regions of North America (e.g., bison, pronghorn, moose, caribou, peccary, wolverine, coati, mountain lion, muskox, and wapiti) and includes several marine mammals (e.g., harbor seal, ringed seal, and walrus). There is some overlap with Florida's domesticated animals and local wildlife, but the region-specific terrestrial and marine mammals are missing (e.g., Florida panther, gray and red fox, manatee, and bottle-nose dolphin). The basic mammal skeleton is discussed with special consideration given to definitive skeletal characteristics used to identify within close genera (i.e., ungulates, canids, and ursids). Illustrations are provided for cranial and post-cranial remains contrasting when appropriate closely related genera and species. No human remains are contrasted in these manuals but an entire chapter is devoted to fragmented and butchered faunal remains.

Gilbert et al. (1996), is focused on the North American region with a concentration on avians exclusively. This manual has a selection of southeast coastal birds that are found in Florida (i.e., sandhill crane, wood stork, black vulture, and turkey). Both cranial and post-cranial avian skeletal remains are addressed. This manual is organized as a key based on the presence or absence of characteristics in each skeletal element. Answering a series of questions will lead to a genus level classification. Illustrations assist in making the final identification. Human remains and fragmented remains are unfortunately not addressed in this manual.

The focus of Cohen and Serjeantson (1996) is specific to Europe and deals only with avians. While the regions covered in this manual do not overlap with the region covered in this project, several of the same families are represented and possess similar characteristics. Post-cranial elements are provided with detailed illustrations and diagnostic features are labeled.

There are no human comparisons made; there is also a lack of information regarding fragmented or butchered remains.

Schmid (1972) is also a region specific identification manual for Europe with representation from both mammals and avians. Both cranial and post-cranial remains of human and non-humans are represented by illustrations with key diagnostic features labeled. The characteristics of the skeletal elements are to the genus level only. Fragmentary and sub-adult remains are unfortunately not addressed.

#### Areas for Improvement

The areas for improvement become clear with each resource's comparison to the domesticated animals and wildlife found in Florida. What is needed is the compilation of a comparative photographic manual of adult and sub-adult humans and non-humans with representation from the most common species of mammals, avians, and reptiles found in the southeastern region of the United States. This manual would include photographic comparisons of both cranial and post-cranial skeletal elements, with the diagnostic features highlighted to differentiate between human and non-human remains, and with further emphasis included to allow for species-specific identification by making close species comparisons (e.g., dog, coyote, red fox, and grey fox). Included would be a chapter describing the different techniques available when diagnostic features are missing due to fragmentary or weathered remains.

To be useful in Florida the volume must incorporate both aspects of the skeletal system, cranial and post-cranial, and include alligators, sea mammals, and long-legged birds. While each

of the available resources covers some, or even a majority, of the species found in Florida's diverse habitat, no single reference includes all Florida species.

### Purpose

The purpose of this thesis is to compile a comprehensive comparative osteological guide of local Florida species to aid in differentiating between human and non-human osteological remains, and further determining a species-specific identification when presented with non-human material. This thesis will bridge the gap between the literature already provided and the species present in Florida and in the southeast United States. It will address both cranial and postcranial skeletal elements and will also address the problems that arise due to encountering fragmentary remains and eroded skeletal elements. The main objective of this project is to present this information with visual comparisons of illustrations and composite photographs that highlight the most diagnostic skeletal features needed to make a species-specific determination.

## **Chapter 2: Basic Anatomy Introduction**

Familiarity with the evolutionary principles inherent with taxonomic classification is essential when approaching identification and analysis of faunal remains. The aim of this chapter is to provide a general overview of the distinctive morphological characteristics of each class and highlight features to aid in a quick class identification. First the characteristics unique to higher taxonomic classification units is introduced, starting with the ways to determine the phylum Chordata and working down through the higher taxa. Next, a description of several adaptive characteristic of the axial and appendicular skeleton unique to each class is presented. Finally, differences in growth patterns between classes, and general differences in bone morphology are discussed.

### **Taxonomic Classification**

Taxonomic (scientific or biological) classification allows for the categorization and grouping of species into hierarchy-based units with similar physical characteristics. Table 1 shows the higher classification units that will be discussed in this thesis. The phylum Chordata is indicated by the presences of a notochord during development. The notochord is a flexible rod-like structure located beneath the neural tube. Depending on what form and whether the notochord persists throughout life this phylum can be divided into three subphyla: Tunicata, Cephalochordata, and Vertebrata (Kent, 1992). Both the tunicates and cephalochordates are considered to be Protochordates.



*Table 1: Basic taxonomic categories*

Category	Taxonomy
Phylum	Chordata
Subphyla	Tunicata, Cephalochordata, Vertebrata
Superclass	Tetrapod
Class	Aves, Reptilia, Amphibia, Mammalia

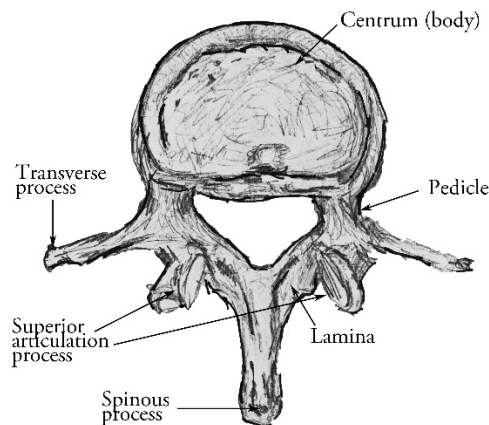
#### Protochordates

The Protochordates have no vertebral column but share several characteristics with vertebrates including a notochord, dorsal hollow central nervous system, gill slits, and clefts occurring at some point during development (Kent, 1992). The subphylum Tunicata, formally known as Urochordata, is made up of marine filter feeders commonly known as sea squirts. During development the notochord is restricted to the tail; however, as an adult the notochord and tail disappear altogether (Kent, 1992). Subphylum Cephalochordata are marine animals defined by a notochord that persists throughout life, extending throughout a segmented body.

#### Vertebrates

In Vertebrates, the notochord is reinforced or replaced by a bony or cartilaginous vertebral column. This subphylum is characterized by four main characteristics: notochord

present at least during development; a pharynx with a pouch or a slit in the lateral walls occurring at some point during development; a dorsal, hollow central nervous system; and a vertebral column (Kent, 1992). Vertebrae that make up the vertebral column consist of a centrum, a neural arch, and various processes. The centrum surrounds the notochord and the neural arch forms over the spinal cord. The presence of the notochord in adult vertebrates varies for each class. This subphylum is divided into six classes: Class Agnatha (jawless fishes), Class Chondrichthyes (cartilaginous fishes), Class Osteichthyes (bony fishes), Class Amphibia (amphibians), Class Reptilia (reptiles), Class Aves (Avians), Class Mammalia (mammals).



*Figure 1: Basic features of vertebrae using a human lumbar as an example.*

### Superclass Tetrapoda

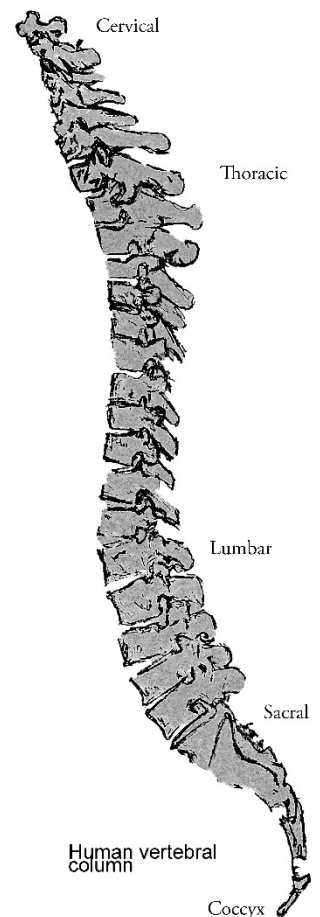
The superclass Tetrapoda is comprised of four limb vertebrates that have evolved to deal with the challenges of living on land. Included in this class are avians, reptiles, amphibians, and

mammals. To deal with the various forces acting on their skeleton, tetrapod vertebrae have become regionally specialized (Kisia, 2010; Kent, 1992). Initially these modifications were simple but as movements became more complex, consequently so did the modifications for each region of the skeleton (Kisia, 2010). In anatomical order, starting anterior to posterior, the vertebrae regions are cervical, thoracic, lumbar, sacral, and caudal/coccygeal. Depending on the species each region can vary in number, shape, and sometimes become fused with several vertebrae into a single skeletal segment.

Cervical vertebrae made their appearance to increase the range of the special senses; including vision to scan for predators, by allowing the neck to pivot, extend, and flex from side to side (Kent, 1992). The thoracic vertebrae are linked with ribs to protect and aid in external respiration (Kent, 1992).

Lumbar vertebrae, depending on vertebrate class, are characterized by their lack of rib articulation. Moving posteriorly they become larger to bear weight in species that routinely assume an erect posture; for non-erect species the lumbar vertebrae size stays uniform (Kisia, 1992). Sacral vertebrae, often with

the presence of two or more elements, fuse to become the sacrum and aid in the support of the pelvic girdle. Caudal/coccygeal tail vertebrae are highly variable in number. Moving posteriorly each vertebrae will gradually reduce in size and the arches and processes will become shorter until the vertebrae consist only of small centra (Kisia, 2010; Reitz and Wing, 1999, Kent, 1992).



*Figure 2: Human vertebral column showing regional specialization, starting with a cervical, thoracic, lumbar, and sacral.*

### Class determination based on skeleton morphology

Several key characteristics are observed in skeletal remains that can aid in quick class determination. Overall bone morphology and growth rates are two of the obvious differences between classes, as well as differences in the axial and appendicular skeleton due to varying environmental and locomotor adaptations.

#### Bone Morphology

Bone morphology, in regards to weight and thickness, can be helpful in class determination even with fragmentary remains. The tetrapods, in order of lightest to heaviest includes avians (depending on size), amphibians, mammals, and reptilians. The degree of thickness of the cortical bone varies as avians are quite thin, while amphibians vary, reptilians tend to be moderate, and the thickest are mammals (Dupras et al., 2012). The medullary cavity size in avians is quite large due to their pneumatic nature, it is smaller in mammals, and significantly reduced in reptiles.

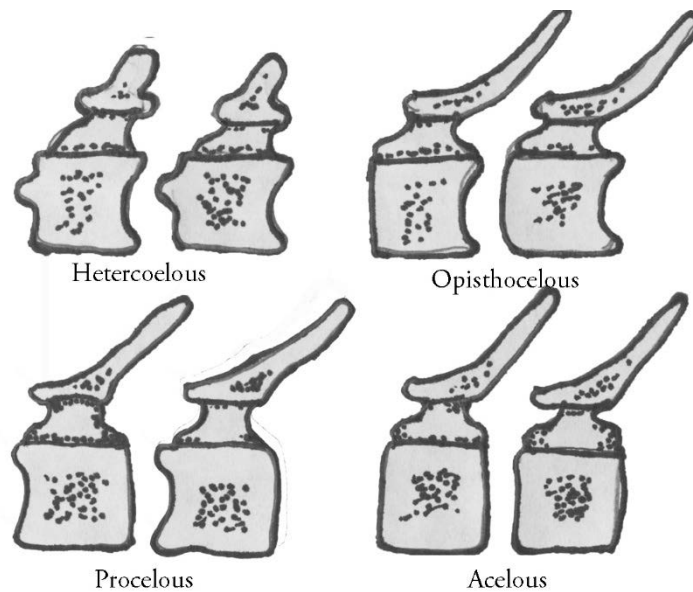
#### Growth Rate

Depending on the class and animal, the correlation between size and age can be misleading when trying to determine the maturity of a specimen. Some classes like reptiles and amphibians have indeterminate growth, meaning that instead of reaching full maturity these animals can continue to grow throughout their life (Kent, 1992; Reitz and Wing, 1999). The alternative is determinate growth which is found in mammals and avians. After reaching maturity

the endochondral bones of the axial and appendicular skeleton will fuse the diaphysis (shaft of the long bone) to the epiphyses (ends of the long bone). Conversely, the ends of reptilian long bones remain cartilaginous; however, in some cases epiphyses are found (Reitz and Wing, 1999; Romer 1997).

### Vertebrae Shape

The standard characteristic divergence is found in the shape of the vertebral centrum. This can determine which class of species is being analyzed; while other characteristics such as the number of vertebrae, points of articulation, unique class characteristics, and the number and type of fused elements can be informative when identifying a specimen's classification (Reitz and Wing, 1999). Below is brief discussion of each of the classes' axial skeletal characteristics.



*Figure 3: Vertebral shape found in avians (heterocoelous), mammals (acelous), reptiles (procelous), and amphibians (typically procelous but opisthocoelous in salamanders).*

### Class axial skeletal characteristics

Four classes make up the superclass Tetrapodia: Class Amphibia (amphibians), Class Reptilia (reptiles), Class Aves (birds), and Class Mammalia (mammals). Tetrapodia is comprised of animals that are most frequently encountered during forensic investigations in Florida.

### Class Aves

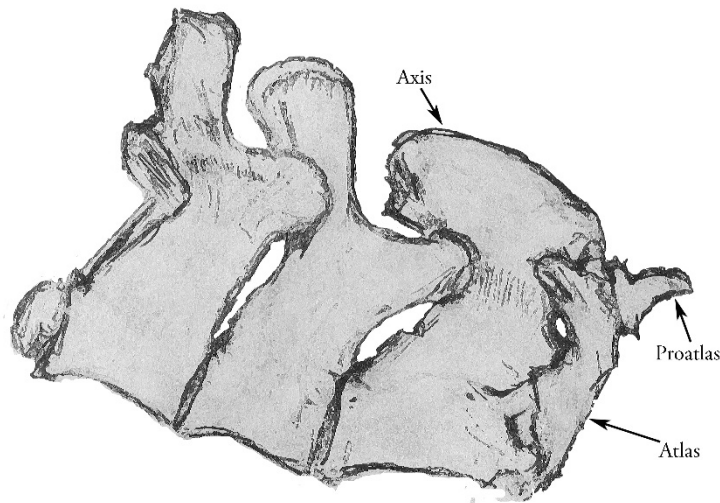
Class Aves centra have saddle shaped ends called heterocoelous, as shown in Figure 3. This class has the greatest number of cervical vertebrae of all vertebrate species, with an average of 12, allowing for the highest degree of neck flexion of all vertebrate species (Kisia, 2010).

Their first cervical vertebrae (Atlas/C1) articulates only with one occipital condyle on their skull, in contrast with the two found on mammalian skulls (Kent, 1992). They have two sacral vertebrae that fuse with the last thoracic, all the lumbar, and the first five caudal vertebrae to become the synsacrum in the adult. This rigid structure fuses with the pelvic girdle to form a compact structure, allowing for their teeter-totter bipedal locomotion (Kent, 1992; Kisia, 2010). They also have fifteen caudal vertebrae, five fused to the sacral vertebrae, the next six are unfused, with the last four fuse to become the pygostyle, which supports the tail feathers used for steering (Kisia, 2010). The unfused caudal vertebrae between the synsacrum and pygostyle allow avians to change their tail position (Kent, 1992). Also, the transverse processes of the cervical vertebrae have transverse foramina to allow for the passage of the vertebral artery and vein.

### Class Reptilia and Class Amphibia

Reptiles and amphibians centra are concave on one end and convex on the other; however, some species can have two types of centra in the vertebral column. If the anterior end is concave and the posterior end is convex then this is called a procoelous vertebrae; if it has the opposite arrangement then it is called opisthocoelous, both are shown in Figure 3 (Kent, 1992). The procelous vertebrae are found in modern reptiles and anurans (i.e., frogs and toads). The opisthocelous vertebrae are found in some salamander species. These types of vertebrae allow for greater flexibility of the trunk, providing a characteristic undulation locomotion pattern suitable for aquatic and terrestrial environments (Kent, 1992; Kisia, 2010, Reitz and Wing, 1999).

The first cervical vertebra of reptiles (Atlas/C1) articulates with the skull with only one occipital condyle. An extra vertebra called a proatlas, an example shown in Figure 4, lies between the atlas and occipital bone, this is found in sphenodonts, crocodilians, and hedgehogs (Kent, 1992). Reptiles have two sacral vertebrae, which fuse into a sacrum. Turtles, specifically, are known to have a high degree of flexibility in their neck due a ball-and-socket joint between each of centra, allowing them to retract their neck into their shell (Kent, 1992). The vertebrae that extend within their shell are fused to the neural plates of the shell (Kisia, 2010).

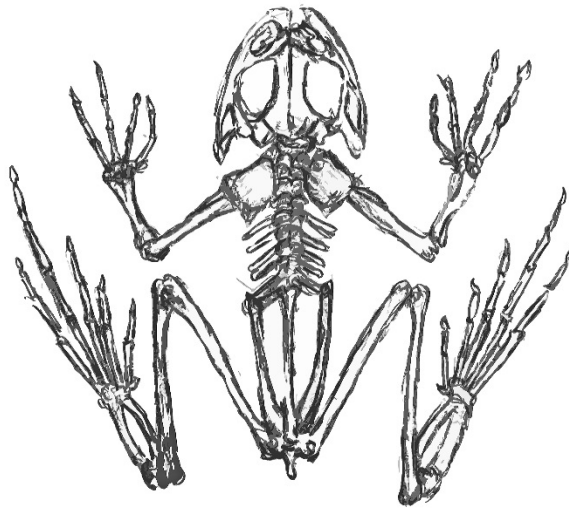


*Figure 4: Example of the proatlas found in Crocodilians*

Amphibians (example of a frog shown in Figure 5) have a single cervical vertebrae which limits head movement (Kent, 1992; Kisia, 2010). The cervical vertebra will articulate with the occipital condyles on the skull. Amphibians have a single sacral vertebra that supports the pelvic



girdle. Amphibians also have trunk vertebrae, which is the name given to vertebrae that occur between cervical and sacral vertebrae that all articulate with ribs. Due to this characteristic there are no thoracic or lumbar vertebrae present in amphibians.



*Figure 5: Example of the amphibian (frog) skeleton*

### Class Mammalia

Class Mammalia have centra that are flat on each end, also known as amphiplatyan (acealous), example shown in Figure 3. Mammals have two occipital condyles that articulate with the first cervical vertebra (Kent, 1992). Typically mammals have seven cervical vertebrae, with the first two modified, the atlas (C1) and axis (C2). A completed human skeletal column is shown in Figure 2. The cervical vertebrae possess transverse foramen to allow passage for the vertebral artery and vein. With some exceptions, mammals have between three-five sacral vertebrae; typically these fuse into a sacrum to support the pelvic girdle (Kent, 1992; Kisia,

2010). The trunk vertebrae show regional specializations allowing them to be differentiated into thoracic and lumbar vertebrae. Thoracic vertebrae are the more cranial subdivision and articulate with the ribs. Lumbar vertebrae are more caudal subdivision and are not associated with ribs in mammals (Kent, 1992; Kisia, 2010).

### Functional Morphology of Locomotion

Variation in the tetrapod appendicular skeleton reflect different degrees of adaptations for several forms of locomotion, however, each class has a primary mode of locomotion that can be quickly distinguished to aid in identification. The tetrapod limb is made of five segments: propodium, epipodium, mesopodium, metapodium, and phalanges (Kent, 1992). These segments have been modified to be utilized in a multitude of different environments; for instance wings for flying, flippers for swimming, hands for grasping or paws for digging (Reitz and Wing, 1999). For the forelimb these segments correspond with the humerus, radius and ulna, carpals, metacarpals, and phalanges respectively. The hind limb corresponds with the femur, fibula and tibia, tarsals, metatarsals, and phalanges respectively. Not every environment requires each species to utilize every skeletal element, therefore a reduction or even a disappearance of a skeletal element sometimes occurs. Other times, fusion of several segments occurs to accommodate particular locomotion patterns (Kent, 1992; Reitz and Wing, 1999).

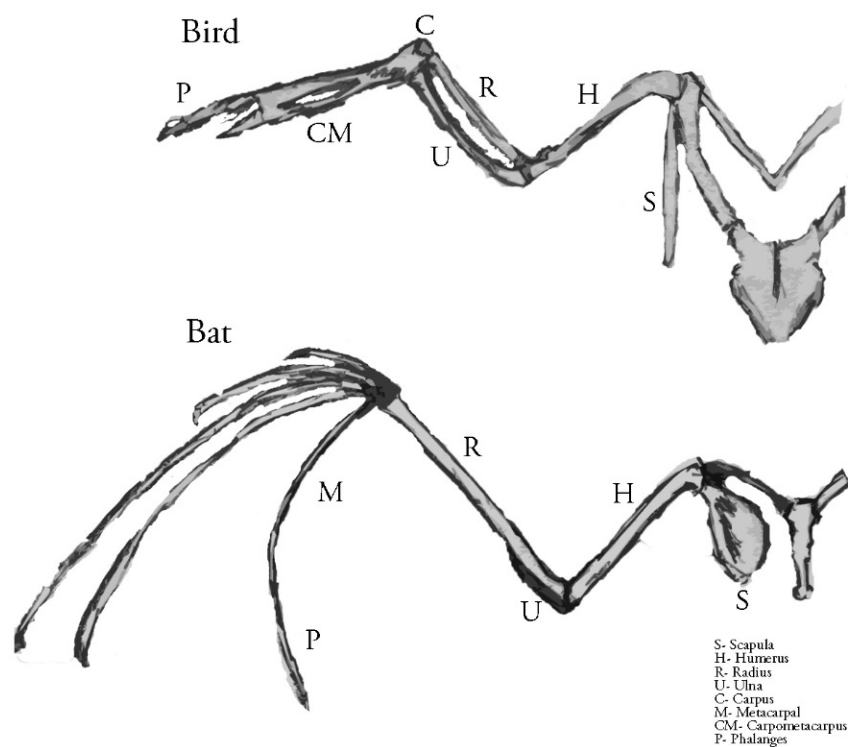
#### *Aquatic*

Swimming propels the body forward with the undulation of trunk muscle attached to the vertebral column, accompanied by paired limbs (fins/flippers) to aid in steering (Kisia, 2010;

Reitz and Wing, 1999; Kent, 1992). In terrestrial lineages, with less emphasis being placed on its use, the appendicular skeleton has gradually reduced in size while generally maintaining the basic tetrapod body pattern (Kent, 1992). The humerus becomes shorter and dense with large processes for muscle attachments. These large processes are attributed to the need for moving through a denser medium; similarly this type of adaptation appears in species that have a tendency to dig through soil (Reitz and Wing, 1999). In some species, for instance the whale, the number of phalanges has greatly increased. The humerus generally is greatly reduced in length but remains broad, with large processes for muscle attachment. Some mammals, such as the bottle-nose dolphin, have lost the remnants of their hind limbs altogether with a few remaining vestigial skeletal elements, like the pelvis, hinting at previous locomotion patterns (Kent, 1992; Reitz and Wing, 1999).

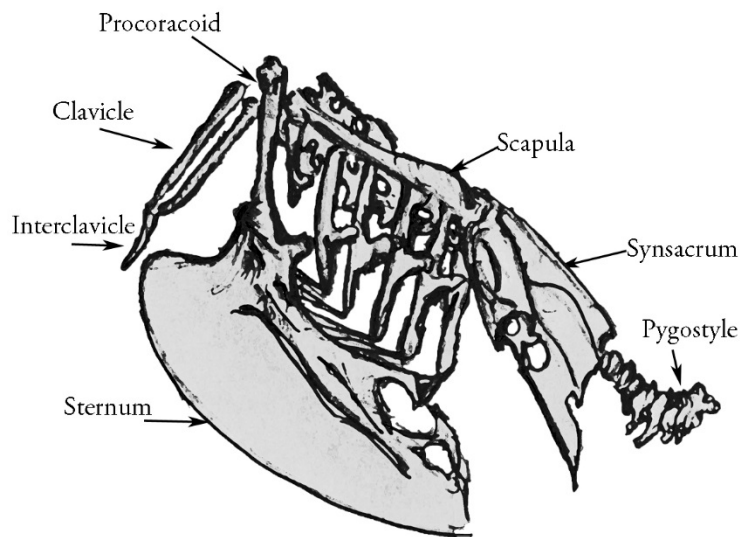
## *Flight*

The adaptations needed for flight are highly complex and requires modification to the entire body. These modifications are different depending on the species, for instance bats and avians have homologous skeletal elements but their path to flight was analogous (Kisia, 2010). The wing of the bat, as seen in Figure 6, is characterized by an elongated humerus, a thin shortened radius, with a reduced ulna. The metacarpals and phalanges (two to five) are elongated and covered by the patagium, making up the majority of the wing. Flight is powered by the movement of the hand (Kisia, 2010).



*Figure 6: Bird and Bat wing adaptations for flight showing the elongation and fusion of different skeletal elements to aid in flight.*

Avians, in contrast, uses the entire forelimb for flight. The phalanges, as seen in Figure 6, are fused, as are the carpals and metacarpals creating the carpometacarpus. The sternum has enlarged to support the attachment of the muscles responsible for flight. The coracoid and clavicle (furcula) are placed between the scapula to provide a rigid frame, as shown in Figure 6, to aid in flight and act as shock absorbers when they land. The lower limbs skeletal elements have also become fused to form the tibiotarsus and tarsometatarsus (Kent, 1992; Kisia, 2010). In some species these skeletal elements have become greatly elongated for wading in the water (i.e., herons and cranes) (Reitz and Wing, 1999; Kent, 1992). Conversely for raptors, penguins, and parrots the tibiotarsus and tarsometatarsus have shortened and become more robust.



*Figure 7: Bird skeleton showing fusion of trunk, tail, and pectoral girdle that aid in maintain a rigid structure during flight.*

## Terrestrial

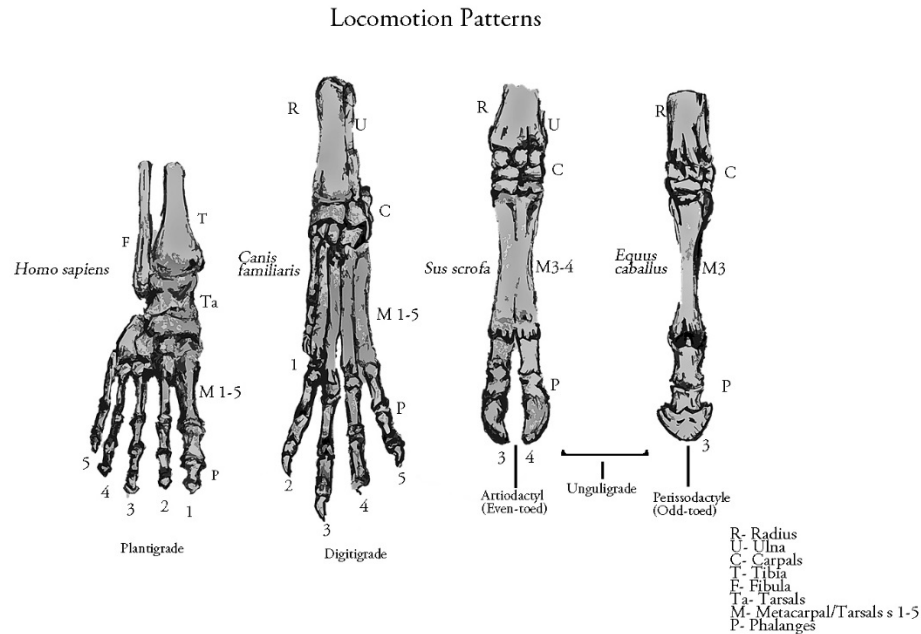


Figure 8: Skeleton can indicate different locomotion pattern examples of plantigrade (human), digitigrade (dog), unguligrade (pig/ even toed; horse/ odd toed).

Modes of terrestrial locomotion include adaptations for walking, running, and hopping. Adaption for speed includes the elongation of the skeletal elements of the limbs comprising the metacarpals and tarsals with fusion or reduction of the remaining skeletal elements of the fore/ or hind limb. Mammals who exhibit pentadactyly, five finger hands and toes, generally have a plantigrade stance, shown by the human example in Figure 8 (Kisia, 1992). This is where the entire sole of the foot strikes the ground during their stride. The skeletal elements correspond with the carpal/ tarsals, metacarpal/ metatarsals, and phalanges. This stance is considered the most primitive and is typically found in in monotremes, marsupials, insectivores, primates, and

also as a specialized adaptations in bears and raccoons (Reitz and Wing, 1999; Kent, 1992; Kisia, 2010).

Mammals that have lost or have a reduced first digit typically have a digitigrade stance, shown by the dog example in Figure 8. This means that they support weight on their digital arches with the ankle/ wrist elevated (Kent, 1992). This is characterized by elongated and unfused metapodials (metacarpals and metatarsals) with weight being place on their toes. This allows for greater running speed, agility, and stealth (Kisia, 2010). This type of stance is found in rabbits, rodents, and most carnivores.

The last modification for terrestrial locomotion is found among ungulates. It is characterized by reduction in the number of digits, with the remaining digits used to balance the animal's weight upon the tips of their digits (Kent, 1992; Reitz and Wing, 1999; Kisia, 2010). This stance is called unguligrade and can be divided into two different orders based upon the number of digits being utilized. If the number of digits being walked on is even then the species is from the order Artiodactyl, and if the number of digits are odd then it is from the Perissodactyl order. The artiodactyl order bears the weight of the body on metapodia 3 and 4, most commonly described as "cloven-hoofed" (e.g., goats, cows, pigs, and deer) (Kent, 1992). The Perissodactyl order bears weight on the third metapodia, most commonly known as the "cannon bone" in horses (Kent, 1992).

These animals run particularly well due to the elongation of their limbs which provides a longer stride to increase and maintain high speeds (Kisia, 2010; Reitz and Wing, 1999). These adaptations are also particularly suited for climbing (Kisia, 2010). Also occurring in

unguligrades is the fusion of the radius and ulna and a reduction of the fibula. The number of metapodials are either reduced or fused into a single skeletal element, although sometimes vestigial remnants support the primary metapodial (Kent, 1992).



## **Chapter 3: Methodology**

### Florida Species

The methodology for this project was created in coordination with the demands of the local forensic anthropologist and by the standards set by the literature provided. The list of Florida species referenced for this project, seen in Appendix D, have been identified by Dr. John J. Schultz as the Florida species that may need to be distinguished from human adult, human sub-adult, and human fetal bones during forensic investigations. Appendix D also was created with the information provided by the Florida Fish and Wildlife Conservation Commission and further edited with consultations by Mr. Frank Logiudice of the University of Central Florida (UCF) Department of Biology and Mr. Irv Quitmyer of the University of Florida (UF) Zooarchaeology department. The species that comprise Florida's non-human populations are diverse and occupy a multitude of different types of habitats, therefore this list compiles not only the most common species of mammals, but reptiles and birds as well. It is significant to note that it is not within the scope of this project to compare every species found in Florida but instead to focus on the species that are most common in Florida, and that are most likely to be found during a forensic investigation.

Notably large bird bones are often submitted for identification by law enforcement, this is in part due to the number of large migratory species found in Florida. A selection of large bird bones, as well as common birds such as the turkeys and chickens, have been included in this list to provide a contrast to human long bones. Domesticated species such as farm animals and pets have also been included because of their proximity to humans. Generally small, medium and large mammals are the most commonly encountered species, however the very smallest animals

have not been included because their small size does not correspond even with fetal bones or small children. Additionally, the reptiles included in this project have been chosen as examples to broadly represent the large number of reptiles present in Florida. These include alligator, gopher tortoise, and sea turtle.

### Collections

Three different skeletal collections have been utilized for this project. The University of Central Florida (UCF) Anthropology Department houses human and non-human remains, some of which have been brought in during forensic investigations. The Vertebrate Collection from the UCF Department of Biology houses non-human specimens brought to the university in for identification and collected for research. The UF's Zooarchaeology Comparative Collection, houses zooarchaeological specimens brought in for identification and those that have been collected during research.

### Photography

A series of photographs of select skeletal elements of the species presented in Appendix D were taken. These photos were taken during visits to each of these collections. These photographs of skeletal elements include in this order: isolated cranium, isolated mandible (and/or intact skull if possible), scapula, humerus, radius, ulna, radius/ulna, femur, tibia, fibula, tibia/fibula, and species-specific analogous structures. The left side was used as a standard, except when the skeletal elements damaged or missing. During this process several sources were

consulted to ensure correct positioning and highlighting of diagnostic features, these include: Adams and Crabtree (2012), France (2009), and France (2011).

### Editing and Highlighting Images

After completing this process for the entire species list, each photo was edited with Adobe Photoshop Elements 11. All skeletal elements are left sided and the photos are oriented first anterior and then posterior view. Further analysis was done of these photos by comparing and contrasting the different species within the same taxonomic families found within Florida. The results chapter describes and highlights the diagnostic features common to family members with consultation from the following resources: Adams and Crabtree (2012), Adams and Crabtree (2008), France (2011), France (2009), Hildebrand (1955), Brown and Gustafson (1979), Elbroch (2006), Romer (1997), Olsen (1964), Olsen (1968), and Olsen (1972).

### Guidelines

The next step was to analyze the information presented by each family and devise a simple guideline for utilizing this information when presented with a whole skeleton, a single skeletal element, or fragmentary remains. Several flow charts were created to aid in making a species-specific identification.

## **Chapter 4: Results**

Taxonomic classification has in the past been based on morphological similarities. However, with the addition of molecular study the classification of a species is subject to some flexibility depending on which criteria is being used to classify (Kent, 1992). It is important to note that it is not within the scope of this project to challenge any classifications determined by new research, but to highlight familial skeletal characteristics that can aid in making a species specific determination. The results of these findings will be arranged by class, order, and family with features highlighted from the species photographed during the span of this thesis.

The morphological traits used to aid in a family and species identification were derived from a number of sources. The first stage involved the analysis of all of the Florida species that were photographed for this thesis. Next, multiple non-human identification manuals were also consulted. The cranium and the mandible features were described following the detailed analysis provided by Elbroch (2006), with input from France (2011), Olsen (1964), Olsen (1968), and Olsen (1972). The post-cranial remains for the Order Artiodactyla and Order Perissodactyla follow the analysis by Brown and Gustafson (1979) with input from France (2011), Adams and Crabtree (2012), Olsen (1964), and Hildebrand (1955). The remaining mammal postcranial remains follow the same example with specific input from Adams and Crabtree (2012), France (2011), and Olsen (1964). Reptiles followed the same example with input from Romer (1997), Sobolik and Steele (1996), and Olsen (1964), while avians were identified with input from Gilbert et al. (1996) and Olsen (1972). In the absence of specific notation regarding a skeletal element for the entire family, observations were made of the regional species photographed, with the same description criteria applied for previously cited diagnostic features.

## Class Mammalia: Terrestrial

### Order Artiodactyla

The order Artiodactyla are commonly known as the even-toed ungulates. The weight of these animals passes through the axis of the third and fourth digits, as shown in Figure 8, with subsequent reduction or disappearance of the remaining digits (Jones and Manning, 1992). This is called a paraxonic foot and is a defining characteristic of this order. Also associated with this order is the elongation of the pre-orbital part of the skull, absence of a baculum, and terminal phalanges encased in hooves (shown in Figure 8) (Jones and Manning, 1992). The following will be a brief outline of the diagnostic skeletal characteristics of the families included in this order: Bovidae, Cervidae, and Suidae.

#### *Family Bovidae*

The family Bovidae includes cattle, antelope, sheep, and goats. Bovids are mostly herbivores, which is reflected in their dentition and overall robustness of their skeleton. Bovids can be further separated into small and large versions, which are reflected in the overall size and degree of robustness of each skeletal element. The species provided as examples of this family, *Bos primigenus* (cattle) and *Capra hircus* (goat), are shown in the photographs below. The observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not provided then observations made of other families and species were used as a baseline to make specific observations of the family in question.

## Cranial Characteristics

### *Cranium*

The cranium, as shown by the example in Figure 9, of this family is often characterized by the presence of unbranching horns, consequently their frontal region or sinuses have become strengthened and enlarged to deal with added weight and the behavioral tenancy to ‘butt’ heads (Elbroch, 2006). The horns in the specimens shown in Figure 9 have both been removed. Also, the goat cranium has been damaged, as portions of the zygomatic arch are missing as well as the premaxillary bone. There are two moderately large incisive foramen that project anteriorly (Fig. 9 1), and the premaxillary bone extends far beyond the nasal bones (Elbroch, 2006). The lacrimal bones form a complete articulation with the nasal bones, and maxillary bones (Elbroch, 2006). There are no lacrimal fenestra present but there are lacrimal foramen present (Fig. 9 2) (France, 2006; Olsen, 1964; Elbroch, 2006). Also, note that their eye orbits are closed and positioned deeply posterolaterally (Fig. 9 3), a trait that is associated with herbivores, that allows for greater peripheral vision to detect predators (Elbroch, 2006). Finally, there are no maxillary incisors or upper canines (Fig. 9 4).

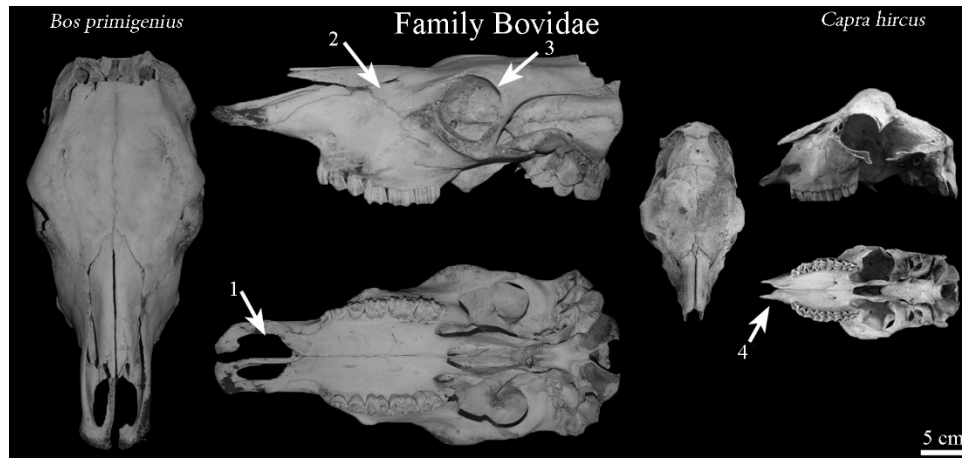


Figure 9: Cranial views of a cow (*Bos primigenius*) and goat (*Capra hircus*).

### *Mandible*

The mandibles of this family, as shown in Figure 10, are long, thick, and tapering (Elbroch, 2006). The coronoid process is very high and curved. The condyloid process has the condyle positioned well above the tooth row (Fig. 10 1) (Elbroch, 2006; France, 2011). The condyle is flat (Fig. 10 2) and does not provide a strong articulation with the cranium to allow for the side to side grinding movement for processing fibrous plant material (Wolniewicz, 2004; Elbroch, 2006). The angular process is rounded and also curved (Fig 10 3) (Elbroch, 2006). Finally, there is a very wide diastema.

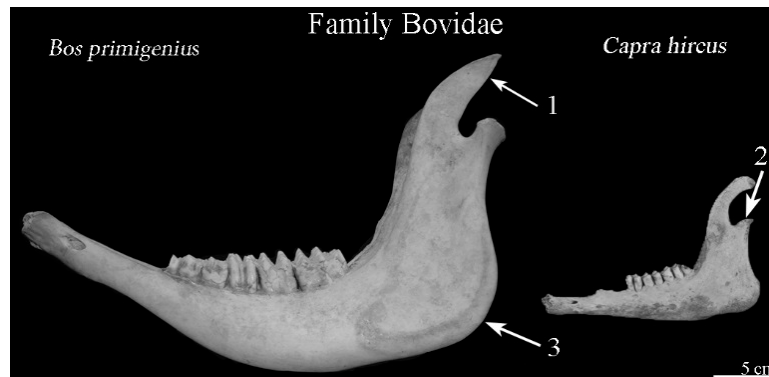


Figure 10: Lateral view of the mandible of a cow (*Bos primigenius*) and goat (*Capra hircus*)

## Post-cranial Characteristics

### *Scapula*

The scapula of this family is characterized by an overall triangle shape, as shown by the examples in Figure 11 (Olsen, 1964; Hildebrand, 1955; Adams and Crabtree, 2012). The spine is position near the cranial edge, transecting nearly the entire length of the body and ending just before the glenoid cavity (Fig. 11 1) (France, 2011; Brown and Gustafson, 1979). The acromion process is quite small in comparison to other families (Fig. 11 2). The coracoid process in rounded, thick, and relatively short (Fig. 11 3) (France, 2011; Brown and Gustafson, 1979). The glenoid fossa (Fig. 11 4) is rounded in cattle and more oval in the goat (France, 2009; Brown and Gustafson, 1979). Also, the neck is relatively long.



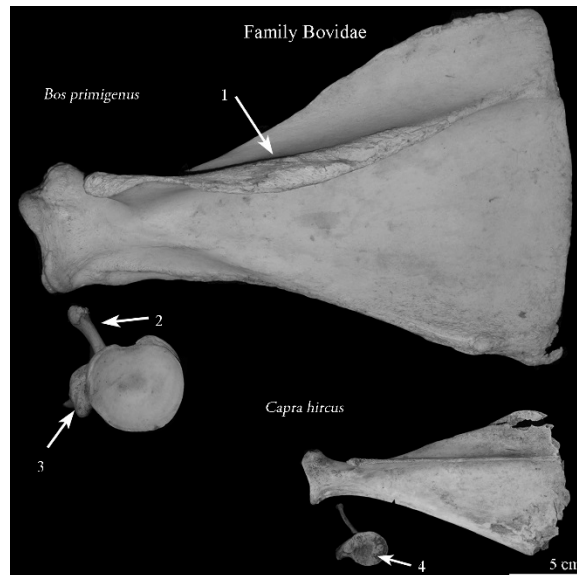


Figure 11: Lateral and anterior views of the left scapula of a cow (*Bos primigenus*) and goat (*Capra hircus*)

## Humerus

There are many overall size differences in this family; however, several key features of the humerus are similar between the various species, as shown by the examples in Figure 12. The greater tubercles (Fig. 12 1) are large and fan-shaped (France, 2011; Brown and Gustafson, 1979). A larger deltoid tuberosity is found in the *Bos* genus (Fig. 12 2). The trochlea is ‘barrel shaped’ visualized on the anterior surface, with a large projecting curve visualized by the inferior view (Fig. 12 3) (Adams and Crabtree, 2012). Also, the angle of the humerus base varies throughout this family (Fig. 12 4) (Olsen, 1964).

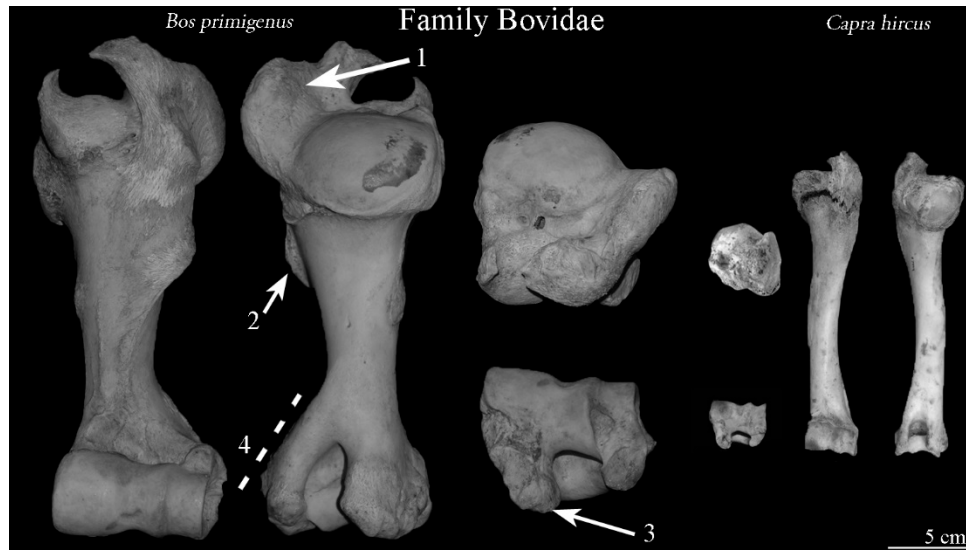


Figure 12: Anterior, posterior, superior, and inferior views of the left humerus of a cow (*Bos primigenus*) and goat (*Capra hircus*)

### *Radius and Ulna*

The radius and ulna are fused in the Bovidae family, as shown by the examples in Figure 13, and the degree of gap (Fig. 13 1) between these two bones can be diagnostic within the order (Olsen, 1964; France, 2011). The length of the olecranon process to the semilunar notch is moderately large (Fig. 13 2). The semilunar notch is crescent shape, with only a small amount of lipping over the edge (Fig. 13 3). Also, the olecranon process of the ulna is usually long and curved (Fig. 13 4) (Brown and Gustafson, 1979).

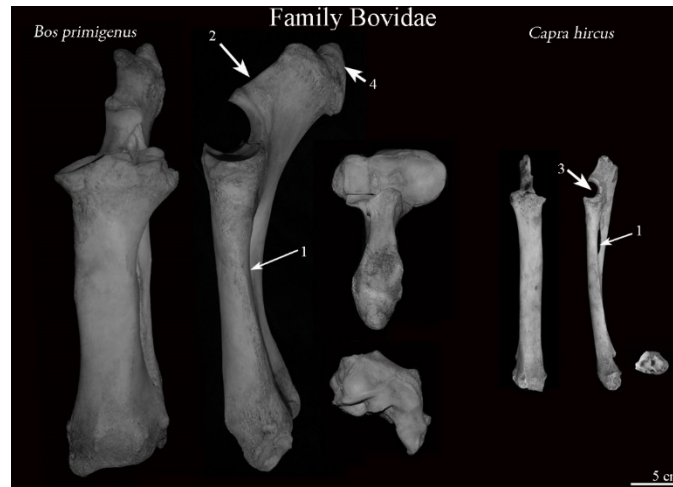


Figure 13: Anterior, medial, superior, and inferior views of the left fused radius and ulna of a cow (*Bos primigenus*) and goat (*Capra hircus*).

### *Metacarpals/Metatarsals*

The metacarpals and metatarsals of this order, examples of a cow shown in Figure 14, results from the fusion of the third and fourth digits. The articulating surface of the carpals and tarsals make a distinct pattern within this family. The proximal metacarpal articulating (Fig. 14 1) surface is D shaped while the metatarsal articulation is more square shaped (France, 2011; Adams and Crabtree, 2012). The distal metacarpus and metatarsal has two articulation sites with the terminal phalanges (Fig. 14 2). While, the vascular groove is deep in the cattle in both the anterior view of the metacarpal and metatarsal (Fig. 14 3), it is not a family characteristic and is not present in the goat (Olsen, 1964; Hildebrand, 1955; Brown and Gustafson, 1979 ). The vascular groove on the metatarsal terminates in the intercondylar fossa; and the nutrient foramen is located superior to the condyles (Fig. 14 4) (Brown and Gustafson, 1979). There are a total of four pits from the curvature of the condyles on the posterior side of the metacarpals and

metatarsals, just superior to the epiphysis of the condyles (Fig. 14 5) (Brown and Gustafson, 1979).

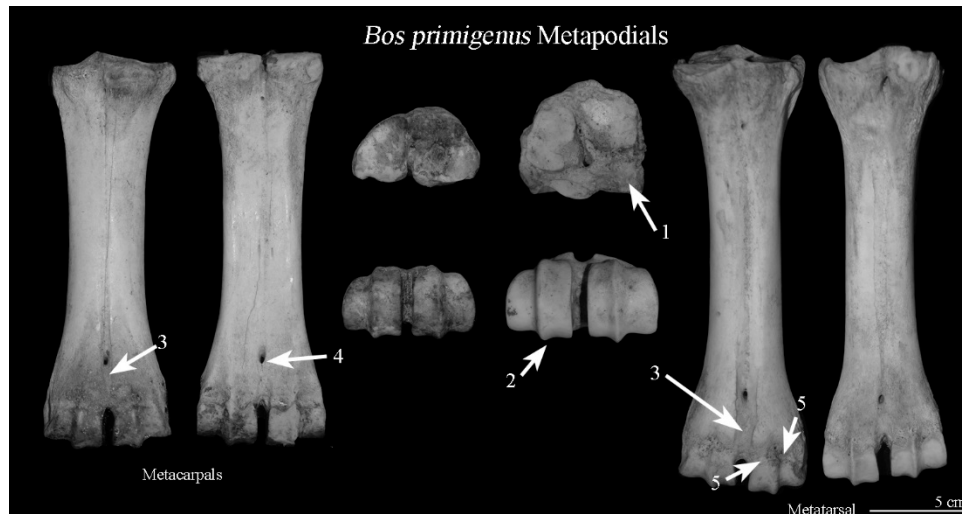


Figure 14: Anterior, posterior, superior, and inferior views of the left metacarpal and metatarsal of a cow (*Bos primigenus*).

### *Femur*

There are only two projecting trochanters in bovids, as shown in Figure 15. The greater trochanter is single, large, roughened (Fig. 15 1) (Brown and Gustafson, 1979). The foveae capitis (Fig. 15 2) is small and circular, in comparison to other families (Adams and Crabtree, 2012). The trochantric fossa is deep and curved inward (Fig. 15 3). There is also a supracondylar fossa on the distal end of the posterior side of the femur (Fig. 15 4) (Brown and Gustafson, 1979). The larger bovids have a flatter head that does not extend past the greater tubercle, this results in an angle that is usually less than 90° (Brown and Gustafson, 1979; Hildebrand, 1955). The distal posterior condyles both appear to be equal in size (Fig. 15 5). The distal end has a deep narrow

pit in the intercondyloid fossa and notches (Fig. 15 6) formed by very strong muscle attachments between the patellar lip and the medial condyle and on the medial side of the medial condyle (France, 2011; Brown and Gustafson, 1979).

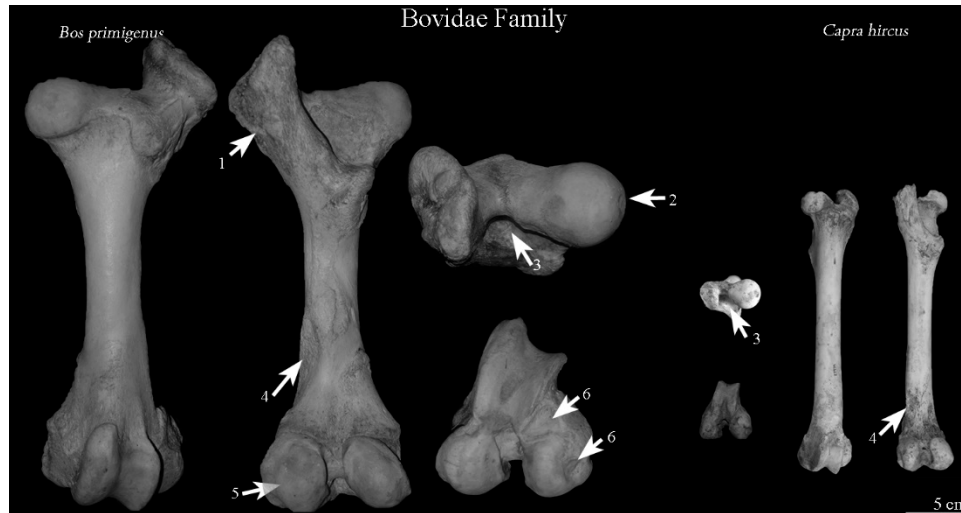


Figure 15: Anterior, posterior, superior, and inferior views of the left femur of a cow (*Bos primigenus*) and goat (*Capra hircus*)

## Tibia

The tibia, as shown by Figure 16, is relatively short and robust in larger bovids and long and narrow in the smaller members of this family (France, 2011). There is a slight curve of the shaft, but not as pronounced as in other species. The fibula (Fig. 16 1) is either a very small proximal remnant attached to the tibia or is not present at all (France, 2011; Olsen, 1964). The tibial tuberosity is large and bulbous, with a slight curvature to the lateral side (Fig. 16 2) (Brown and Gustafson, 1979). The tibia crest has an edge that is rounded and projects sharply medial,

more so in cows than goats (Fig. 16 3) (Brown and Gustafson, 1979). Also, the lateral side of the tibial plateau has a deep notch (Fig. 16 4) (Brown and Gustafson, 1979).

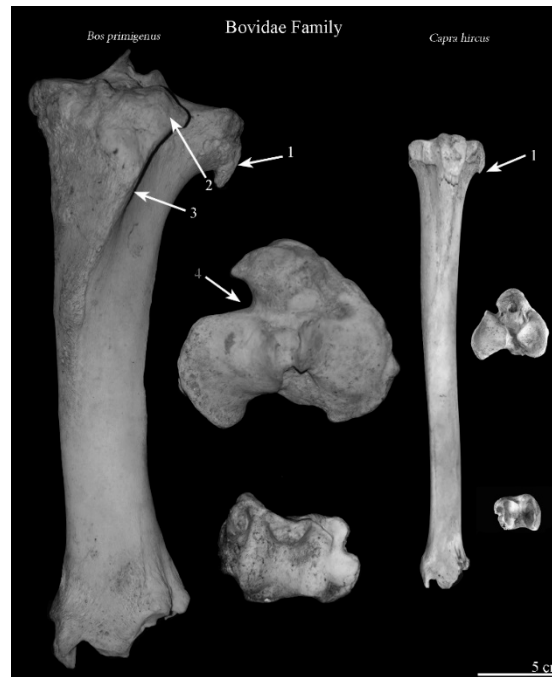


Figure 16: Anterior, Superior, and inferior views of the left tibia of a cow (*Bos primigenus*) and goat (*Capra hircus*).

### Family Cervidae

Family Cervidae is composed of the deer species. The white-tailed deer, *Odocoileus virginianus*, is the regional variant that has been included in this thesis as an example. Cervids are herbivores with selenodont dentition (Elbroch, 2006). They have no upper incisors and instead use their hard palate to assist in grinding up plant material (Elbroch, 2006). The observations made for this section has been inferred from multiple sources of information, if specific details of a feature were not provided then observation made of other families and species were used as a baseline to make specific observations of the family in question.

## Cranial characteristics

### *Cranium*

Cervids, as shown in Figure 17, have large, gracile skulls, narrowing towards the anterior. The rostral fenestrae (Fig. 17 1) are large and a distinctive characteristic for this family (Elbroch, 2006). The lacrimal bone does not meet the nasal bones and a lacrimal fenestra is formed (Fig. 17 2); a lacrimal pit is also present and the degree of depth can assist in differentiating within this family (Fig. 17 3) (Olsen, 1964; Elbroch, 2006; France, 2011). The orbits are large, closed, and located posterolaterally (Fig. 17 4) (Elbroch, 2006). There are supraorbital foramen within an oval shaped depression just medial to the orbit (Fig. 17 5), no maxillary dentition is present in this family (Fig. 17 6) (Elbroch, 2006; France, 2011). Depending on the age and sex of the specimens, horns (Fig. 17 7) may be present (Elbroch, 2006). The shape and length of the vomer can assist in identification in the Cervidae family, for example the vomer in white-tailed deer extends posteriorly and divides the nares into two chambers (Elbroch, 2006).

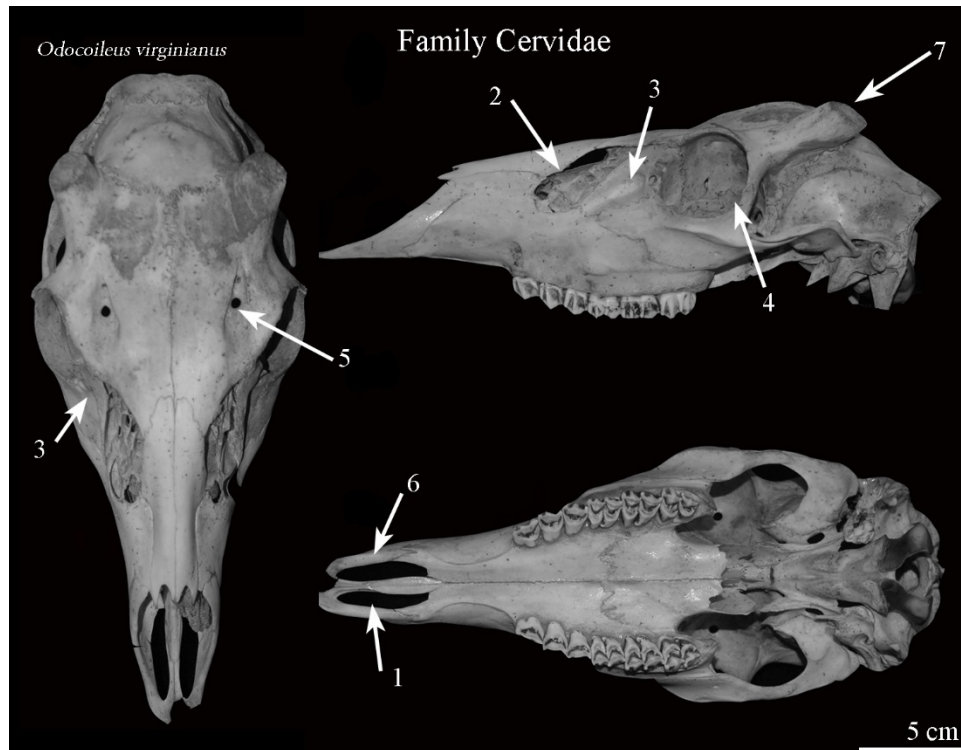


Figure 17: Cranial views of a white-tailed deer (*Odocoileus virginianus*)

### *Mandible*

The mandible for this specimen was not available to be photographed. The Cervid family mandible is typically long and tapers toward the anterior (Elbroch, 2006). The coronoid process is high, slender, and curves towards the posterior (Elbroch, 2006). The condyle of the condyloid process is typical of herbivores; flat, small and positioned well above the tooth row (Elbroch, 2006). The angular process is rounded and large (Elbroch, 2006).



## Post-cranial characteristics

### *Scapula*

The scapula is triangular shaped, as shown in Figure 18. The spine of the scapula is located very near to the cranial edge, with small amount of curvature; it terminates just short of the neck (Fig. 18 1) (France, 2011; Brown and Gustafson, 1979). The acromion process (Fig. 18 2) is a short, narrow, rounded stalk (France, 2011; Hildebrand, 1955). The coracoid process appears short, and curves inferiorly (Fig. 18 3) (France, 2011; Brown and Gustafson, 1979). The glenoid fossa is round with no cavities present (Fig. 18 4).

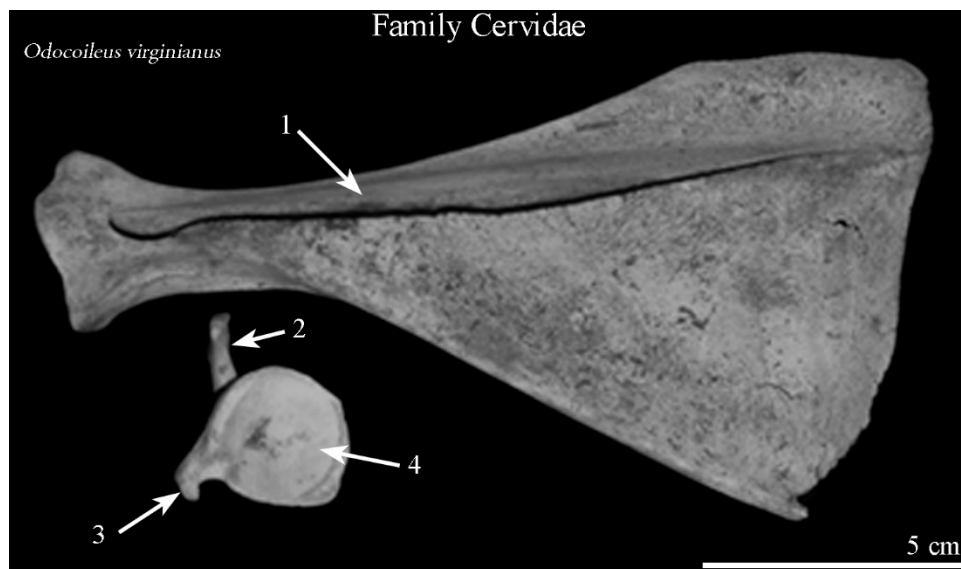


Figure 18: Anterior and lateral views of the left scapula of a white-tailed deer (*Odocoileus virginianus*).

### *Humerus*

The humerus of the Cervidae family, as shown by the examples in Figure 19, is characterized by a large greater tubercle (Fig. 19 1) with a curved and rugged appearance (France, 2011; Olsen, 1964; Brown and Gustafson, 1979). The deltoid tuberosity is only slightly rugged and does not project, leaving the shaft with a slight curvature (Fig. 19 2) (Brown and Gustafson, 1979). The epicondyle has a slight curvature but not as dramatic as in the Bovidae family (Fig. 19 3). The margins of the olecranon fossa are less sharp than found in other families allowing for a gradual merging with the shaft above (Fig. 19 4) (Adams and Crabtree, 2012; Brown and Gustafson, 1979). Also, the lateral condyle has a blunt pointed curvature (Fig. 19 5), and only one intertubercular groove with a triangular indentation between the greater and lesser tubercles (Fig. 19 6) (Brown and Gustafson, 1979).



Figure 19: Anterior, posterior, superior, and inferior views of the left humerus of a white-tailed deer (*Odocoileus virginianus*).

### *Radius and Ulna*

In this family the radius and ulna become fused in the adult (France, 2011; Hildebrand, 1955). The specimen shown in Figure 20, has yet to fuse. There is a smaller notch between a fused radius and ulna than is seen goats and sheep (Olsen, 1964). The proximal end of the radius has a sharp indentation (Fig. 20 1), and the area that articulates with the ulna can be visualized here (Fig. 20 2) (Adams and Crabtree, 2012; Brown and Gustafson, 1979). The proximal end of the radius is slightly concave (Fig. 20 3), and there are two ridges that are prominent as they approach the distal part of the radius (Fig. 20 4) (Adams and Crabtree, 2012; Brown and Gustafson, 1979). The olecranon process is large and well-developed with a moderate depression (Adams and Crabtree, 2012). The shaft of the ulna is thin and narrow and eventually fuses to the radius (Fig. 20 6) (Brown and Gustafson, 1979). The semi-lunar notch is short ending with a medial facet where the radius will articulate (Fig. 20 7). Also, the curvature of the semi-lunar notch forms moderate lipping (Fig. 20 8).

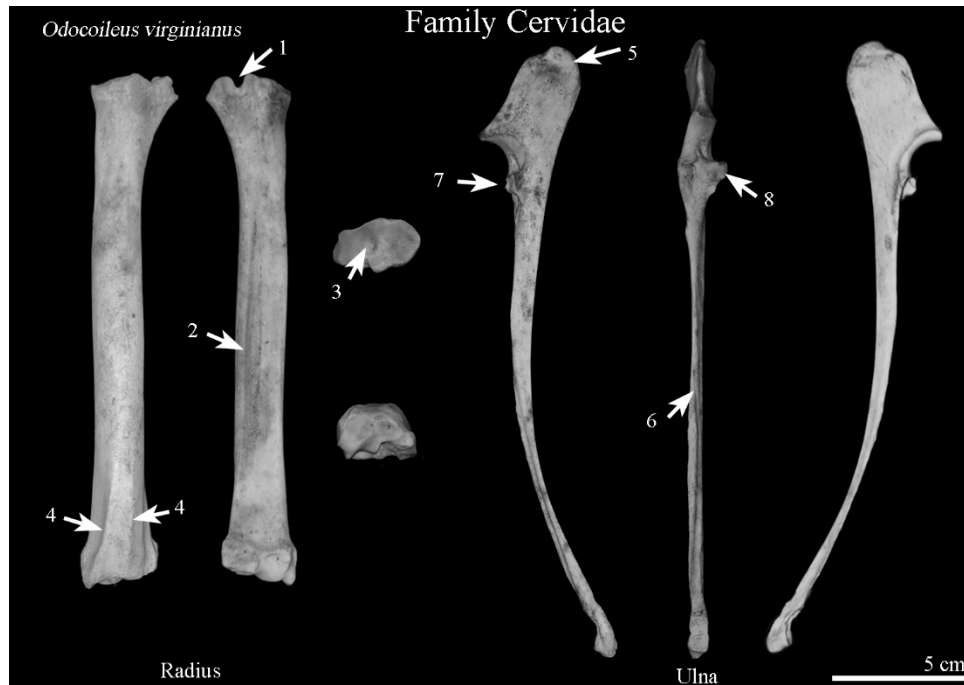


Figure 20: Anterior, posterior, superior, and inferior views of the left radius of a white tailed deer (*Odocoileus virginianus*). Medial, lateral, and anterior views of the left ulna.

### *Metacarpals/ Metatarsals*

The metapodials of this family, as shown in Figure 21, are composed of the fused third and fourth metacarpal and metatarsals (Adams and Crabtree, 2012; Hildebrand, 1955; Brown and Gustafson, 1979). The metatarsals are significantly longer than the metacarpals and have a deep groove on the anterior surface (Fig. 21 1) and a wider shallow depression on the posterior surface (Fig. 21 2) side along the length of the shaft (France, 2011; Olsen, 1964; Brown and Gustafson, 1979). The proximal ends have large nutrient foramen and distinctive patterns for carpal and tarsal articulations (Fig. 21 3) (Brown and Gustafson, 1979). The distal end has two condyles which is distinctive for this order (Fig. 21 4). Also, there is only one pit at the edge of the

epicondyles on the medial side in contrast to the Bovids that have two (Fig. 21 5) (Brown and Gustafson, 1979).

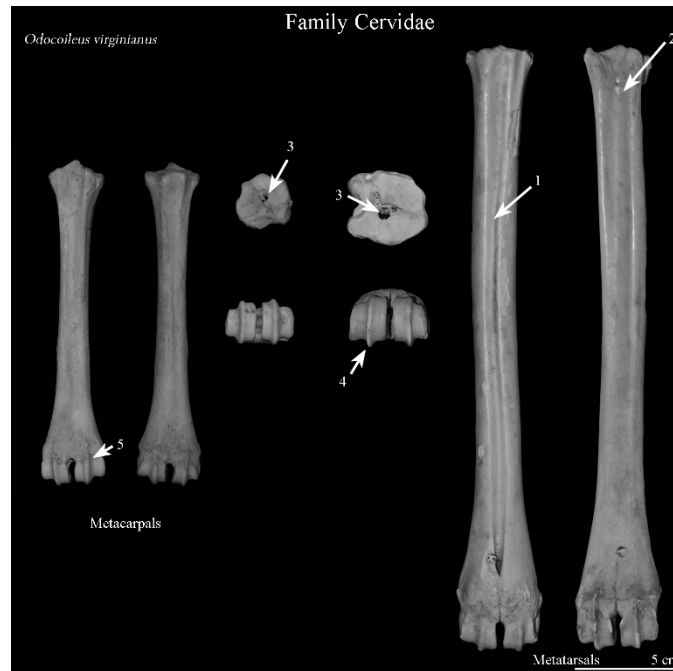


Figure 21: Anterior, posterior, superior, and inferior views of the left metacarpals and left metatarsals of a white-tailed deer (*Odocoileus virginianus*).

### *Femur*

The femur from the Cervidae, as shown in Figure 22, is characterized by a well-developed greater trochanter (Fig. 22 1); the angle between the femoral head and the greater trochanter is less than 90° (Olsen, 1964; Hildebrand, 1955; Adams and Crabtree, 2012). The femoral head lacks a ‘mushroom’ like appearance (Fig. 22 2). The intertrochantric fossa is deep, following the angle of the greater trochanter (Fig. 22 3) (Brown and Gustafson, 1979). The fovea capitis is a circular, shallow depression (Fig. 22 4). The shaft of the femur only shows a slight

curvature from the proximal end, and is oriented nearly straight from the midpoint to the distal end (Fig. 22 5). The distal end of the shaft has very distinctive supracondylar sulci for muscle attachments (Fig. 22 6) (Brown and Gustafson, 1979; France, 2011). The condyles are large and rounded with an angle similar to the greater trochanter (Fig. 22 7). Also, the patellar surface (Fig. 22 8) is very sculpted with the medial side projecting higher, and the lateral condyle also has distinctive notches present (Fig. 22 9) (Brown and Gustafson, 1979; France, 2011).



Figure 22: Anterior, posterior, superior, and inferior views of the left femur of a white-tailed deer (*Odocoileus virginianus*).

## Tibia

The tibia of the family Cervidae, as shown by the examples in Figure 23, has a very prominent tibial tuberosity (Fig. 23 1), with a sharply angled tibial crest (Brown and Gustafson, 1979; France, 2011; Adams and Crabtree, 2012). The shaft is slender with a slight curvature. The medial condyle shown on the tibia plateau has a slight indentation (Fig. 23 2) (Brown and Gustafson, 1979; France, 2012). There is a ligament tubercle off the posterior edge of the lateral condyle (Fig. 23 3) (Brown and Gustafson, 1979). The distal end has two articular facets (Fig. 23 4) for the articulation with the astragalus (Adams and Crabtree, 2012; Hildebrand, 1955). The posterior view of the distal end of the tibia has a distinctive groove starting mid-shaft and terminating near the medial malleolus (Fig. 23 5) (Brown and Gustafson, 1979). Also, there is no fibula for this family (Olsen, 1964; France, 2011).



Figure 23: Anterior, posterior, superior, and inferior views of the left tibia of a white-tailed deer (*Odocoileus virginianus*)

### Family Suidae

The family Suidae includes hogs and pigs. Suids are omnivores and have bunodont dentition (Hesse and Wapnish, 1985). While the feet have four digits they only bear their weight on the third and fourth digits (Kent, 1992). The wild boar, *Sus scrofa*, is shown below to illustrate the prominent family characteristics. The observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not provided then observations made of other families and species were used as a baseline to make specific observation of the family in question.



## Cranial characteristics

### *Cranium*

The skull of the suids, as shown in Figure 24, have a very slender projecting rostrum and premaxillary (Fig. 24 1) (Elbroch, 2006). The braincase is large and angular while projecting dorsally (Fig. 24 2), they have a well-developed occipital crest (Fig. 24 3), a supraoccipital shield that is triangular in shape (Fig. 24 4), and a very long paraoccipital process (Fig. 24 5) (Olsen, 1964; Elbroch, 2006; France, 2011). Eye orbits are open and relatively small with small rounded postorbital projections (Fig. 24 6) (Elbroch, 2006). Also, suids have distinctive canines that project outward (Fig. 24 7), and they do not exhibit horns (Elbroch, 2006).

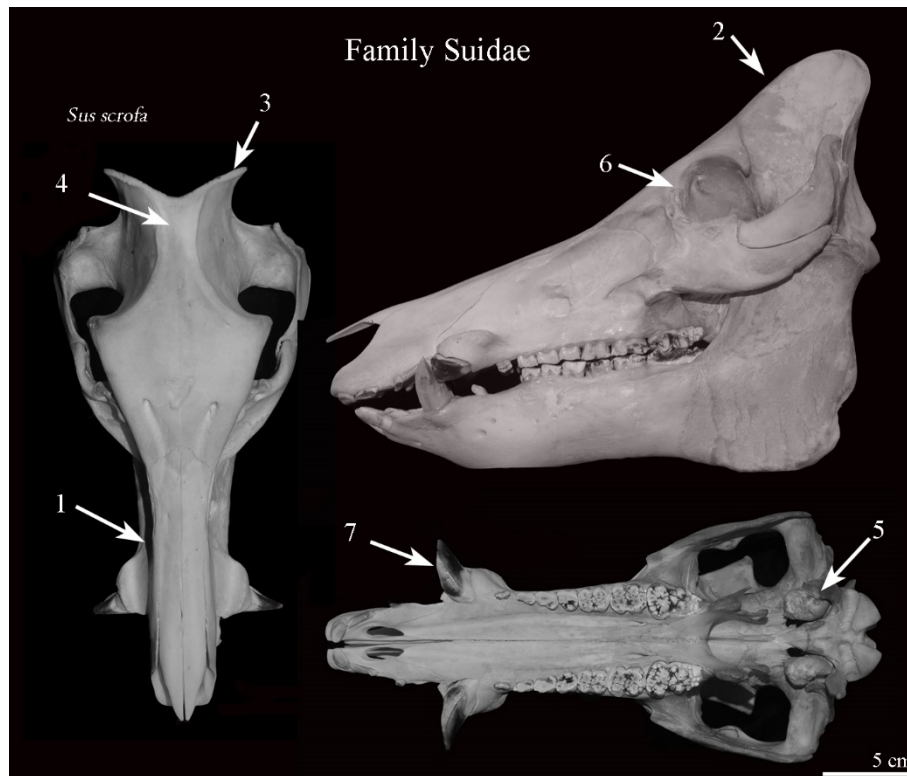


Figure 24: Cranial views of a wild boar (*Sus scrofa*)

### *Mandible*

The mandible, as shown in Figure 25, is robust and long (Elbroch, 2006). The coronoid process is short and pointed (Fig. 25 1) (Elbroch, 2006; France, 2011). The condyle (Fig. 25 2) is curved, and positioned well above the tooth row (Elbroch, 2006). The angular process is rounded with a slight indentation in curvature (Fig. 25 3) (Elbroch, 2006). Also, the diastema is large but smaller than the others of this order (Fig. 25 4) and the family has wide projecting canines (Fig. 25 5) (Elbroch, 2006).

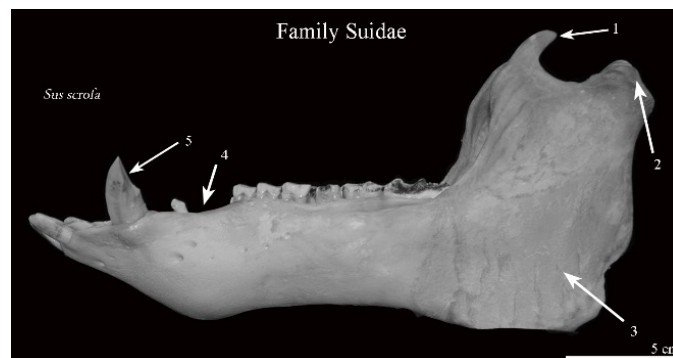


Figure 25: Lateral views of the mandible of a wild boar (*Sus scrofa*)

### Post-cranial characteristics

#### *Scapula*

The scapula of this family, as shown in Figure 26, is triangular shaped. The neck is narrow in comparison with the body. The cranial border is flat, with a raised rounded edge (Fig. 26 1) (France, 2011). The acromion process (Fig. 26 2) is either reduced, or not present (France,

2011; Adams and Crabtree, 2012). The coracoid process is small and round (Fig. 26 3). The scapular spine is wide and transect the body nearly in equal parts, ending before the neck and medial border (Olsen, 1964; France, 2011). It also exhibits a large tuberosity midway (Fig. 26 4) (Adams and Crabtree, 2012). While, the lateral border has a sharp inferior angle (Fig. 26 5), and the glenoid fossa is oval-shaped (Fig. 26 6) (France, 2011).

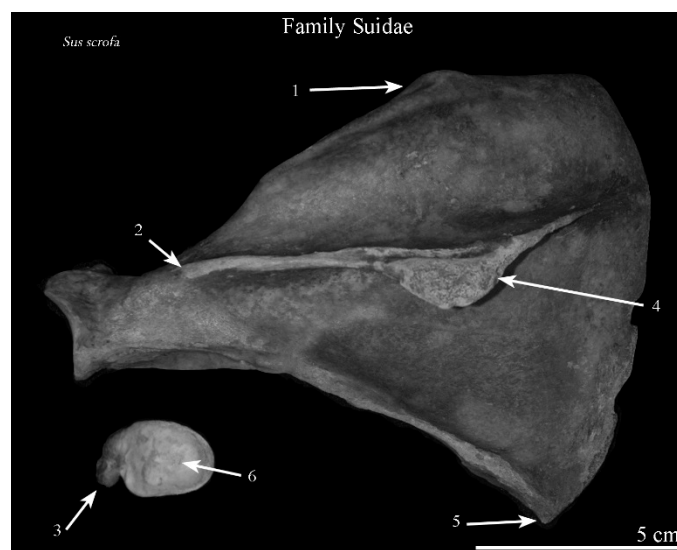


Figure 26: Lateral and anterior views of the left scapula of a wild boar (*Sus scrofa*).

### *Humerus*

The Suidae humerus, as shown in Figure 27, is characterized by a broad proximal head, tapering shaft, and flaring distal end (France, 2011). The greater tubercle (Fig. 27 1) is large, flaring, with a roughened bulbous appearance, and the intertubercular groove is very prominent forming a nearly closed circle (Fig. 27 2) (France, 2011). The deltoid tuberosity forms a moderate blunted projection (Fig. 27 3). The lateral supracondylar crest (Fig. 27 4) is large and

curved (France, 2011). The epicondyle has a moderate curving tuberosity (Fig. 27 5). Also, there is a supratrochlear foramen (Fig. 27 6) present in this family, and the trochlea and capitulum are angled in line with the humeral head (Fig. 27 7) (Olsen, 1964).



Figure 27: Anterior, posterior, superior, inferior views of the left humerus of a wild boar (*Sus scrofa*)

### *Radius and Ulna*

The radius and ulna, as shown by Figure 28, fuse together in adults in this family (Olsen, 1964). The olecranon process (Fig. 28 1) is large, bulbous, and curved laterally (France, 2011; Adams and Crabtree, 2012). The olecranon process slopes towards the semilunar notch (Fig. 28 2) which forms a crescent shaped semi-circle due to the fusion of the radius and ulna (Fig. 28 3),

and there is moderate lipping on the edge (Fig. 28 4). There is only a slight gap (Fig. 28 5) between the fused elements (Olsen, 1964).

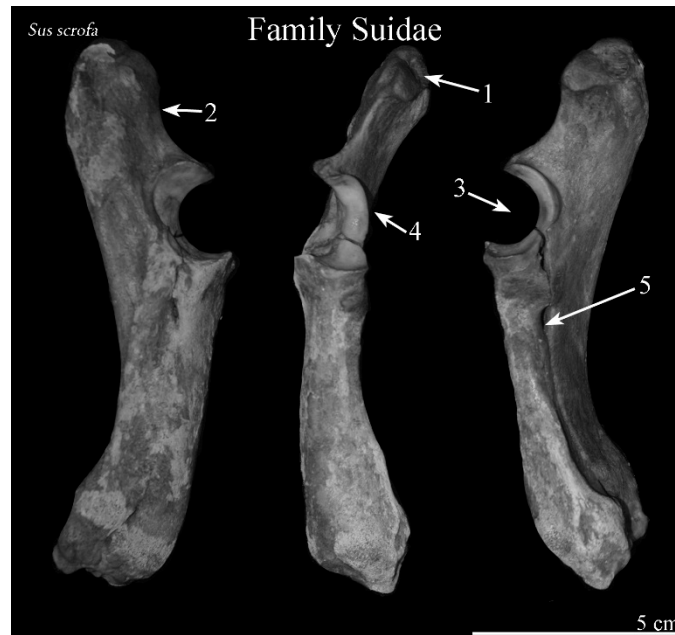


Figure 28: Lateral, anterior, and medial views of the left fused radius and ulna of a wild boar (*Sus scrofa*)

#### *Metacarpals/ Metatarsals*

The metapodials for this species were unavailable during data collections. They are short and broad (France, 2011). This family is an artiodactyl and walks on four metapodials (two-five) on each foot (Adams and Crabtree, 2012). The third and fourth metapodials bear the majority of the weight with the reduced second and fifth metapodials acting as secondary support (Olsen, 1964; Kent, 1992).

## *Femur*

The femur of the Suidae family, as shown in Figure 29, is short and thick, with a well-developed greater trochanter (Fig. 29 1) (Adams and Crabtree, 2012). The intertrochanteric fossa is moderately deep due to the well-developed trochanters (Fig. 29 2). There is a groove from the lesser trochanter down to the posterior shaft (Fig. 29 3), near the supracondylar sulci for muscle attachments (Fig. 29 4). The condyles are in line with angle from the greater trochanter (Fig. 29 5), and there is a distinctive notch (Fig. 29 6) above medial condyle (France, 2011; Adams and Crabtree, 2012). Also, the trochlea is sculpted with only a slight elevation of the medial side, which is not as drastic as is seen with the Cervids (Fig. 29 7).



Figure 29: Anterior, posterior, superior, and inferior views of the left femur of a wild boar (*Sus scrofa*)

### *Tibia and Fibula*

The tibia and fibula, as shown in Figure 30, are not fused in this family (France, 2011). The tibia is short, thick, and does not have a flaring medial malleolus giving it a straight appearance. The tibial tuberosity is very well-developed (Fig. 30 1), with a sharply angled tibial crest (Fig. 30 2) (France, 2011). The medial condyle shown on the tibia plateau has a moderately deep indentation (Fig. 30 3) (France, 2011). Also, the fibula is ‘oar-shaped’ (Fig. 30 4), with the distal end resembling a square (Fig. 30 5) (France, 2011).

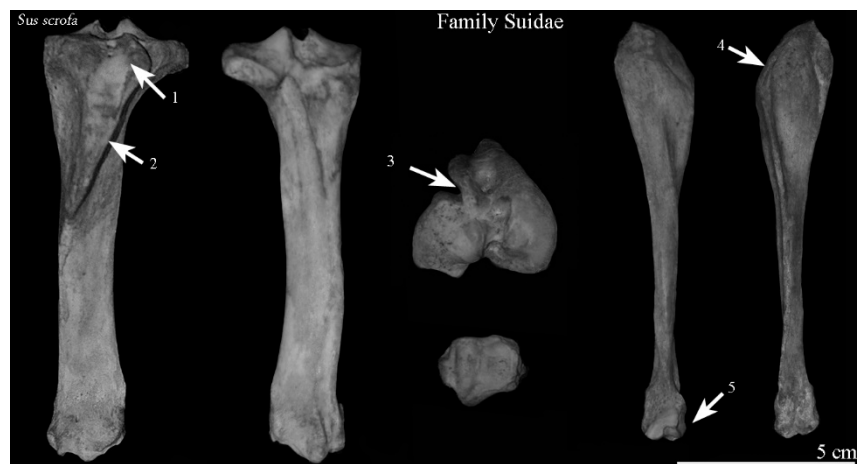


Figure 30: Anterior, posterior, superior, and inferior views of the left tibia of a wild boar (*Sus scrofa*).

### Order Perissodactyla

This order is known as the odd-toed ungulates. They are characterized by a mesaxonic foot, which means the weight of these animals passes through the axis of the middle digit (Kent, 1992). Typically they bear their weight either on one or three digits. Unlike the Order

Artiodactyla which lacks the upper incisors, this order has strong incisors used for tearing grass (Elbroch, 2006).

### *Family Equidae*

The Family Equidae is composed of several different species. The sole surviving genus is *Equus*; which includes horses, donkeys, and zebras. Equid skulls reflect the modifications that evolved for the massive muscle attachments required for their herbivore subsistence pattern (Elbroch, 1992). They have hypsodont dentition, characterized by high-crowned teeth, necessitated by their high coarse diets (Hesse and Wapnish, 1985). The observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not provided then observations made of other families and species were used as a baseline to make specific observations of the family in question.

### Cranial characteristics

#### *Cranium*

The cranium found in the genus *Equus*, as shown in Figure 31, are large and slender (Olsen, 1964; Elbroch, 2006). The orbits are large and oval, have a closed post-orbital bar, and are positioned posteriorlaterally behind the tooth row (Fig. 31 1) (Elbroch, 2006). The rostrum is very long extending to form a point that resembles a triangle (Fig. 31 2) (Olsen, 1964; Elbroch, 2006; France, 2011). There are no rostral fenestrae (Fig. 31 3) in this family or lacrimal fenestrae



or pits (Fig. 31 4) (Olsen, 1964, Elbroch, 2006; France, 2011). The occipital crest curves to form a hook posterior to the occipital condyle (Fig. 31 5). The sagittal crest is small, formed by the convergent of the temporal ridges (Fig. 31 6) (Olsen, 1964; Elbroch, 2006). Also, note the presence of maxillary incisors in this family, in contrast of the absence of incisors in Bovids and Cervids (Elbroch, 2006; France, 2011).

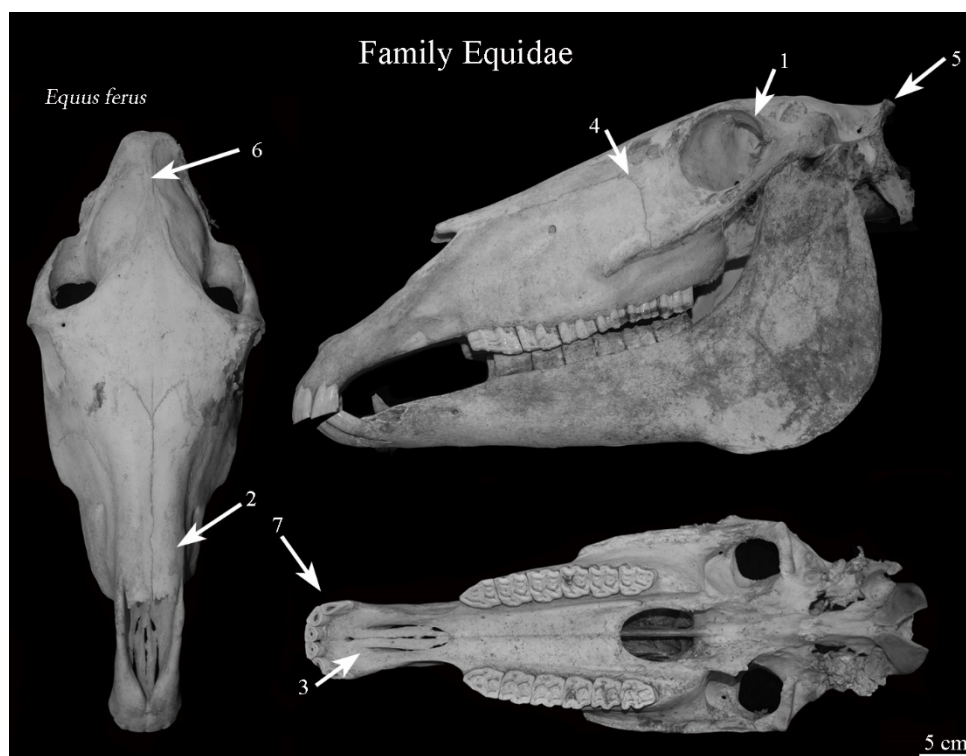


Figure 31: Cranial views of a common horse (*Equus ferus*). The nasal bones have been damaged post-mortem.

### Mandible

The mandible, as shown in Figure 32, is large, heavy, and tapers anteriorly (Elbroch, 2006). The coronoid process is positioned high, sloping superior from the tooth row and curving

slightly posterior (Fig. 32 1) (Elbroch, 2006). The condyle (Fig. 32 2) is large, and positioned well above the tooth rows (Elbroch, 2006). The angular process is very robust and curved (Fig. 32 3), and the canine tooth (Fig 32 4) occasionally is present and is thought to be vestigial (Elbroch, 2006).

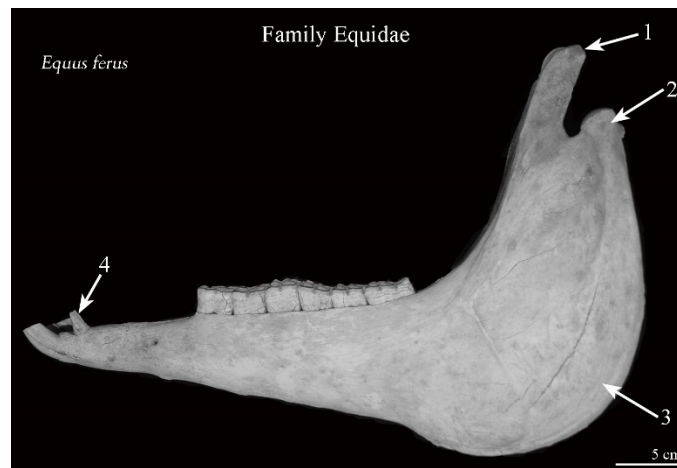


Figure 32: Lateral view of the mandible of a common horse (*Equus ferus*).

## Post-cranial characteristics

### *Scapula*

The scapula, as shown in Figure 33, is long and triangular. It is characterized by an elongated narrow spine (Fig. 33 1) that ends before the glenoid fossa (Olsen, 1964, France, 2011). The coracoid process is large, thick, and curved with a knob-like appearance (Fig. 33 2). The acromion process is reduced, and sometimes not visualized (Adams and Crabtree, 2012). The neck of the scapula is long and slightly tapers from the body (Fig. 33 3) and the glenoid fossa is circular and is moderately deep (Fig. 33 4).

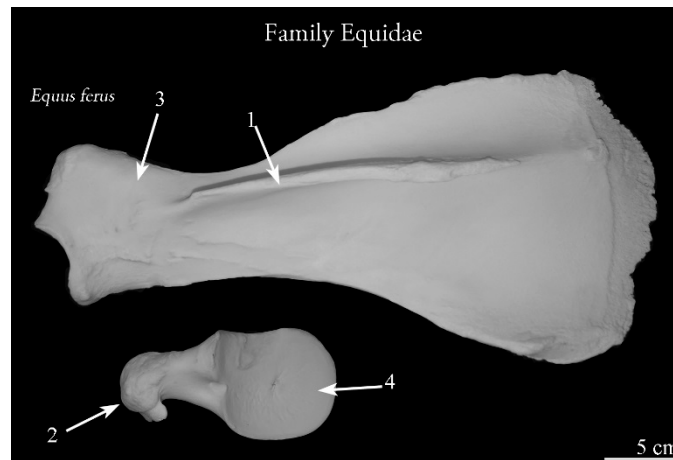


Figure 33: Lateral and anterior views of the left scapula of a common horse (*Equus ferus*)

### *Humerus*

The humerus, as shown in Figure 34, is large and thick. The proximal end resembles a square and the distal end flares at an angle (Brown and Gustafson, 1979). The greater and lesser tubercles are relatively the same size (Fig. 34 1) with an intermediate tubercle creating two intertubercular grooves having a wave-like appearance (Fig. 34 2) (Brown and Gustafson, 1979; Adams and Crabtree, 2012). The humeral head has a notch (Fig. 34 3) (France, 2011). There is a large deltoid tuberosity and ridge (Fig. 34 4) (Brown and Gustafson, 1979; France, 2011, Adams and Crabtree, 2012). There is a small raised node (Fig. 34 5) located at mid-shaft on the medial side named the teres tuberosity (Brown and Gustafson, 1979). The lateral supracondylar crest is sharply angled (Fig. 34 6). The coronoid fossa is a deep, elongated furrow (Fig. 34 7) (Brown and Gustafson, 1979). Note the position of the condyles on the distal end. They are nearly parallel with the humeral head (Fig. 34 8). Also, the epicondyle has a large curved medial tubercle (Fig. 34 9) (Brown and Gustafson, 1979; France, 2011).

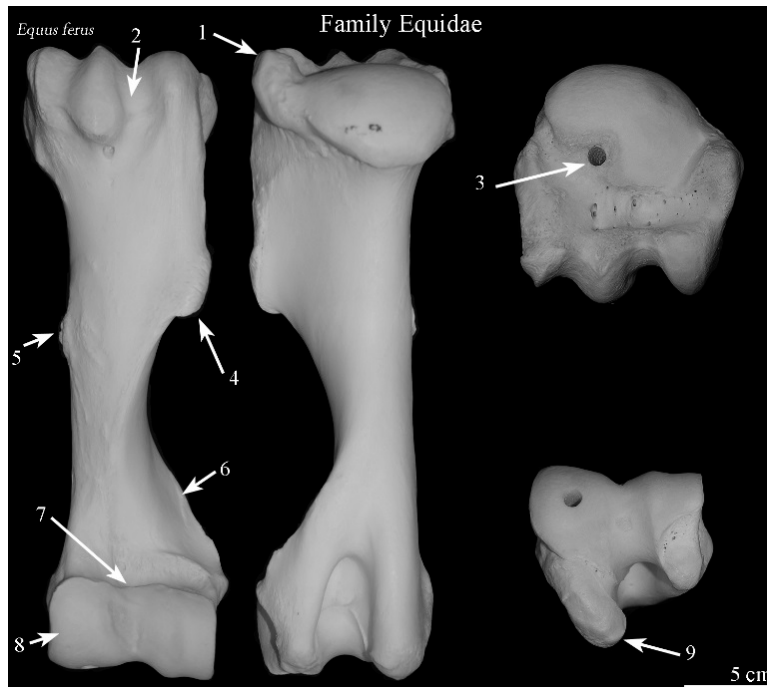


Figure 34: Anterior, posterior, superior, inferior views of the left humerus of a common horse (*Equus ferus*)

### *Radius and Ulna*

The radius and ulna, as shown in Figure 35, fuse in adults for Family Equidae and while there is no noticeable gap (Fig. 35 1) in this specimen it is typically seen throughout this family (France, 2011). The olecranon process is large, bulbous, and exhibits a slight curvature (Fig. 35 2) (Brown and Gustafson, 1979; France, 2011; Adams and Crabtree, 2012). The semilunar notch is crescent-shaped, due the fusion of the radius and ulna (Fig. 35 3), with only a small amount of lipping (Fig. 35 4) on the outer edge of the semilunar notch. On the anterior surface of the radius there is a large radial tuberosity (Fig. 35 5) (Brown and Gustafson, 1979). Also, the carpal articular facets (Fig. 35 6) have a distinctive pattern (France, 2011; Brown and Gustafson, 1979).

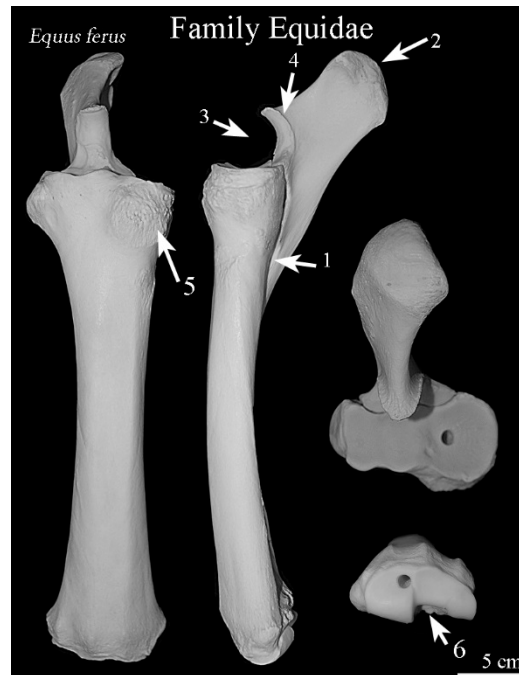


Figure 35: Anterior, medial, superior, and inferior views of the left fused radius and ulna of a common horse (*Equus ferus*)

### *Metacarpals/ Metatarsals*

The main metacarpal and metatarsal of this family, as shown in Figure 36, is the third digit, with the second (Fig. 36 1, 6) and fourth (Fig. 36 2, 7) digits (lateral metapodia) reduced and acting to support the main axis (Adams and Crabtree, 2012). The distal end has only one articulation surface (Fig. 36 3) (Olsen, 1964; France, 2011). There are two pits (Fig. 36 4) on the posterior side of the metacarpals and metatarsals, just superior to the epiphysis of the condyles (Brown and Gustafson, 1979). The proximal end of the metatarsal is more circular (Fig. 36 5), while the metacarpal is more D shaped (France, 2011).

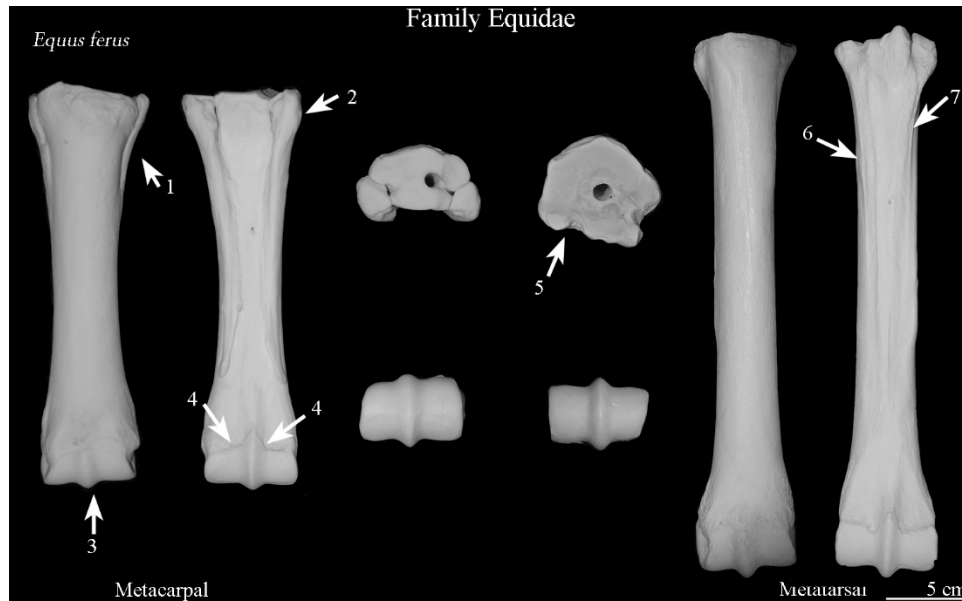


Figure 36: Anterior, posterior, superior, and inferior views of the left metacarpal and the left metatarsal of a common horse (*Equus ferus*)

### *Femur*

The femur, as shown in Figure 37, has a very large, thick, and curved greater trochanter (Fig. 37 1) (Brown and Gustafson, 1979; France, 2011). There is also a curved third trochanter (Fig. 37 2) projecting laterally (Olsen, 1964; Brown and Gustafson, 1979; France, 2011). The intertrochanteric fossa is deep, due to the flaring greater trochanter (Fig. 37 3), and the fovea capitis (Fig. 37 4) is large, and v-shaped (Adams and Crabtree, 2012; France, 2011). There is a deep supracondyloid fossa due to large muscle attachments (Fig. 37 5) (Brown and Gustafson, 1979). The shape and orientation of the condyles are angled laterally (Fig. 37 6). Also, the patellar surface, is sculpted, with the medial ridge prominently elevated (Fig. 37 7), and there is a

pronounced notch (Fig. 37 8) on the lateral side between the patellar surface and condyle (Brown and Gustafson, 1979; France, 2011; and Adams and Crabtree, 2012).

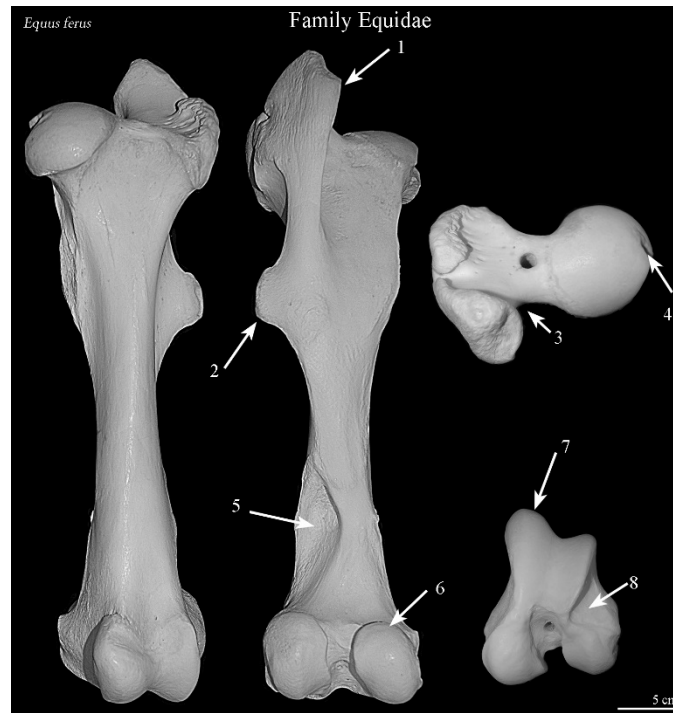


Figure 37: Anterior, posterior, superior, and inferior views of the left femur of a common horse (*Equus ferus*)

## Tibia

The tibia, as shown in Figure 38, is large, with a thick and straight shaft (Brown and Gustafson, 1979). The tibial tuberosity is well developed and bulbous (Fig. 38 1), with the tibial crest (Fig. 38 2) longer than it is wide (Brown and Gustafson, 1979). There is a wide notch (Fig. 38 3) visible on proximal view from the tibial plateau, and a smaller notch from a fold of the crest (Fig. 38 4) (Brown and Gustafson, 1979; France, 2011). The lateral intercondylar tubercles curves higher than the medial (Fig. 38 5), and there are prominent lines for muscle attachment on

the posterior side of the shaft (Fig. 38 6) (Brown and Gustafson, 1979). Also, note the fused lateral malleolus (Fig. 38 7) which is a remnant of the distal fibula (Olsen, 1964; France, 2011; Adams and Crabtree, 2012). The fibula was unavailable to photograph.

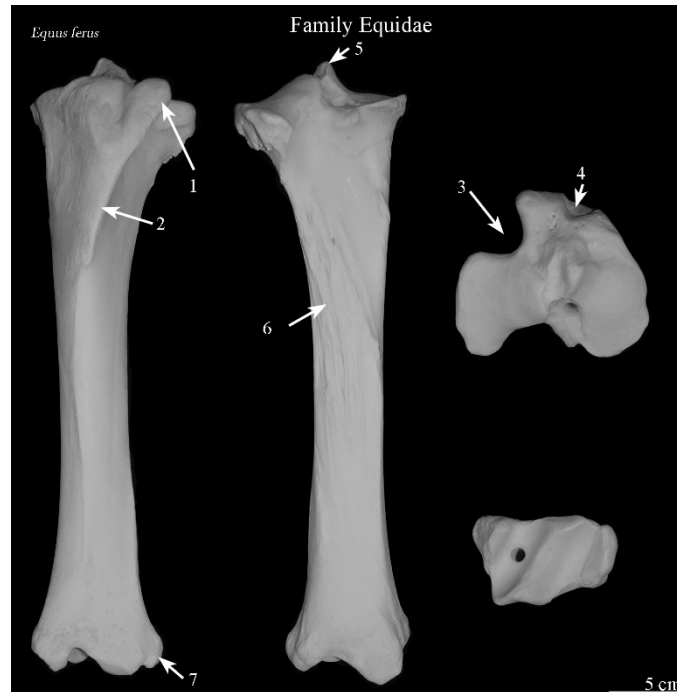


Figure 38: Anterior, posterior, superior, and inferior views of the left tibia of a common horse (*Equus ferus*).

## Order Carnivora

The order Carnivora is diverse and despite the common misnomer not all members are carnivorous. They can occupy both terrestrial and aquatic habitats, and their skulls can be recognized by powerful muscle attachments, long canines, and a carnassial tooth (Kent, 1992).



### *Family Canidae*

The family Canidae consist of dogs (*Canis lupus familiaris*), coyotes (*Canis latrans*), grey foxes (*Urocyon cinereoargenteus*), red foxes (*Vulpes vulpes*) and wolves (*Canis lupus*). Canids have prominent canine teeth that are slightly blunted and are used for grabbing and immobilizing prey (Elbroch, 2006). The posterior teeth are designed for holding and crushing; the lateral movement required for these actions is only permitted by the strong articulation between the cranium and mandible and muscle attachments to the well-developed sagittal crest, zygomatic arch, and glenoid fossa (Elbroch, 2006). Canids have well developed carnassials and a digitigrade locomotion pattern (Kent, 1992; Elbroch, 2006). The observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not provided then observations made of other families and species were used as a baseline to make specific observations of the family in question.

### Cranial characteristics

#### *Cranium*

Canid craniums, shown in Figure 39, tend to have a slender triangular appearance, starting anteriorly from the zygomatic arch (Elbroch, 2006). Differentiating between the species within this family is best approached by observing the size variation of each feature and degree of expression. The orbits are open and positioned forward, as is typical of mammalian carnivores (Elbroch, 2006). The braincase is large and rounded. The temporal ridges converge into the sagittal crest. Where the temporal ridges converge (Fig. 39 1) and the degree of elevation of the

sagittal crest can give insight for species determination (Elbroch, 2006; France, 2011; Olsen, 1964). The zygomatic arches are heavy and wide (Fig. 39 2) (Elbroch, 2006). The prominence of the arc of the occipital crest and supraoccipital shield (Fig. 39 3) provides additional information that can differentiate species and genus within this family (Elbroch, 2006). The post-orbital processes are short, triangular and can range from blunt to sharp (Fig. 39 4) and the rostrum is long and narrow (Fig. 39 5) (Elbroch, 2006).

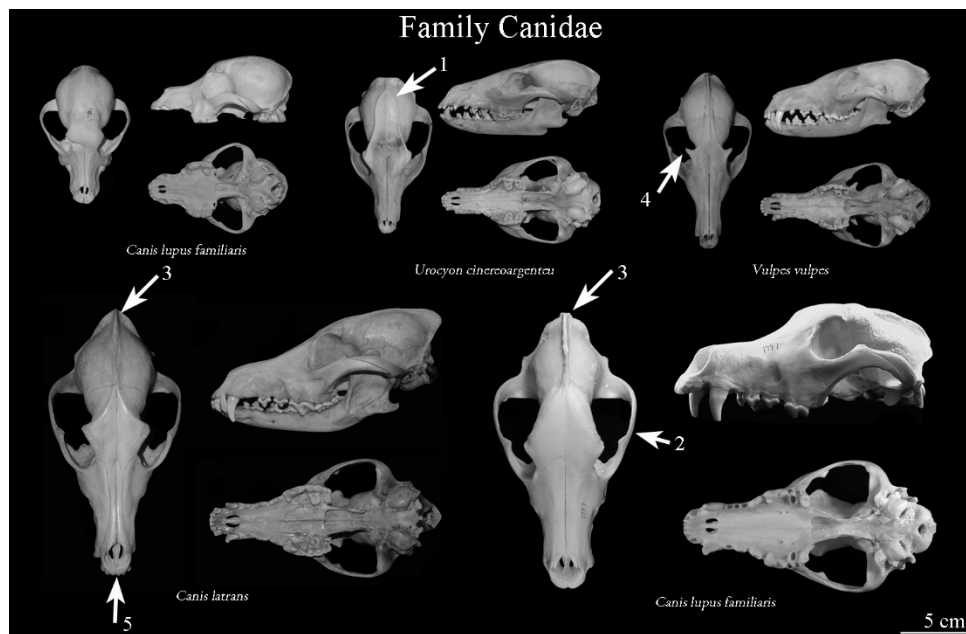


Figure 39: Cranial views of a medium and large dog (*Canis lupus familiaris*), coyote (*Canis latrans*), grey fox (*Urocyon cinereoargenteus*), and red fox (*Vulpes vulpes*)

### Mandible

The mandible, as shown in Figure 40, is long and curved, narrowing anteriorly (Elborch, 2006). The coronoid process elevates sharply and is large with a rounded edge (Fig. 40 1)

(France, 2011). The condyle is thick, round, and aligned with the tooth rows (Fig. 40 2) (Elbroch, 2006). The angular process projects posteriorly and is small, thick, and rounded (Fig. 40 3) (Elbroch, 2006). There are generally two pair of mental foramina (Fig. 40 4) with the exception of the gray wolf, *Canis lupus* that has three (Elbroch, 2006). The diastema is moderately long (Fig. 40 5).

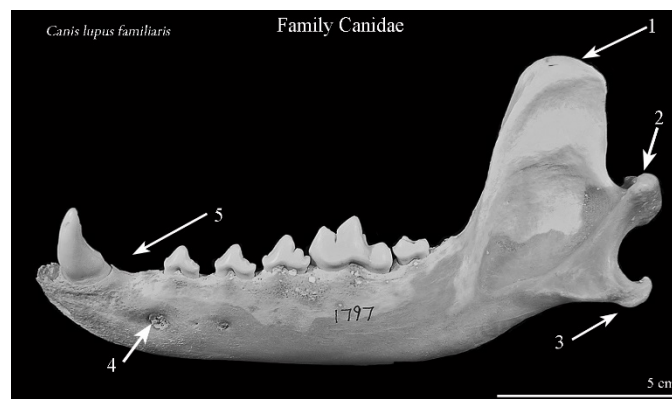


Figure 40: Lateral view of the mandible of a large dog (*Canis lupus familiaris*)

## Post-cranial characteristics

### *Scapula*

The shape of the scapula is elongated and narrow (Adams and Crabtree, 2012). The spine, as shown in Figure 41, is diagonal in this family (Fig. 41 1) and divides the scapula into two nearly equal halves (Olsen, 1964; France, 2011). The bodies outline is mostly rectangular with rounded angled edges (Olsen, 1964; France, 2011). The coracoid process is small and rounded (Fig. 41 2), and the acromion process is narrow and curved (Fig. 41 3) (France, 2011;

Olsen, 1964). The glenoid fossa is oval shaped (Fig. 41 4). The inferior angle (Fig. 41 5) is ‘buttressed’ from an attachment site for the teres major (Olsen, 1964; France, 2011).

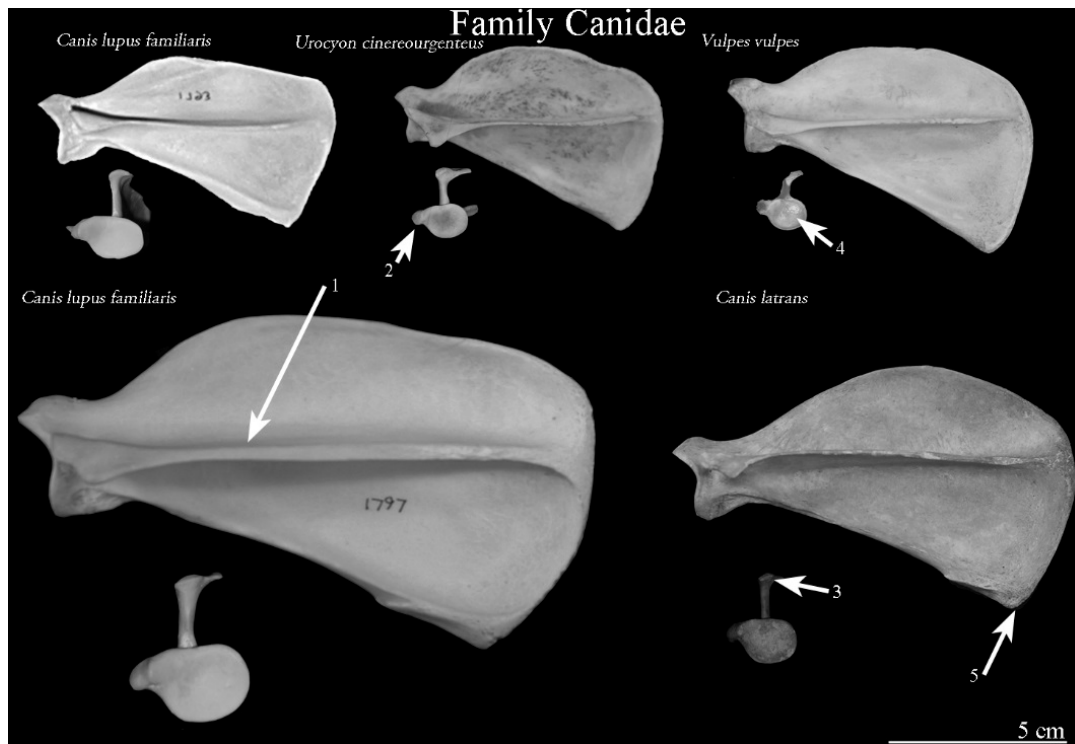


Figure 41: Anterior and lateral views of the left scapula for the medium and large dog, coyote, grey and red fox

## Humerus

The humerus of the Canidae family, as shown in Figure 42, is characterized by long, generally straight shaft with some variation. The greater tubercle is rounded and moderately elevated (Fig. 42 1). The deltoid tuberosity is a marginally raised, roughened area just inferior to the greater tubercle (Fig. 42 2). The distal shaft in *Vulpes vulpes* (red fox) has a slight curvature (Fig. 42 3). There is a large supratrochlear foramen, also known as a septal aperture, due to the

radial fossa communicating with the olecranon fossa (Fig. 42 4) (Adams and Crabtree, 2012; France, 2011; Olsen, 1964).

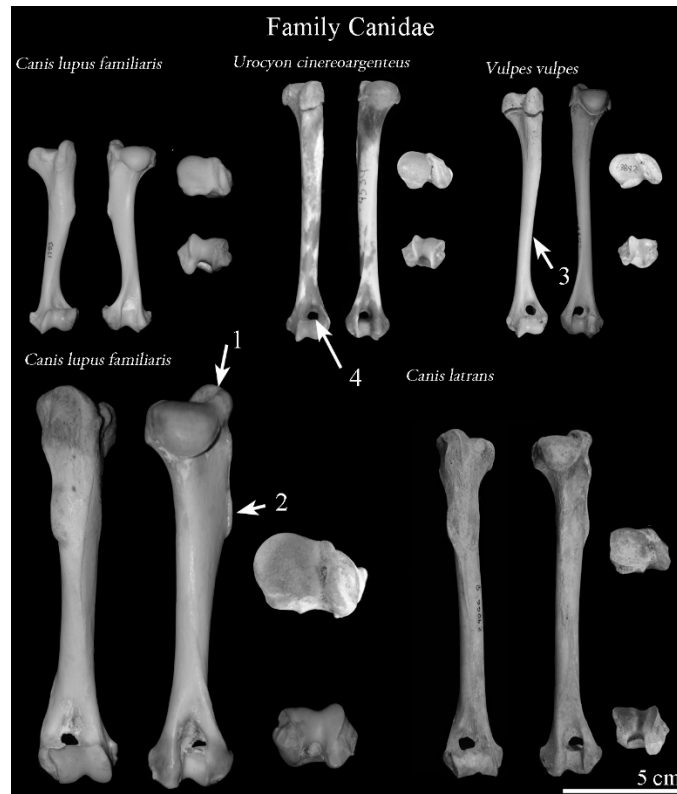


Figure 42: Anterior, posterior, superior, and inferior of the left humerus of the medium and larger dog, coyote, grey and red fox

### *Radius and Ulna*

The radius and ulna, as shown in Figure 43, do not fuse in this family (Olsen, 1964). The radius has a distinctive head and neck (Fig. 43 1), and the distal shaft straightens until it flares at the epiphysis (Fig. 43 2). The ulna is long and slender, and the olecranon process varies from bilobed to flat (Fig. 43 3) (France, 2011; Olsen, 1964). The semilunar notch is nearly a complete

semicircle with minimal lipping (Fig. 43 4). The coronoid process forms a distinctive point with the radial notch (Fig. 43 5) and the styloid process of the ulna is narrow and tapers off to a point (Fig. 43 6) (Adams and Crabtree, 2012; France, 2011).



Figure 43: Anterior, posterior, superior, and inferior views of left humerus; Anterior, posterior views of the left ulna as well as medial, anterior, and lateral views of the ulna head for a red fox.

### *Femur*

The femoral head, as shown in Figure 44, varies from being equal in height to slightly higher than the greater trochanter (France, 2011; Adams and Crabtree, 2012). The neck is longer and pinched, creating a ball-shaped femoral head (Fig. 44 1), and the greater trochanter (Fig. 44 2) is moderately large and rounded (France, 2011). The intertrochanteric fossa is deep and follows the curvature of the greater trochanter (Fig. 44 3). The fovea capitis is a small circular depression (Fig. 44 4), and the condyles are parallel with the greater and lesser trochanter (Fig. 44 5) (Adams and Crabtree, 2012). The patellar surface is sculpted with each ridge

approximately equal in height (Fig. 44 6). Also, there is a notch in the between the lateral condyle and lateral ridge (Fig. 44 7).



Figure 44: Anterior, posterior, superior, and inferior views of the left femur of a medium and large dog, coyote, grey and red fox.

### *Tibia and Fibula*

The tibia and fibula, as shown in Figure 45, are not fused in this family (Olsen, 1964). The tibia is long and slender, with a slight sinuous curvature (Olsen, 1964). The tibial tuberosity (Fig. 45 1) is of a moderate size, rough, lobule, and the crest is not as sharply angled as in other families (Fig. 45 2) (France, 2011; Adam and Crabtree, 2012). There is a prominent notch (Fig.

45 3) on the tibial plateau (France, 2011). There is a small projection off the lateral condyle (Fig. 45 4). The distal surface of the tibia has two facets for articulating surfaces (Fig. 45 5) (Adams and Crabtree, 2012). Additionally, the fibula is long, thin, and narrow (Fig. 45 6) (France, 2011). The proximal end is curved and thin, and the distal ends taper into square shape, giving it an uneven appearance (Fig. 45 7).



Figure 45: Anterior, posterior, superior, and inferior views of the left tibia of a medium sized dog; Medial and lateral views of the left fibula.

### Family Felidae

The family Felidae is composed of many species including the domestic cat (*Felis catus*), mountain lion (*Puma concolor*), and bobcat (*Lynx rufus*). Felines are specialized hunters and have many characteristics that reflect this behavior (Elbroch, 2006). Their canines are very long and slender. Felines have well developed carnassials having a fine edge. The articulation of the mandible to the cranium is very strong, allowing for a powerful hinge motion to grip their prey



(Elbroch, 2006). They support their weight on their digital arches with the ankle/ wrist elevated in a digitigrade stance (Kent, 2012). The size variation of the skeletal elements within this family can help with species identification. Observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not provided then observations made of other families and species were used as a baseline to make specific observations of the family in question.

### Cranial characteristics

#### *Cranium*

The feline cranium, as shown in Figure 46, is short, wide, and rounded with wide zygomatic arches, short curved rostrums, and large forward facing orbits (Olsen, 1964; Elbroch, 2006). The orbits (Fig. 46 1) are open, shaped by large triangular post-orbital processes that end in a blunted or sharp point depending on the species (Elbroch, 2006). Temporal ridges (Fig. 46 2), depending on the species, range from faint to prominent, converging to form a triangular pattern before rising to become a sagittal crest (Fig. 46 3) (Elbroch, 2006). The occipital crest is a prominent wedge shape, and the degree of expression is due to the amount of projection of the supraoccipital shield in proportion to the overall size of the braincase (Fig. 46 4) (Elbroch, 2006).

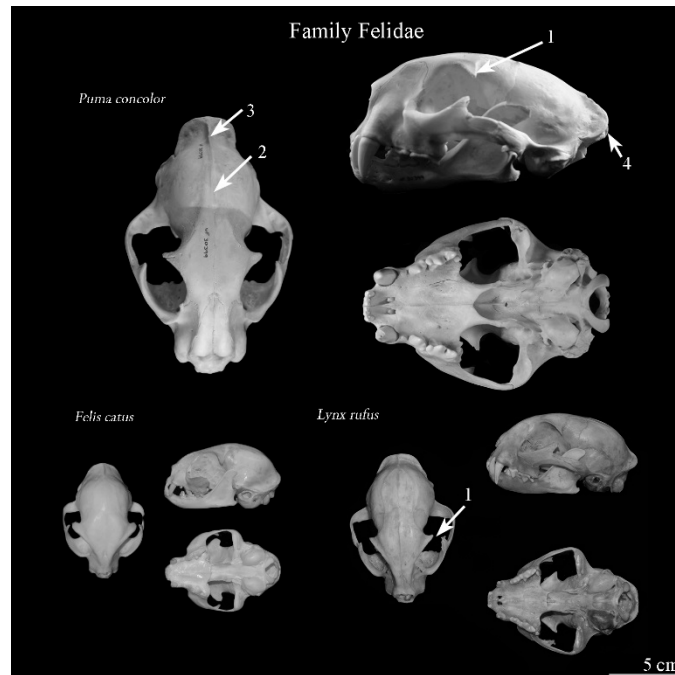


Figure 46: Cranial views for a Florida panther (*Puma concolor*), bobcat (*Lynx rufus*), and common domesticated cat (*Felis catus*).

### *Mandible*

The mandible, in this family, as shown in Figure 47, project horizontally, curving towards the anterior. The coronoid process (Fig. 47 1) is slender and rises at approximately a 45° angle. In bobcats there is a slight change of angle at the midpoint of elevation (France, 2011). The condyle is rounded and in line with the tooth row (Fig. 47 2), and the angular process is rounded and projects posteriorly, ranging from short to large in length (Fig. 47 3) (Elbroch, 2006). The masseteric fossa (Fig. 47 4) is deep to accommodate large muscle attachments (Elbroch, 2006).

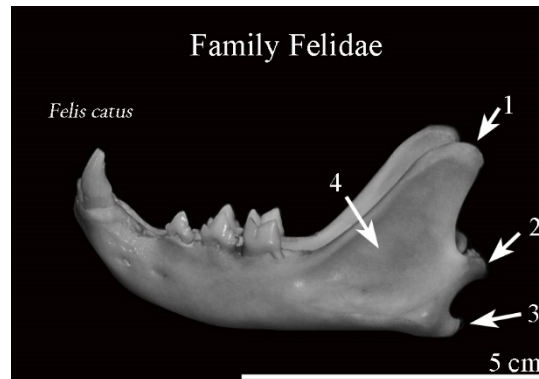


Figure 47: Lateral view of the mandible of a cat (*Felis catus*)

### Post-cranial characteristics

#### *Scapula*

The scapula of the Felidae family, as seen in Figure 48, is fan shape. The cranial edge (Fig 48 1) is rounded with a straight caudal edge (Fig. 48 2) (Olsen, 1964; France, 2011). The body is bisected by a diagonal spine which has a crest that rounds caudally (Olsen, 1964). The coracoid process is small, narrow and curved (Fig. 48 3), and the acromion process is narrow, with a fan like curve (Fig. 48 4) (France, 2011). Also, there is a large metacromial process (Fig. 48 5), in effect a secondary acromion process, and the glenoid fossa is oval shaped with a slight depression (Fig. 48 6) (France, 2011; Olsen, 1964).

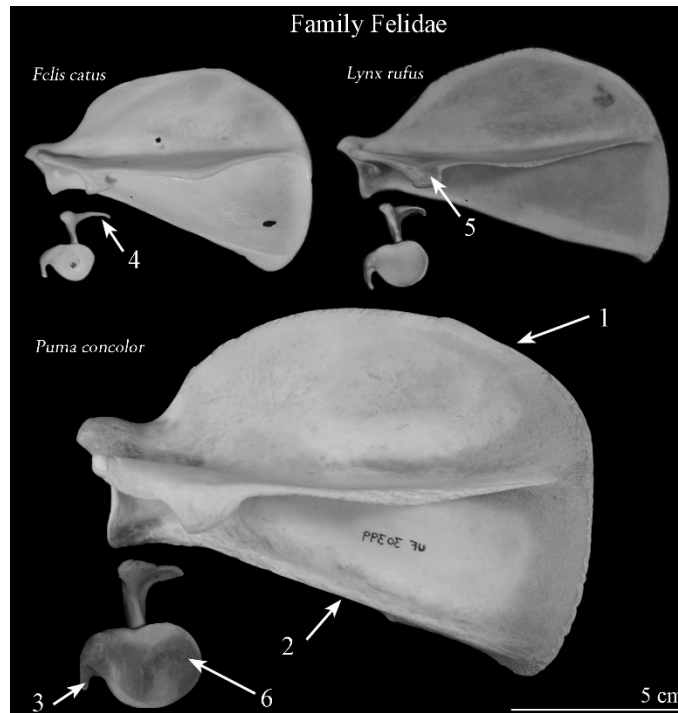


Figure 48: Anterior and lateral views of the left scapula of a cat, bobcat, and Florida panther.

### *Humerus*

The humerus of the Felidae family, as seen in Figure 49, has a slender shaft, which flares distally. There is a moderately sized greater tubercle with rounded edges that arch slightly above the humeral head (Fig. 49 1). The intertubercular groove is not very deep due to a smaller greater tubercle (Fig. 49 2). There is an entepicondyle foramen (Fig. 49 3) and are no supratrochlear foramen; conversely the Canidae family has the opposite (Olsen, 1964; France, 2011; Adams and Crabtree, 2012). The capitulum is larger than the trochlea (Fig. 49 4), and the lateral epicondyle forms a sharp point (Fig. 49 5).

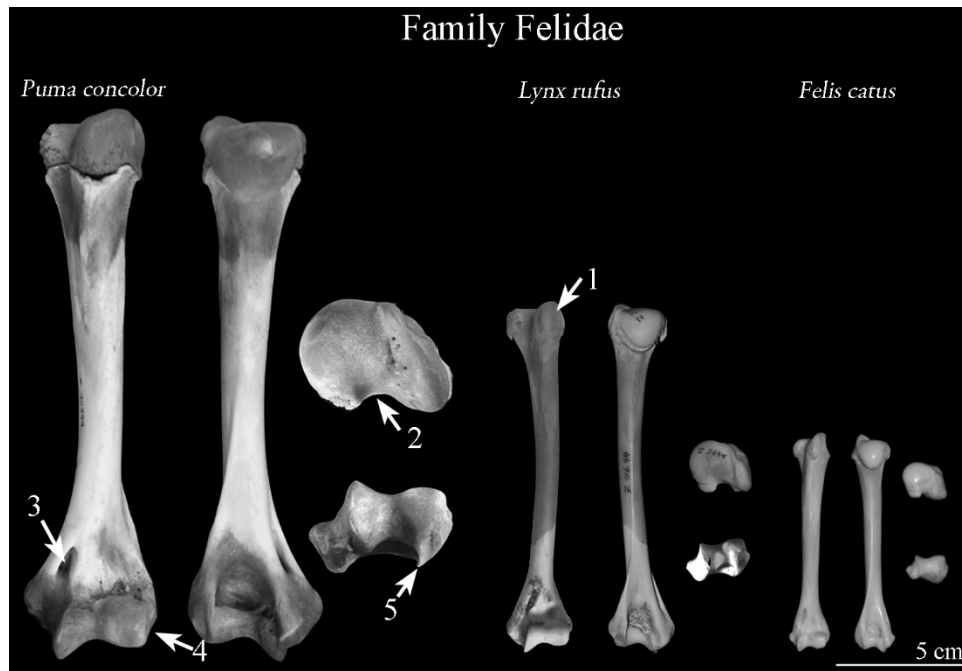


Figure 49: Anterior, posterior, superior, and inferior views of the left humerus of a Florida panther, bobcat, and cat.

### *Radius and Ulna*

The radius and ulna, as seen in Figure 50, do not fuse in this family (Olsen, 1964). The radius has a defined head and neck (Fig. 49 1), and the shaft has a slight curve, and the radial styloid process curves to a small projected point (Fig. 49 2) (France, 2011; Olsen, 1964). The ulna has a wide proximal end and tapers distally. The olecranon process (Fig. 49 3) is well developed, with a square shaped, bilobed appearance (France, 2011; Adams and Crabtree, 2012). The semilunar notch forms a semicircle with a moderate amount of lipping (Fig. 49 4). The coronoid process has a triangular appearance (Fig. 49 5) and the radial notch is well developed (Fig. 49 6) (Olsen, 1964; France, 2011; Adams and Crabtree, 2012).

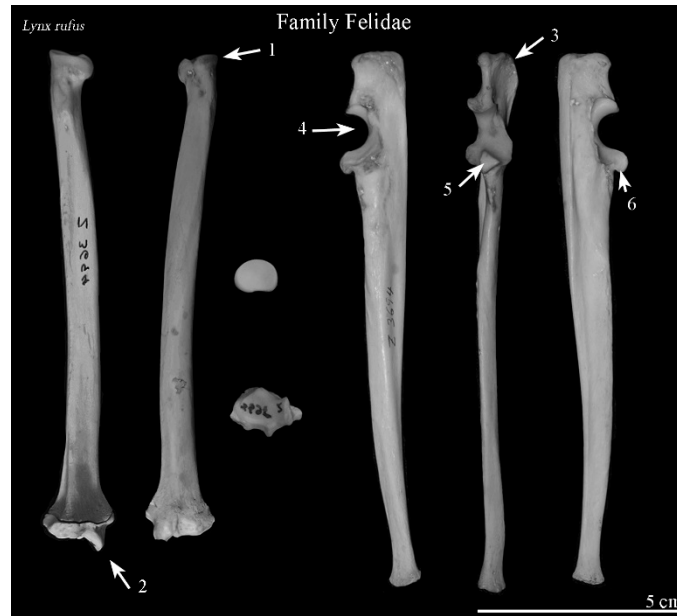


Figure 50: Anterior, posterior, superior, and inferior views of the left radius of a bobcat; Lateral, anterior, and medial views of the left ulna. Note the distal epiphysis of the ulna is missing.

### *Femur*

The femur, as seen in Figure 51, has a small greater trochanter (Fig. 51 1), a reduced neck, and an undersized femoral head (France, 2011; Olsen, 1964). The intertrochanteric fossa is moderately deep (Fig. 51 2), the fovea capitis is circular and moderately depressed (Fig. 51 3), the intercondylar line is deepened (Fig. 51 4), and the condyles are angled towards the greater trochanter (Fig. 51 5) (France, 2011).

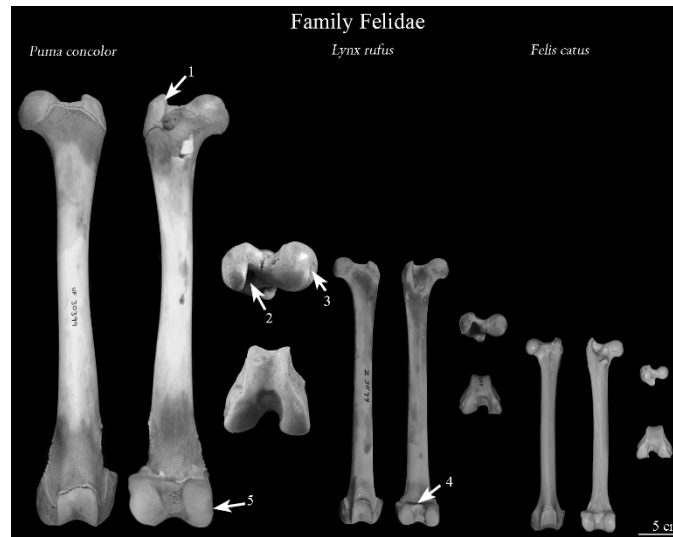


Figure 51: Anterior, posterior, superior, and inferior views of the left femur of a Florida panther, bobcat, and cat.

### *Tibia and Fibula*

The tibia and fibula, as seen in Figure 52, are not fused in this family (Olsen, 1964). The tibia is long and slender, with a variation, within the family, in the curvature of the shaft. The tibial tuberosity is less projected than in other families (Fig. 52 1) (France, 2011). While, the tibial crest has a more acute angle (Fig. 52 2). The tibial plateau (Fig. 52 3) has no “true” notch but the border varies in each species in this family (France, 2011). The medial malleolus is curved, thick, and prominently arched (Fig. 52 4) (France, 2011). The fibula is narrow and thin (Fig. 52 5). The proximal and distal ends have a triangular appearance (Fig. 52 6).



Figure 52: Anterior, posterior, superior, and inferior views of the left tibia of a bobcat; Medial and lateral views of the left fibula.

### Family Mustelidae

The Mustelidae family includes weasels, otters, and badgers. They are diverse in overall size and form. Mustelids are generally carnivores and support adaptations for predation (Elbroch, 2006). Mustelids can be digitigrade or plantigrade (Kent, 1992). The species photographed for this thesis is the river otter, *Lutra canadensis*. The observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not provided



then observations made of other families and species were used as a baseline to make specific observations of the family in question.

### Cranial characteristics

#### *Cranium*

The craniums in Mustelids, as seen in Figure 53, are flat (Fig. 53 1) with braincases that range from triangular wedge-shaped to long and slender (France, 2011; Elbroch, 2006). The skull has wide-set slender zygomatic arches (France, 2011; Elbroch, 2006). The rostrum is short and wide-set (Fig. 53 2) (Olsen, 1964; Elbroch, 2006). The orbits are medium, positioned toward the anterior, and opened (Fig. 53 3) (Elbroch, 2006). The post-orbital processes range from blunted to sharp (Fig. 53 4) (Elbroch, 2006). The temporal ridges in this family range from faint to prominent, converging location is variable at the genus level (Elbroch, 2006). The prominence of the sagittal crest is variable but the occipital crest is usually well-developed (Fig. 53 5). The infraorbital foramina are elongated and oval (Fig. 53 6) (Elbroch, 2006; Olsen, 1964; France, 2011).

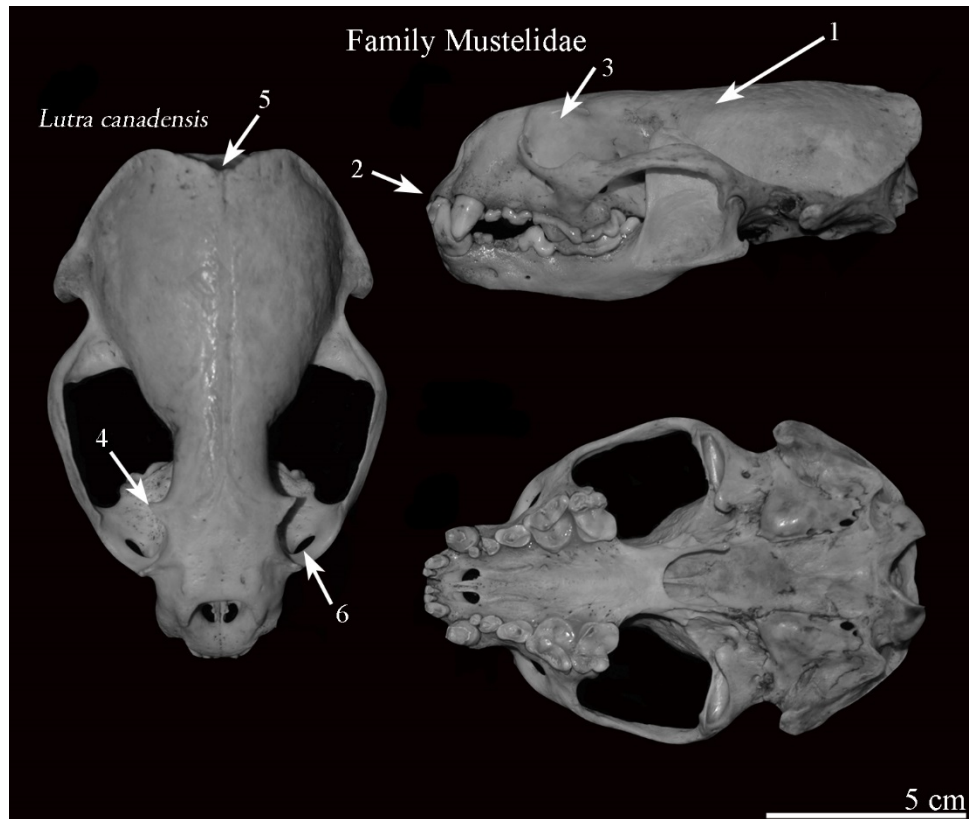


Figure 53: Cranial views of a river otter (*Lutra canadensis*)

### *Mandible*

The mandible of the Mustelidae family, as seen in Figure 54, projects horizontally towards the anterior, curving slightly with the elevation of the sharp, slender canines (Elbroch, 2006). The coronoid process can vary in form; starting with a sharp vertical elevation from the tooth rows with a variance in angle towards the posterior border (Fig. 54 1) (Elbroch, 2006; France, 2011). The condyles are thick and round (Elbroch, 2006). The angle that the condyloid process projects posteriorly varies within the family (Fig. 54 2) (Elbroch, 2006). The angular

process ranges from blunt and squat to slightly longer and more rounded (Fig. 54 3) (Elbroch, 2006).

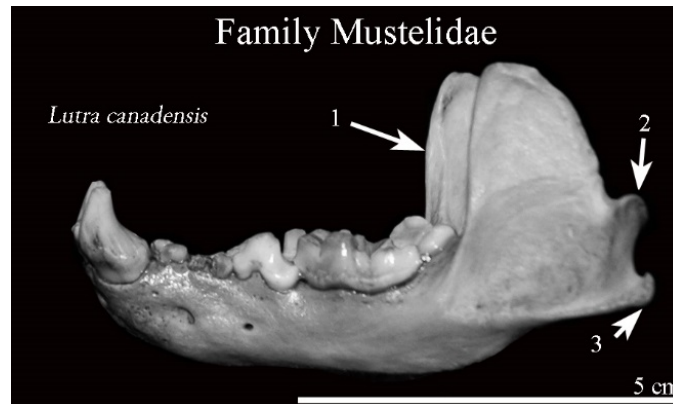


Figure 54: Lateral view of the mandible of a river otter (*Lutra canadensis*)

### Post-cranial characteristics

#### *Scapula*

The scapula, as seen in Figure 55, is characterized by a large rounded hump on the cranial edge, gradually sloping towards the caudal edge (Fig. 55 1) (Olsen, 1964; France, 2011). The spine (Fig. 55 2) projects obliquely from the glenoid fossa towards the vertebral border (France, 2011; Olsen, 1964). The coracoid process is thick and curved (Fig. 55 3), and the acromion process (Fig. 55 4) is well developed, with a large metacromial (Fig. 55 5) process (second acromion) (France, 2011; Olsen, 1964). Also, there is a faint inferior scapular spine (Fig. 55 6) with a postscapular fossa (Fig. 55 7). The glenoid fossa is oval shaped (Fig. 55 8) (Olsen, 1964).

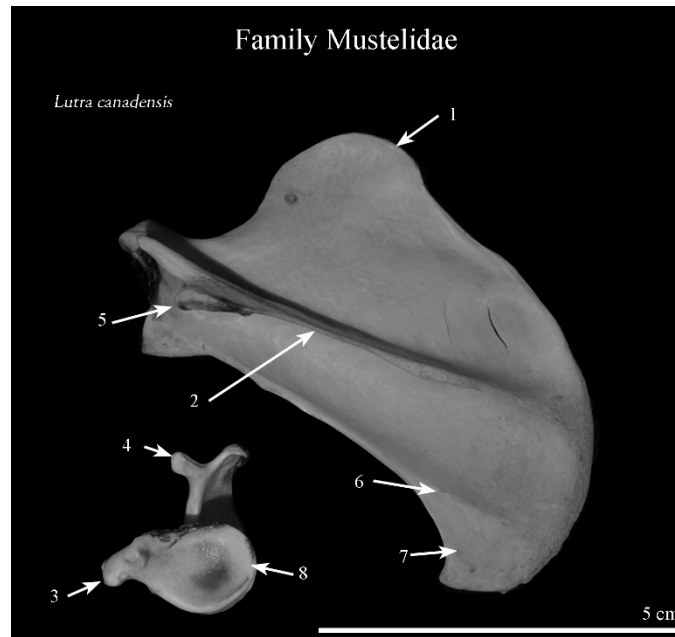


Figure 55: Anterior and lateral views of the left scapula of a river otter (*Lutra canadensis*)

### *Humerus*

The humerus, as seen in Figure 56, is short, with a curved shaft, and a wide flaring distal end (France, 2011; Olsen, 1964). The greater tubercle is small with only a minimal amount of elevation over the humeral head (Fig. 56 1). There is small intertubercular notch (Fig. 56 2) and the deltoid tuberosity is moderately sized with a smooth raised edge (Fig. 56 3). There is a large supracondylar ridge (Fig. 56 4) and there is an entepicondylar foramen (Fig. 56 5) (France, 2011; Olsen, 1964). The medial epicondyle flares distally (Fig. 56 6), and the trochlea is smaller than other families and in line with the capitulum (Fig. 56 7) (France, 2006).

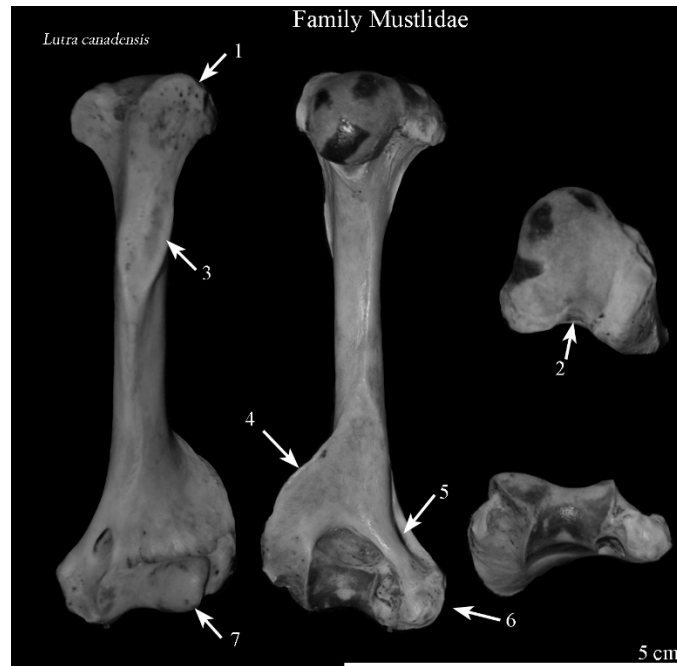


Figure 56: Anterior, posterior, superior, and inferior view of the left humerus of a river otter (*Lutra canadensis*)

### *Radius and Ulna*

The radius and ulna of this family, as can be seen in Figure 57, are not fused (Olsen, 1964). The radius has a wide head (Fig. 57 1) with upturned curved edges. The neck is well defined and the shaft of the radius is short, flaring distally (France, 2011). There is a raised line on the posterior surface of the distal shaft for a muscle attachment (Fig. 57 2). The ulna notch borders are raised and slightly curved (Fig. 57 3). The ulna is short, widened proximally and tapering distally (France, 2011). The olecranon process (Fig. 57 4) has a square outline with a slight curvature and is also short (Fig. 57 5) and bulbous. The semilunar notch is crescent shaped with a moderate amount of lipping (Fig. 57 6) and the interosseous crest is thick and raised (Fig. 57 7).

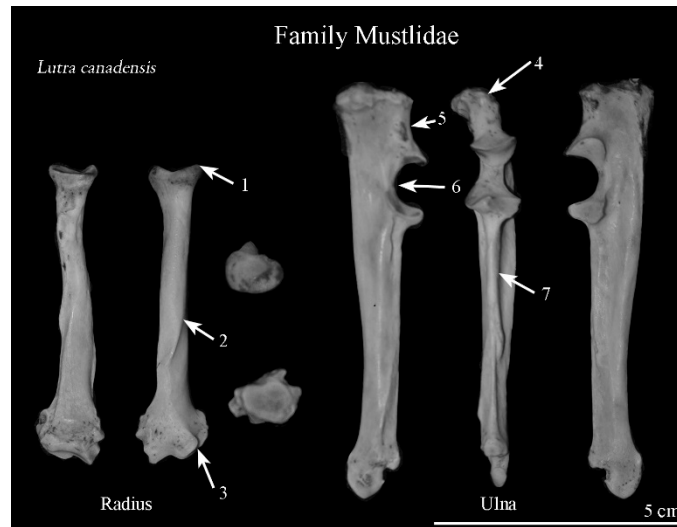


Figure 57: Anterior, posterior, superior, and inferior views of the left radius; medial, anterior, and lateral views of the left ulna of a river otter (*Lutra canadensis*)

### *Femur*

The femur, as seen in Figure 58, is short and widens distally (France, 2011). The femoral head is large, with a tapering neck, exhibiting a “mushroom” appearance. The greater trochanter (Fig. 58 1) is small, positioned parallel with the femoral head, while the lesser trochanter is rounded, and small (Fig. 58 2). The intertrochanteric fossa has only a slight depression (Fig. 58 3). The fovea capitis has a moderately sized circular depression (Fig. 58 4) and the patellar lip extends far superior than other families (Fig. 58 5). The condyles are angled inward towards the intercondylar fossa (Fig. 58 6) (France, 2011).

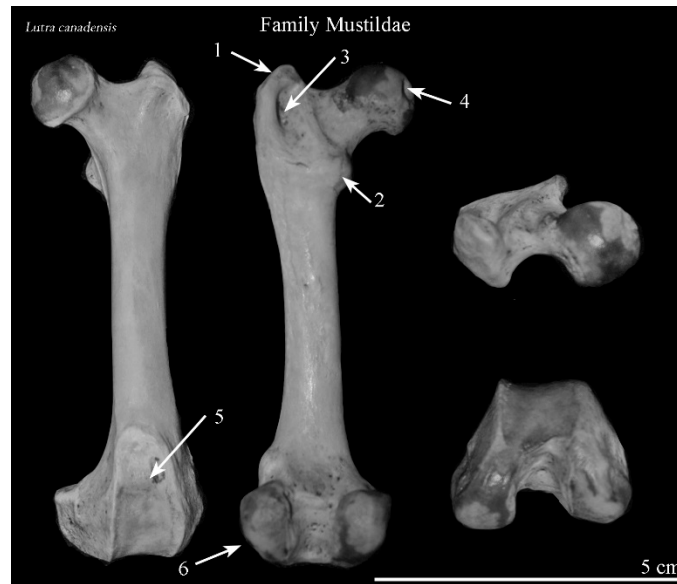


Figure 58: Anterior, posterior, superior, and inferior views of the left femur of a river otter (*Lutra canadensis*).

### *Tibia and Fibula*

The tibia and fibula for this family are not fused during adulthood (Olsen, 1964). The tibia, as seen in Figure 59, is long and slender with a slight curvature towards the lateral side. The distal end resembles an isosceles right triangle; especially when viewed from the posterior. The tibial tuberosity is small and flat (Fig. 59 1), with the tibial crest angled nearly parallel to the shaft (Fig. 59 2). The tibial plateau is D-shaped without a distinctive notch created by a large tibial tuberosity (Fig. 59 3). The medial malleolus is rounded, slender, and curves to the midline (Fig. 59 4). The fibula is thin and narrow (France, 2011). The proximal end is square shaped with a curve towards the medial (Fig. 59 5) while the distal end is diamond shaped (Fig. 59 6).

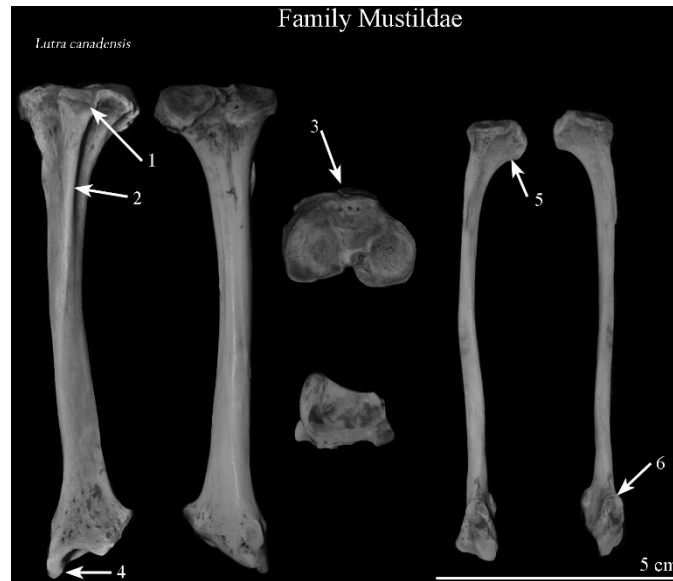


Figure 59: Anterior, posterior, superior, and inferior views of the left tibia; lateral and medial views of the left fibula of a river otter (*Lutra canadensis*).

### *Family Procyonidae*

The family Procyonidae contains many species including the ringtails (*Bassariscus astutus*), raccoons (*Procyon lotor*), and coatis (genera *Nasua* and *Nasua*) (Elbroch, 2006). They are omnivorous and support specialized dentition that include canines that are blunt and sharp. The carnassial tooth is poorly developed, as the molars are used mainly for crushing instead of shearing (Elbroch, 2006). They have a plantigrade locomotion pattern used both terrestrially and arboreally (Kent, 1992). The example used for this family is the raccoon, *Procyon lotor*. The observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not provided then observations made of other families and species were used as a baseline to make specific observations of the family in question.



## Cranial characteristics

### *Cranium*

The family Procyonidae cranium, as seen in Figure 60, is generally triangular, ranging from short slender, to short and broad, and having a long slender rostrum (Fig. 60 1) (Elbroch, 2006; France, 2011; Olsen, 1964). The zygomatic arches are large and wide-set while converging sharply to the anterior (Elbroch, 2006). The braincase is broad and oval with developed v-shaped temporal ridges that curve into a slight sagittal crest (Fig. 60 2). The post-orbital processes, ranging from small to large, are triangular shaped and project in various degrees from blunt and sharp (Fig. 60 3) (Elbroch, 2006; Olsen, 1964). The occipital crest is well developed (Fig. 60 4) (Elbroch, 2006).

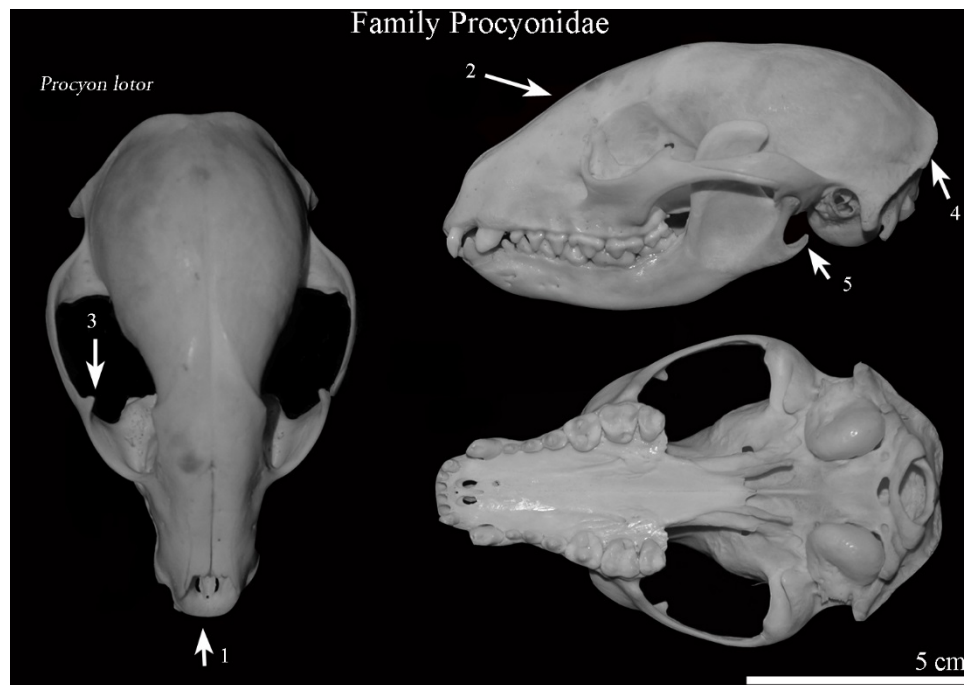


Figure 60: Cranial views of a raccoon (*Procyon lotor*).

## *Mandible*

The body of the mandible is long, curving towards the anterior surface (Elbroch, 2006). The coronoid process is large and rounded, ranging from gradually sloping to the posterior or sharply elevated, with the posterior side concave (Elbroch, 2006; France, 2011)). The condyle is round, short, and thick; while projecting towards the posterior. The angular process is small and narrow, projecting posteriorly with a slight curve (Fig. 60 5) (Elbroch, 2006; Olsen, 1964).

## Post-cranial characteristics

### *Scapula*

The scapula, as seen in Figure 61, has a curved cranial edge, with a large notch (Fig. 61 1) before the glenoid fossa (France, 2011; Olsen, 1964). The body is transected by a diagonal scapular spine (Fig. 61 2) that nearly divides the scapula in half (Adams and Crabtree, 2012; Olsen, 1964). The coracoid process is small and rounded (Fig. 61 3). The acromion process is short and thick, with a slight flare (Fig. 61 4), and there is a second metacromial process (Fig. 61 5) (France, 2011). Additionally the scapula has a small inferior spine (Fig. 61 6) that has created a small postscapular fossa (Olsen, 1964).

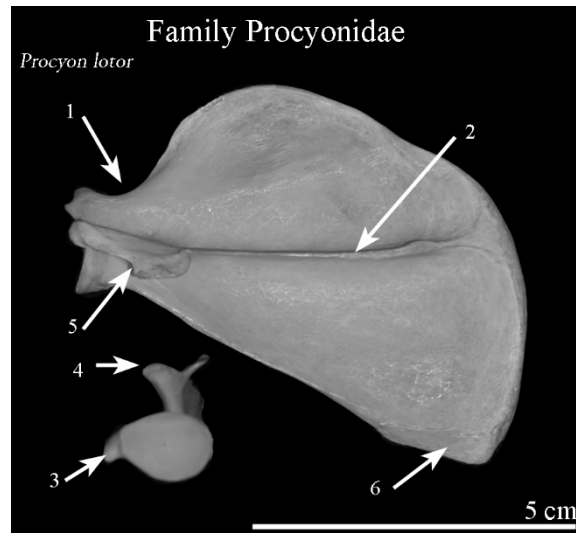


Figure 61: Anterior and lateral view of the left scapula of a raccoon (*Procyon lotor*).

### *Humerus*

The humerus, as seen in Figure 62, is short, slender, and flares distally (France, 2011). The greater tubercle is small and parallel to the humeral head (Fig. 62 1). The deltoid tuberosity is smooth with a raised elevation starting broad proximally and tapering past the mid-point of the anterior shaft (Fig. 62 2). The supercondyloid crest is moderate in size (Fig. 62 3) (France, 2011). Other features include a small entepicondylar foramen (Fig. 62 4) and the trochlear and capitulum are on the same axis (Fig. 62 5) (Olsen, 1964; France, 2011).



Figure 62: Anterior, posterior, superior, and inferior views of the left humerus of a raccoon (*Procyon lotor*).

### *Radius and Ulna*

The radius and ulna, as seen in Figure 63, are not fused in this family (Olsen, 1964). The radial head is well developed and circular, indicating a supinating-like motion is possible for this joint (Fig. 63 1) (Polly, 2007). The radial shaft is long and slender while the distal end flares widely. There is a small radial styloid process with a slight curvature (Fig. 63 2). The ulna is long, narrow, and tapers distally (Adams and Crabtree, 2012). The olecranon process (Fig. 63 3) is short, and square shaped with slight bi-lobule projections (France, 2011). The semilunar notch is crescent shaped (Fig. 63 4), with a small degree of lipping (Fig. 63 5). Also, the styloid process is thick, rounded with a slight curve projecting anteriorly (Fig. 63 6).

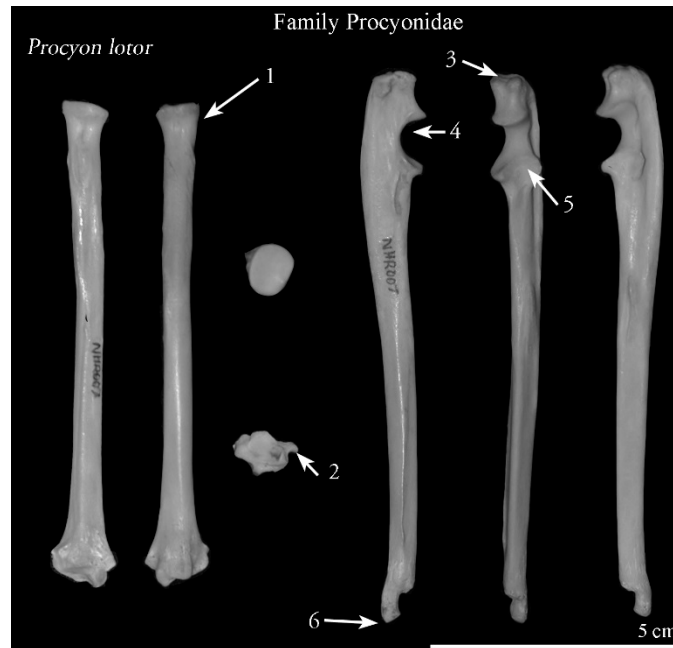


Figure 63: Anterior, posterior, superior, and inferior views of the left radius; Lateral, anterior, and medial views of the left ulna of a raccoon (*Procyon lotor*).

### *Femur*

The femur, as shown in Figure 64, is short, widening distally with a slight lateral rotation (France, 2011). The humeral head is well developed, with a slight narrowing of the neck. The greater trochanter is small, positioned below the humeral head (Fig. 64 1), and the lesser trochanter is equally as reduced (Fig. 64 2) (France, 2011). The intertrochanteric fossa is moderately deep (Fig. 64 3). The fovea capitis is a shallow, circular depression (Fig. 64 4), and the condyles are angled towards the intercondylar fossa, and are approximately equal in size (Fig. 64 5). Also, the patellar surface is flat (Fig. 64 6).



Figure 64: Anterior, posterior, superior, and inferior views of the left femur of a raccoon (*Procyon lotor*).

### *Tibia and Fibula*

The tibia and fibula, as seen in Figure 65, remain unfused in this family (Olsen, 1964). The tibial tuberosity (Fig. 65 1) is reduced, with the tibial crest curving slightly to the lateral (Fig. 65 2). The tibia is slender with a slight curvature (Fig. 65 3) near the midpoint of the shaft. The tibia plateau lacks a notch (Fig. 65 4), and is approximately D shaped (France, 2011). The fibula is long, narrow, and thin. The proximal end is square shaped with small notch on the end (Fig. 65 5). The distal end is rectangular shaped (Fig. 65 6).

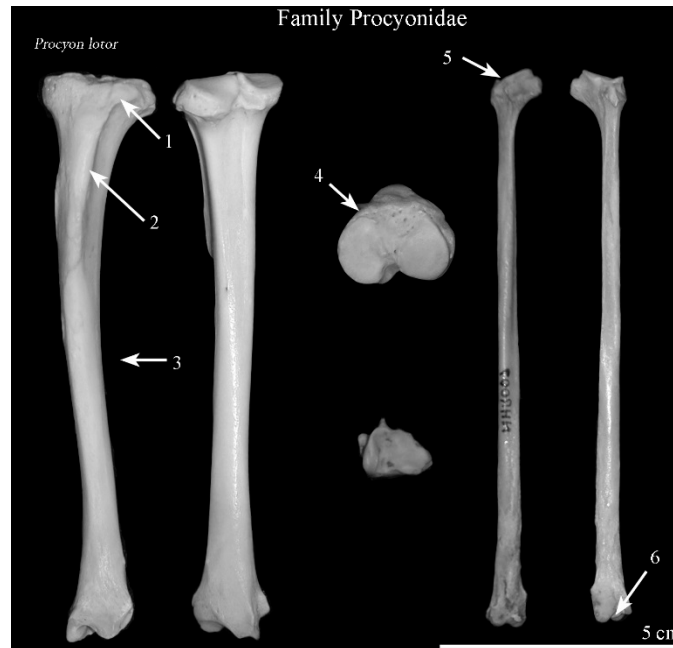


Figure 65: Anterior, posterior, superior, and inferior views of the left tibia; lateral and medial views of the left fibula of a raccoon (*Procyon lotor*).

### *Family Ursidae*

The family Ursidae consists of eight species across five genera. The only species' located in North America are the black bear (*Ursus americanus*) and brown bear (*Ursus arctos*). Ursids are omnivores, with prominent canines that have blunted edges to grab and immobilize prey (Elbroch, 2006). The posterior teeth are designed for holding and crushing; the lateral movement required for these actions is only permitted by the strong articulation between the cranium and mandible and muscle attachments to a well-developed sagittal crest, zygomatic arch, and glenoid fossa (Elbroch, 2006). They lack carnassials, and have a plantigrade stance. The observations made for this section have been inferred from multiple sources of information, if specific details

of a feature were not provided then observations made of other families and species were used as a baseline to make specific observations of the family in question.

### Cranial characteristics

#### *Cranium*

The skulls of the Ursidae family, as shown in Figure 66, are large and elongated, with wide- set zygomatic arches to accommodate the large masseter muscles used in the lateral movements required for crushing (Elbroch, 2006). The rostrum is moderately sized for this order (Fig. 66 1). The orbits are small, face forward, and lack a complete orbit, while the post-orbital process is triangular with a blunt rounded edge (Fig. 66 2) (Olsen, 1964, Elbroch, 2006). The temporal ridges (Fig. 66 3) come together to form a triangular or U-shaped pattern depending on the species. These ridges then continue posterior to form the sagittal crest (Fig. 66 4) (Elbroch, 2006). The occipital crest forms a prominent arc around a large supraoccipital shield (Fig. 66 5) (Elbroch, 2006).



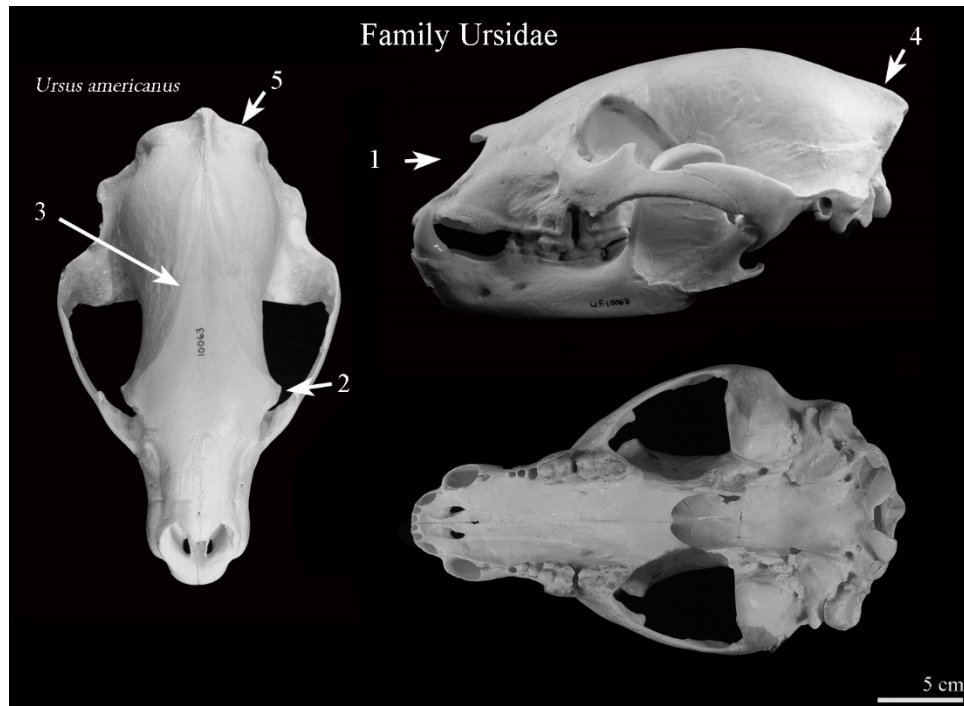


Figure 66: Cranial views of a black bear (*Ursus americanus*).

### *Mandible*

The mandible, as shown in Figure 67, is thick, projecting horizontally towards the anterior surface while curving slightly (Elbroch, 2006). The coronoid process is large and round, sloping towards the posterior surface (Fig. 67 1) (France, 2011; Elbroch, 2006). The condyle is rounded and thick, projecting posteriorly (Fig. 67 2) (Elbroch, 2006). The angular process is slender and pointed, curving to the posterior (Fig. 67 3) (Elbroch, 2006). Also, the number of mental foramina are variable throughout this family (Elbroch, 2006).

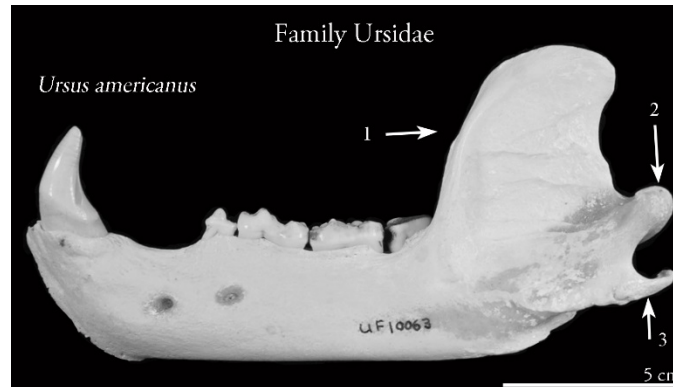


Figure 67: Lateral view of the mandible of a black bear (*Ursus americanus*).

## Post-cranial characteristics

### *Scapula*

The scapula, as seen in Figure 68, is square shaped with rounded edges (France, 2011). The cranial edge raises with a rounded hump (Fig. 68 1), before continuing straight (France, 2011). The vertebral edge connects with a diagonal spine (Fig. 68 2) that nearly divides the body of the scapula in half (Olsen, 1964; Adams and Crabtree, 2012). There is a second inferior spine (Fig. 68 3), which creates a postscapular fossa (Fig. 68 4) (Olsen, 1964; France, 2011). The acromion process is large and curved (Fig. 68 5), and the coracoid process is small and rounded (Fig. 68 6) (France, 2011). Also, the glenoid fossa is oval in shape (Fig. 68 7).

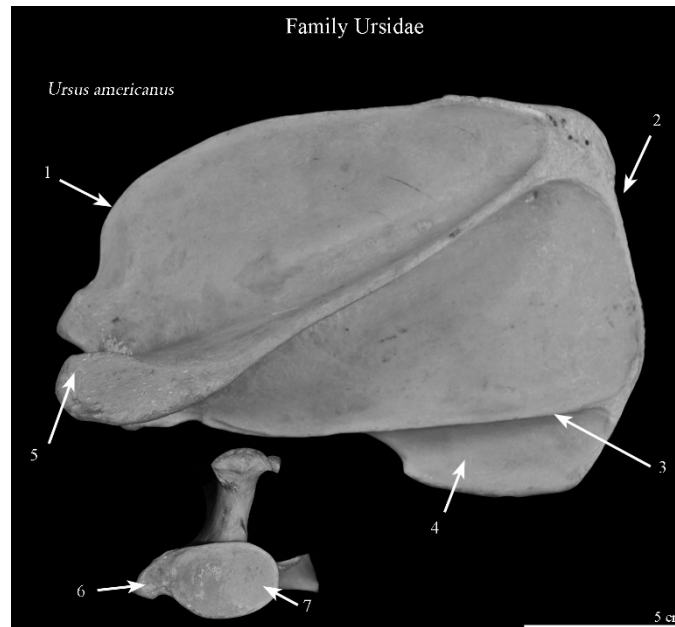


Figure 68: Anterior and lateral view of the left scapula of a black bear (*Ursus americanus*).

### *Humerus*

The humerus of the family Ursidae, as seen in Figure 69, is characterized by a small greater trochanter (Fig. 68 1) positioned inferior to the humeral head (France, 2011). The deltoid tuberosity is a raised ridge (Fig. 68 2), and the supercondylar crest is moderately developed (Fig. 68 3) (France, 2011; Adams and Crabtree, 2012). In addition, there is a supratrochlear foramen (Fig. 68 4), the medial epicondyle is nodular in shape (Fig. 68 5), and the olecranon fossa creates a deep curvature (Fig. 68 6) (France, 2011; Olsen, 1964).



Figure 69: Anterior, posterior, superior, and inferior views of the left humerus of a black bear (*Ursus americanus*).

### *Radius and Ulna*

The radius and ulna, as seen in Figure 70, do not fuse in this family (Olsen, 1964). The radial head is well developed with a slight incline and raised borders (Fig. 70 1). The proximal view shows a projection that helps to distinguish it from the human radial head (Fig. 70 2) (France, 2011; Adams and Crabtree, 2012). The shaft of the radius has a slight twist (Adams and Crabtree, 2012). The styloid process of the radius has a superior angle of approximately 45° (Fig. 70 3). The ulna is wide proximally and tapers distally with a slight curvature (France, 2011). The olecranon process is thick, with a variation within the species in the extent of its a bi-lobule

appearance (Fig. 70 4) (France, 2011; Adams and Crabtree, 2012). Also, the semilunar notch appears twisted to the side (Fig. 70 5) without significant lipping (Fig. 70 6) and the styloid process is thick and rounded (Fig. 70 7).

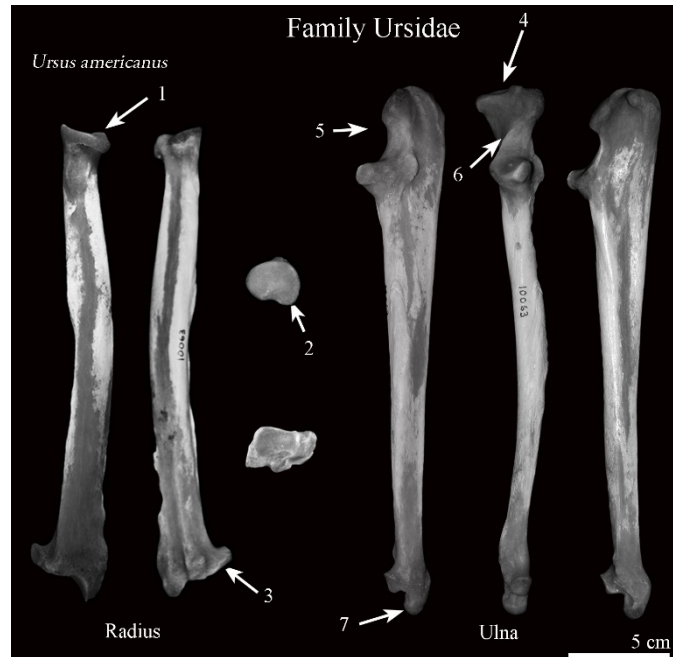


Figure 70: Anterior, posterior, superior, and inferior views for the left radius; lateral, anterior, and medial views for the left ulna of a black bear (*Ursus americanus*).

### *Femur*

The femur of this family, as seen in Figure 71, has a well-developed, rounded femoral head (France, 2011). The greater trochanter is small and is positioned inferior to the neck of the femoral head (Fig. 71 1) (France, 2011). The lesser trochanter is reduced (Fig. 71 2), the intertrchanteric fossa is moderately developed (Fig. 71 3), the fovea capitis is circular and moderately depressed (Fig. 71 4), and the patellar lip has defined edges (Fig. 71 5) but does not

have a sculpted appearance (Fig. 71 6). The condyles are unequal in shape. While the medial condyle (Fig. 71 7) is more rounded the lateral condyle is more squarely shaped. They both are angled towards the intercondylar fossa resulting in the ability to bring the knees under the body (Adams and Crabtree, 2012). Additionally there is a notch above the lateral condyle (Fig. 71 8) giving the distal view a “pinched” look on the medial aspect (France, 2011).

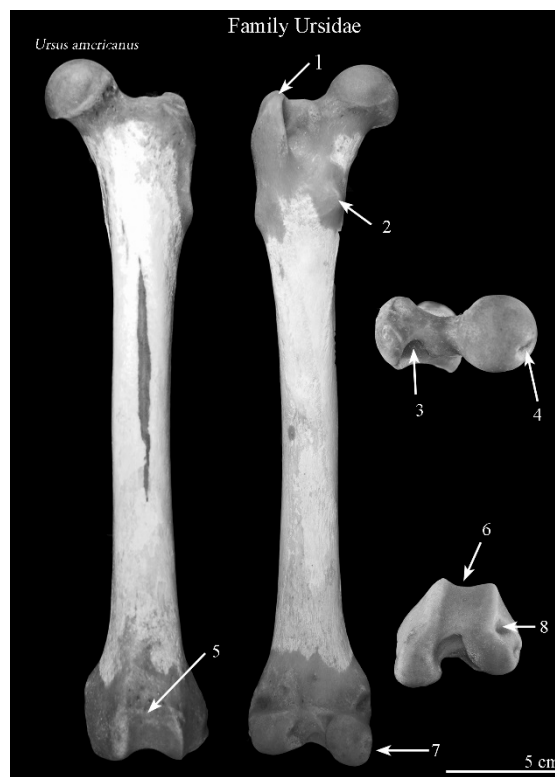


Figure 71: Anterior, posterior, superior, and inferior views of the left femur of a black bear (*Ursus americanus*).

### *Tibia and Fibula*

The tibia and fibula of this family, as seen in Figure 72, are not fused (Olsen, 1964). The tibial tuberosity is slightly elevated from the shaft but remains flat overall (Fig. 72 1). The shaft

is long, thick, and straight and the tibial plateau lacks a notch (Fig. 72 2) (France, 2011). The distal portion is triangular shaped with a pointed medial malleolus (Fig. 72 3). The fibula head and distal end are nearly equal in thickness to the shaft, with only a slight narrowing of the head (Fig. 72 4), and the distal end is rounded and has visible surfaces for articulation (Fig. 72 5).

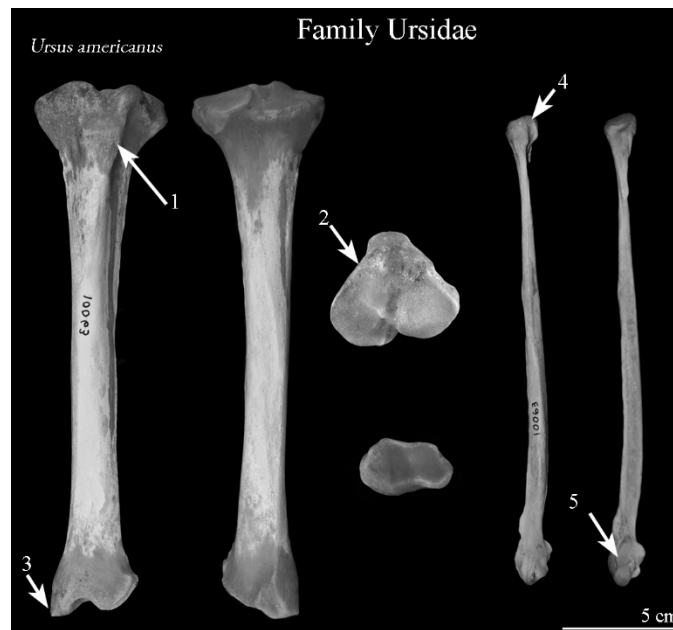


Figure 72: Anterior, posterior, superior, and inferior views of the left tibia; lateral and medial views of the left fibula of a black bear (*Ursus americanus*).

### Order Cingulata

This order is comprised of insectivorous mammals that lack incisors or canine teeth. The only surviving member of this order is the Dasypoids, the armadillos (*Dasypus novemcinctus*). They typically have short limbs that have been adapted for digging (Kent, 1992).

### *Family Dasypodidae*

The *Dasypus novemcinctus*, the nine-banded armadillo is the species common to Florida. They have short legs, homodontic peg-like dentition that lacks enamel (Elbroch, 2006; France, 2011). They also have large claws used for digging (Kent, 1992). The observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not provided then observations made of other families and species were used as a baseline to make specific observations of the family in question.

### Cranial characteristics

#### *Cranium*

The family Dasypodidae, as seen in Figure 73, has a very distinctive round cranium with a projecting narrow tubular shaped rostrum (Fig. 73 1) (Elbroch, 2006). The orbits are small, open, and positioned posterolaterally (Elbroch, 2006). Also, there are no post-orbital processes (Fig. 73 2). The braincase is very small and the cranium is mostly smooth with a slight rise of the sagittal and occipital areas, but not enough to be called a crest (Fig. 73 3) (Elbroch, 2006; France, 2011). This species lacks anterior dentition (Fig. 73 4) (Elbroch, 2006; France, 2011).



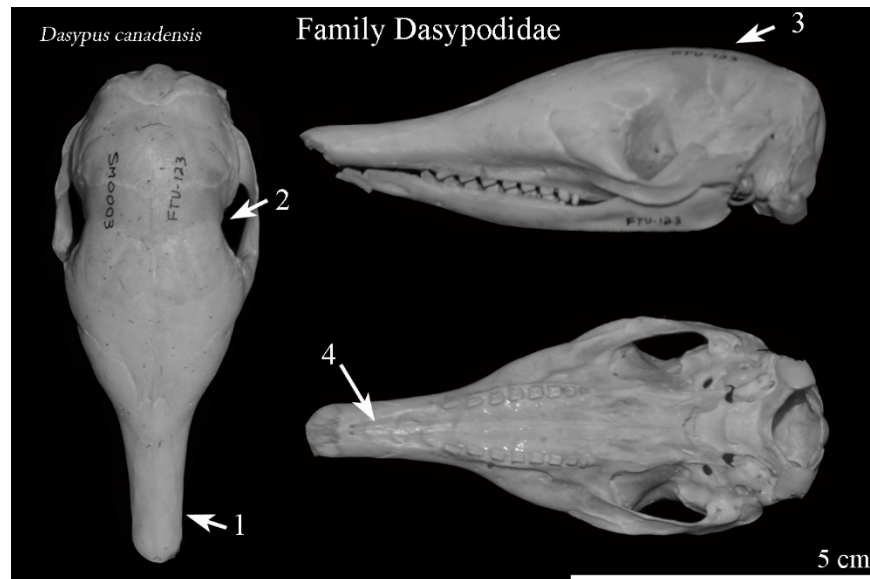


Figure 73: Cranial views for a armadillo (*Dasypus novemcinctus*).

### Mandible

The mandible, as seen in Figure 74, is long and very slender, narrowing towards the anterior surface (France, 2011). The coronoid processes is curved to the posterior, narrow in width, and has the tip angled towards the posterior (Fig. 74 1) (Elbroch, 2006). The angular process (Fig. 74 2) is curved horizontally with the condyle rounded (Fig. 74 3) and curving to the posterior; both are aligned to form a box like projection (Elbroch, 2006).



Figure 74: Lateral view of the mandible of a armadillo (*Dasypus canadensis*).

### Post-cranial characteristics

#### *Scapula*

The scapula, as seen in Figure 75, has a very distinctive isosceles triangular shape. The scapular spine is thick, curved and diagonally shaped (Fig. 75 1) and the caudal border is curved and rounded (Fig. 75 2). The acromion process (Fig. 75 3) is long and narrow, resembling a ‘hook’. The coracoid process is small and rounded (Fig. 75 4). There is an inferior spine, creating a postscapular fossa (Fig. 75 5), and the glenoid fossa is oval shaped with a moderately deep depression (Fig. 75 6) (France, 2011; Olsen, 1964).

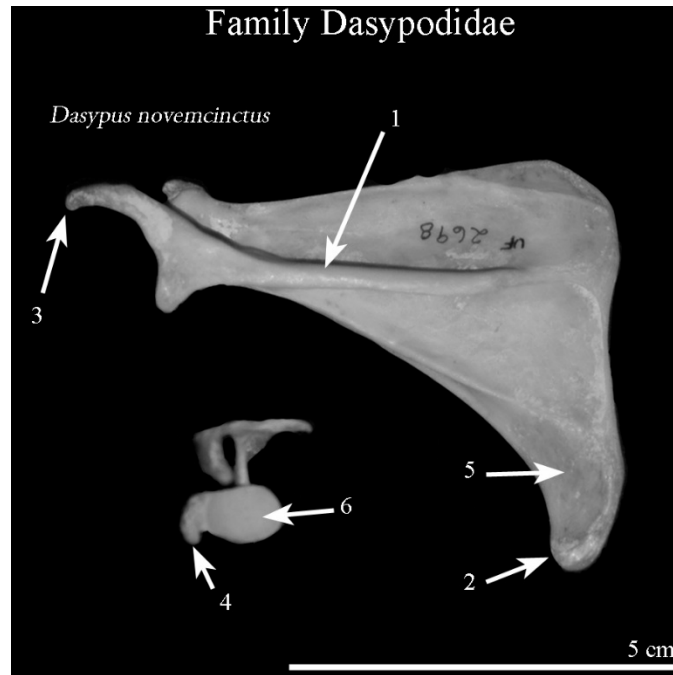


Figure 75: Anterior and lateral view of the left scapula of a armadillo (*Dasypus novemcinctus*).

### *Humerus*

The humerus, as seen in Figure 76, is short with exaggerated tubercles and ridges due to the adaptations needed for digging (Polly, 2007). The greater tubercle (Fig. 76 1) is moderately sized and rounded with a slight projection above the humeral head (France, 2011). The deltoid tuberosity and ridge are very large (Fig. 76 2), the supracondylar ridge is well developed (Fig. 76 3), there is an entepicondylar foramen (Fig. 76 4), and there is a small intertubercular groove (Fig. 76 5) (France, 2011; Olsen, 1964).

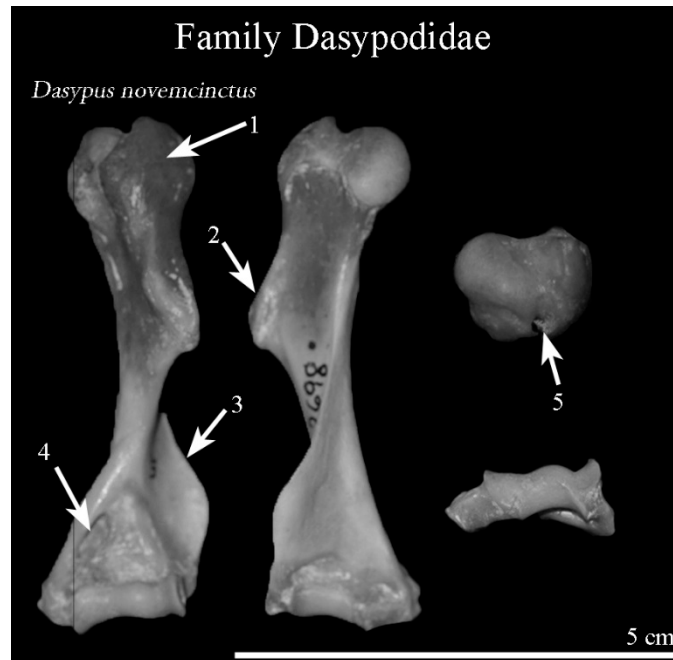


Figure 76: Anterior, posterior, superior, and inferior views of the left humerus of an armadillo (*Dasypus novemcinctus*).

### *Radius and Ulna*

The radius and ulna, as seen in Figure 77, does not fuse in this family (Olsen, 1964). The radius is shortened and curved, with an elongated radial head (Fig. 77 1) and the distal portion is elongated and flares (Fig. 77 2) (France, 2011). The ulna is shortened and broad with an elongated olecranon process with a sculpted head (Fig. 77 3) (France, 2011). Also, the semilunar notch is located nearly midshaft (Fig. 77 4), and the distal portion is rounded (Fig. 77 5).

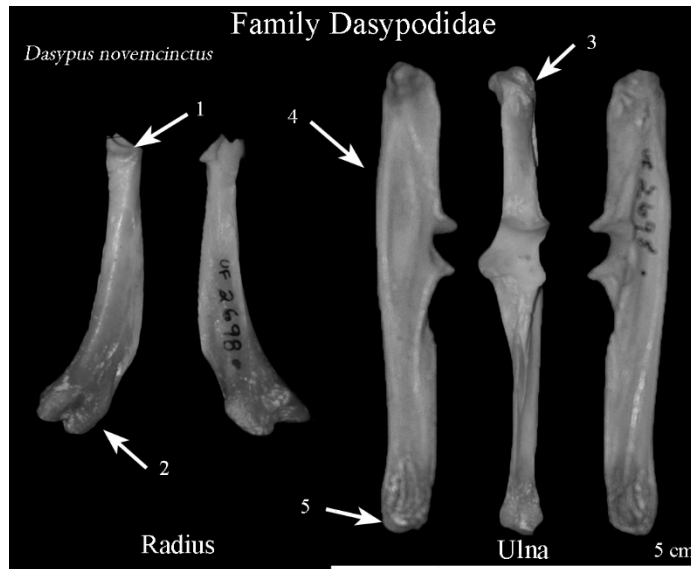


Figure 77: Lateral and medial views of the left radius; lateral, anterior, and medial views of the left ulna of a armadillo (*Dasypus novemcinctus*).

### *Femur*

The femur, as seen in Figure 78, is short with exaggerated projections and a curved shaft (France, 2011). The greater (Fig. 78 1), lesser (Fig. 78 2), and third (Fig. 78 3) trochanters are large and extended (France, 2011). Also, the fovea capitis is a crescent notch (Fig. 78 4) and the condyle are aligned with the angle of the greater trochanter (Fig. 78 5).

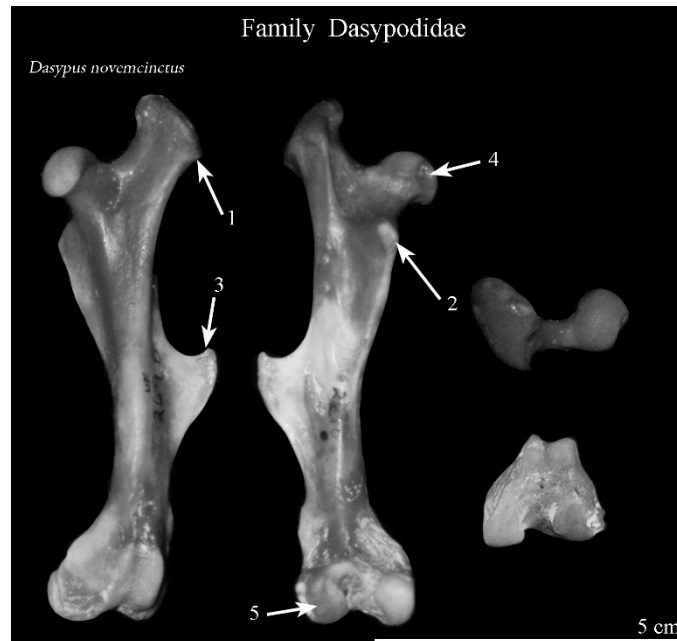


Figure 78: Anterior, posterior, superior, and inferior views of the left femur of a armadillo (*Dasypus novemcinctus*).

### *Tibia and Fibula*

The tibia and fibula, as seen in Figure 79, are fused in this family (Olsen, 1964). The tibia is short and thick, and the tibial tuberosity is moderately sized (Fig. 79 1) with a moderately angled tibial crest (Fig. 79 2). The fibula is irregularly shaped with the shaft narrowing at the midpoint before flaring to join the distal tibia (Fig. 79 3). Also, the medial condyle of the tibial plateau has a distinctive flare where it fuses to the head of the fibula (Fig. 79 4).

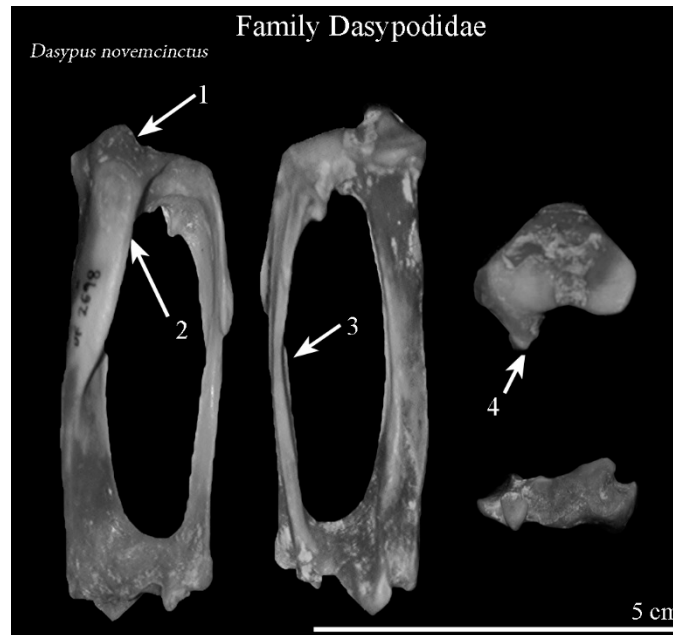


Figure 79: Anterior, posterior, superior, and inferior views of the left fused tibia and fibula of an armadillo (*Dasypus novemcinctus*)

## Order Rodentia

The order Rodentia is the largest mammalian order (Kent, 1992). Rodents are characterized by a single pair of long, curved incisors that have enamel on the outer surface only. They do not have canines, and a diastema is found between the incisors and the premolars/molars (Kent, 1992).

### *Family Castoridae*

There is only one member comprising this family, the American beaver *Castor canadensis*. This rodent is partly aquatic and has modifications to accommodate both environments (Elbroch, 2006). Their dentition is characterized by continuously growing

(hypsodontic) large incisors that are covered with yellow enamel; this adaptation is useful for gnawing bark and other plant materials. Their molars are lophodontic (which are not continuously growing) (Hesse and Wapnish, 1985). The observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not provided then observations made of other families and species were used as a baseline to make specific observations of the family in question.

### Cranial characteristics

#### *Cranium*

The cranium, as seen in Figure 80, is large and dense with a long and narrow braincase (Elbroch, 2006). The rostrum is short and wide with the nasal bones tapering towards the anterior aspect of the skull (Fig. 80 1) (Elbroch, 2006). The zygomatic arches are thick wide-set, and curve slightly towards the posterior (Fig. 80 2) (Elbroch, 2006). The orbits are small, open, and are set facing the anterior (France, 2011; Elbroch, 2006). There is no post-orbital process on the frontal bones but there is a well-developed triangular process (Fig. 80 3) on the zygomatic arches (Elbroch, 2006). The temporal ridges (Fig. 80 4) are well developed, converging towards the posterior with a V-shape pattern, to form a well-developed sagittal crest (Elbroch, 2006). Additionally, the occipital crest (Fig. 80 5) is moderately developed, and there is a deep notch formed by long projections of the auditory meatus and the zygomatic arch (Fig. 80 6) (France, 2011; Elbroch, 2006; Olsen, 1964).



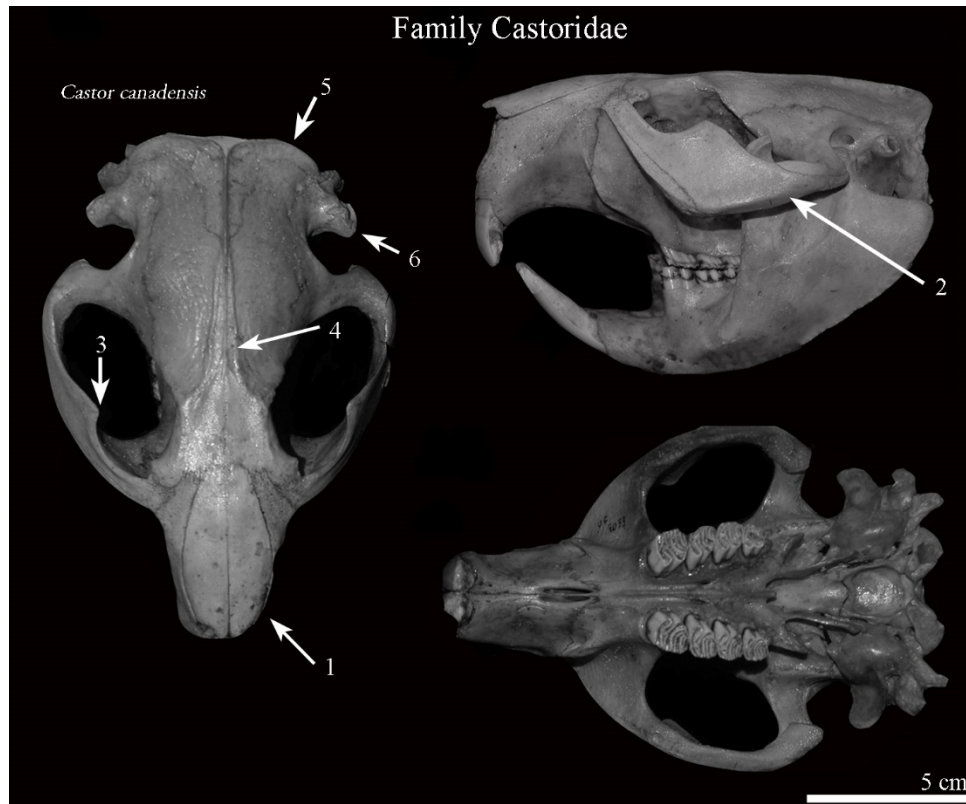
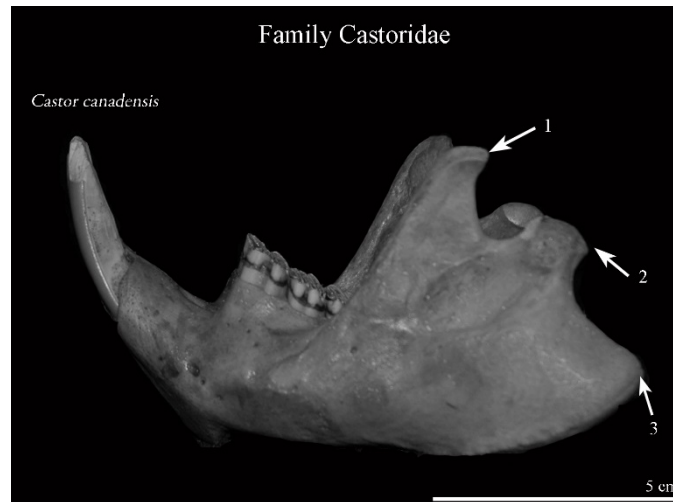


Figure 80: Cranial views of a beaver (*Castor canadensis*).

### *Mandible*

The mandible, as seen in Figure 81, has a distinct shape. From the posterior aspect of the mandible the body projects at a decreased angle until the tooth rows end, then continues forward curving towards the anterior aspect of the skull (Elbroch, 2006). The coronoid process (Fig. 81 1) is thick and rounded, rising at a near vertical elevation, and curving toward the posterior aspect of the mandible (Elbroch, 2006). Additionally, the condyle is rounded, short, and thick (Fig. 81 2), and the angular process is large and curves toward the posterior aspect of the mandible (Fig. 81 3) (Elbroch, 2006).



*Figure 81: Lateral view of the mandible of a beaver (Castor canadensis).*

### Post-cranial characteristics

#### *Scapula*

The scapula, as seen in Figure 82, is “pear” shaped. The cranial, vertebral, and inferior borders are rounded (Fig. 82 1). The coracoid process is reduced with a small curvature (Fig. 82 2) and the acromion process is a strong, continuous arch from the midpoint of the scapular spine (Fig. 82 3) (France, 2011). Additionally, the spine is diagonal and divides the body in equal parts and the glenoid fossa is oval with a slight depression (Fig. 82 4) (Olsen, 1964; France, 2011).

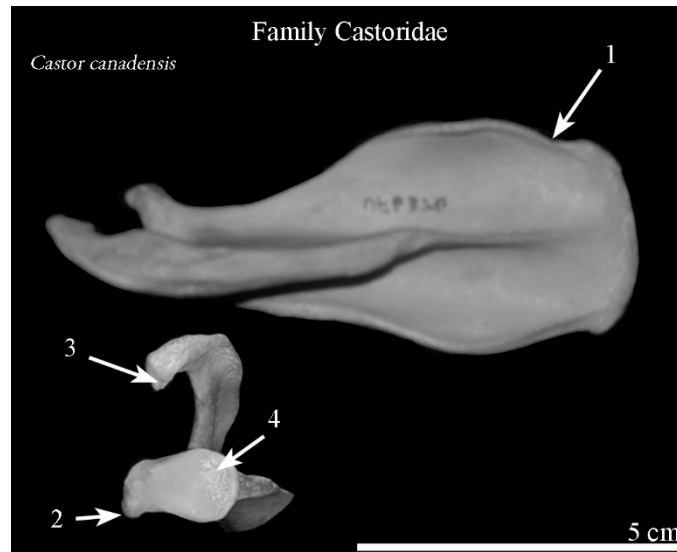


Figure 82: Lateral and anterior view of the left scapula of a beaver (*Castor canadensis*).

### *Humerus*

The humerus, as seen in Figure 83, has very pronounced features and a wide, flaring distal end (France, 2011). The greater tubercle (Fig. 83 1) is large but does not project higher than the humeral head (France, 2011). The intertubercular groove is small (Fig. 83 2). The deltoid tuberosity is a very large, rounded, and roughened projection (Fig. 83 3) (Olsen, 1964; France, 2011). Additionally, the supracondyloid ridge is large and widely flaring (Fig. 83 4). The trochlea is more pronounced than the capitulum (Fig. 83 5) (France, 2011).

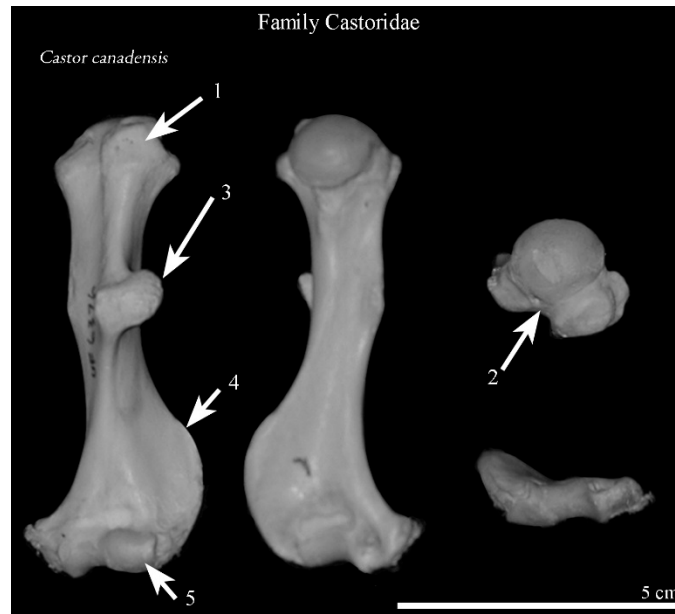


Figure 83: Anterior, posterior, superior, and inferior views of the left humerus of a beaver (*Castor canadensis*).

### *Radius and Ulna*

The radius and ulna, as seen in Figure 84, are not fused in this family (Olsen, 1964). The radial head is well developed with small a degree of curvature at the edges (Fig. 84 1). The shaft is slender and straight. The distal portion flares and has a small styloid process (Fig. 84 2). The ulna is short, broad, and narrows distally. The olecranon process (Fig. 84 3) is moderately large and sculpted with a pyramid-like shape. The semilunar notch is crescent shape, with a moderate amount of lipping. The styloid process is a small, nodule like projection (Fig. 84 4).

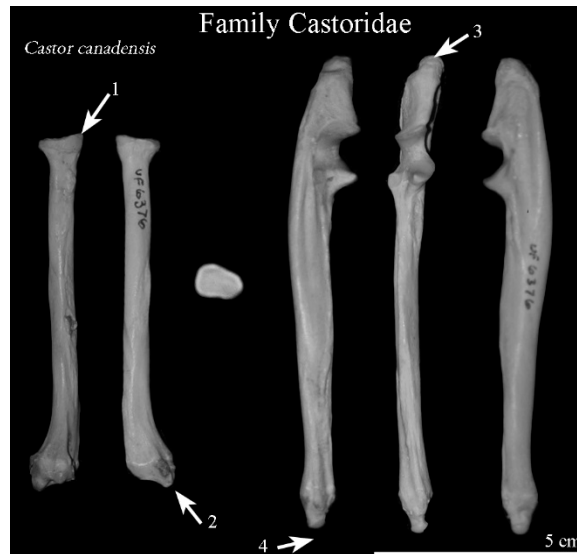


Figure 84: Anterior, posterior, and superior view of the left ulna; lateral, anterior, and medial views of the left ulna of a beaver (*Caster canadensis*).

### *Femur*

The femur, as seen in Figure 85, is short, heavy, thick, and widens distally (France, 2011). The femoral head is well developed, with a narrow neck creating a “mushroom” like appearance. The greater trochanter is very large and projects higher than the femoral head (Fig. 85 1), while the lesser trochanter is moderately sized (Fig. 85 2) (France, 2011). There is a third trochanter located just superior to the midpoint of the shaft (Fig. 85 3). The distal shaft is the widest part of the femur (Fig. 85 4) and the patellar surface is well defined, without having exaggerated borders (Fig. 85 5) (Olsen, 1964). The fovea capitis is a shallow depression (Fig. 85 6) while, the condyles are unequal in size, and angled towards the flaring epicondyles (Fig. 85 7).

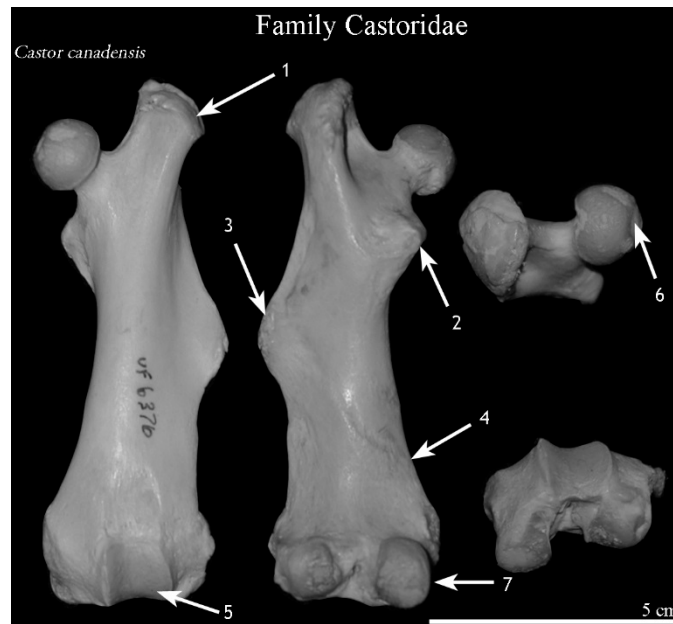


Figure 85: Anterior, posterior, superior, and inferior views of the left femur of a beaver (*Castor canadensis*).

### *Tibia and Fibula*

The tibia and fibula, as seen in Figure 86, are fused, but remain distinguishably separate elements in this family (Olsen, 1964; France, 2011). The tibia is slender with a marked curvature ending past the midpoint of the shaft. The tibial tuberosity is moderately developed (Fig. 86 1) and the tibial crest is long, ending past the midpoint of the shaft (Fig. 86 2). The styloid process of the fibular head is ‘hooked’, and projects inferiorly (Fig. 86 3). Also there is no gap between the medial condyle and tibial tuberosity (Fig. 86 4) and the distal surface does not have pronounced articular grooves (Fig. 86 5).

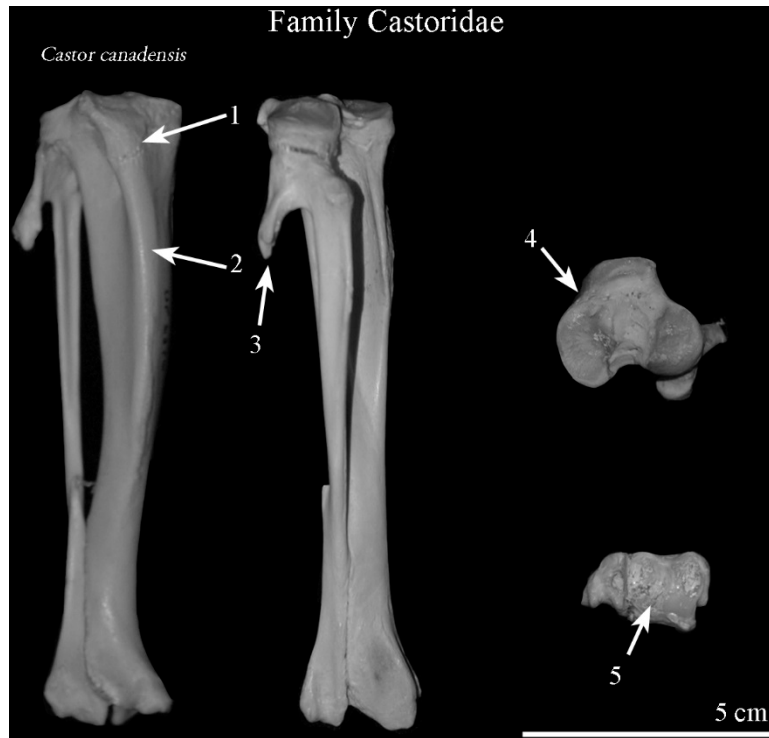


Figure 86: Anterior, posterior, superior, and inferior views of the left fused tibia and fibula of a beaver (*Castor canadensis*).

### Class Mammalia: Marine

#### Order Sirenia

This order is comprised of two families: Trichechidae and Dugongidae. These are marine mammals and have many adaptations to an aquatic environment including having very dense bones.

### *Family Trichechidae*

The family Trichechidae is comprised of manatees. The species local to Florida waters is known as the West Indian manatee, *Trichechus manatus*. They have molariform teeth that are continually replaced. The specimen available for documentation was unfortunately a juvenile and was missing the epiphysis to all of the post-cranial bones. The observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not provided then observations made of other families and species were used as a baseline to make specific observations of the family in question. This section in particular observations have been inferred based on the information from the previous sections, due to a lack of information making similar observation for marine mammals.

### Cranial characteristics

#### *Cranium*

The cranium, as seen in Figure 87, is very large, heavy with a tapering, triangular shaped rostrum (Fig. 87 1) (Elbroch, 2006). The braincase is small. The orbits are open, small, and positioned anteriorly (Elbroch, 2006). The zygomatic arches are thick, wide-set and form a blunted point (Fig. 87 2) (Elbroch, 2006). The frontal bones lack post-orbital processes. The temporal ridges are well developed, projecting towards the posterior without meeting to form a sagittal crest. The occipital crest is well-developed (Fig. 87 3) (Elbroch, 2006).



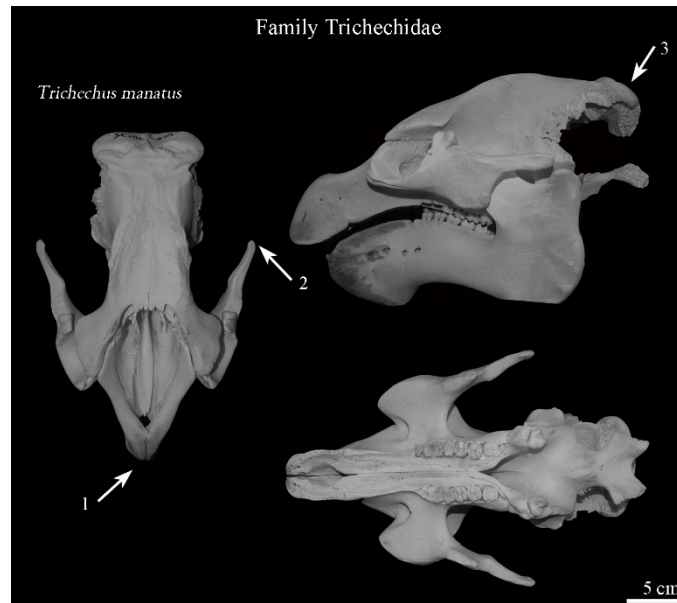


Figure 87: Cranial views of a manatee (*Trichechus manatus*).

### *Mandible*

The mandible is very large and heavy. The coronoid process is square shaped, angled towards the anterior aspect of the mandible then curves back to the posterior aspect of the cranium (Elbroch, 2006). The condyle is very high, positioned just below the coronoid process, which is rounded and thick (Elbroch, 2006). Also, the angular process is thick and curves towards the posterior aspect of the mandible.

### Post-cranial characteristics

#### *Scapula*

The scapula, as seen in Figure 88, is very large and dense, with rounded edges. The cranial border has a slight depression before rising to the superior angle (Fig. 88 1). The inferior angle curves laterally (Fig. 88 2). The scapular spine is thin and blade like, terminating at the midpoint of the body (Fig. 88 3). The acromion process is large and rounded (Fig. 88 4).

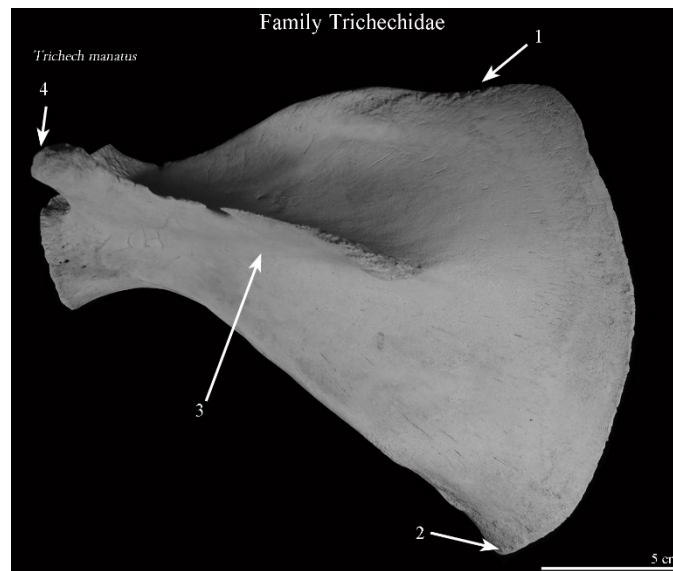


Figure 88: Lateral view of the left scapula of a juvenile manatee (*Trichechus manatus*).

### *Humerus, Radius, and Ulna*

The post-cranial elements of the family Trichechidae available for this study did not contain the pelvic girdle lower appendage (femur, tibia/fibula, metatarsal, or phalanges). The humerus, as seen in Figure 89, is dense and reduced with smoothed features; while still retaining a diagnostic curvature (Fig. 89 1). The radius has a clear radial head, narrowing neck and shaft, and flaring distal end (Fig. 89 2). The ulna has a semilunar notch, reduced olecranon process, and a wide square shape distal end (Fig. 89 3).

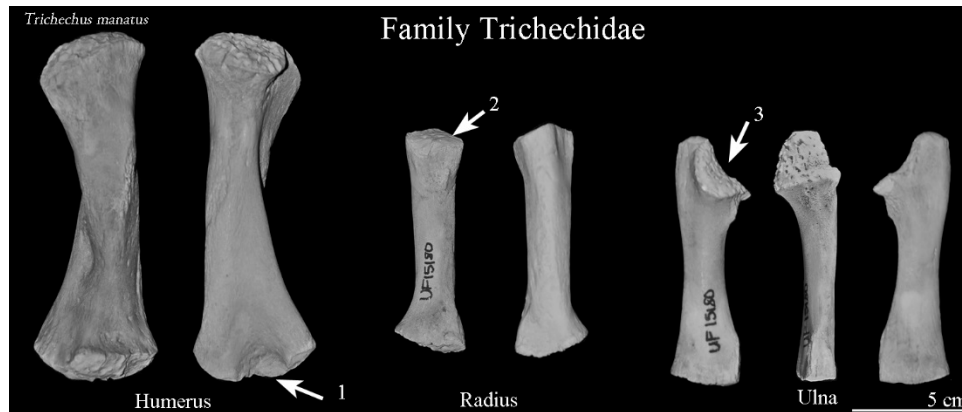


Figure 89: Anterior and posterior views for the left humerus and radius; lateral, anterior, and medial views for the left radius of a juvenile manatee (*Trichechus manatus*).

## Order Cetacea

The order Cetacea is composed of two suborders: the Mysticeti (i.e., baleen whales) and the Odontoceti (i.e., orcas, dolphins, porpoises, beaked whales, and sperm whales). The two suborders can be differentiated by the shape of their skulls and the presence or absence of teeth (Kent, 1992). The Mysticeti have long, arched rostrums that can accommodate baleen attachments while the Odontoceti have very large concave foreheads to accommodate the fatty tissue used in echo location and small homodont peg like dentition (Elbroch, 2006).

### *Family Delphindae*

The family Delphindae is a part of the Odontoceti suborder. The specimen used for this family is the bottle-nosed dolphin, *Tursiops truncatus*. The observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not

provided then observations made of other families and species were used as a baseline to make specific observations of the family in question. For this section in particular observations have been inferred based on information from the previous sections and information provided for several marine based orders by Berta et al. (2006). Specific information on Delphinds was not available for all skeletal elements so observations for several different orders were used to make inferences for this particular family.

### Cranial characteristics

#### *Cranium*

The cranium of the Delphinid, as seen in Figure 90, is triangular shaped (Elbroch, 2006). It is also telescoped, meaning the facial bones are displaced in relation to the braincase (Elbroch, 2006). The premaxilla and maxilla make up most of a long slender rostrum that projects anteriorly (Fig. 90 1) (Elbroch, 2006). There are two large nasal holes (Fig. 90 2) and the orbits are low, open, and very large (Fig. 90 3). There are very thin zygomatic bones, not seen in this specimen, visualized on the ventral side (Elbroch, 2006). The occipital crest displays a slight rise.

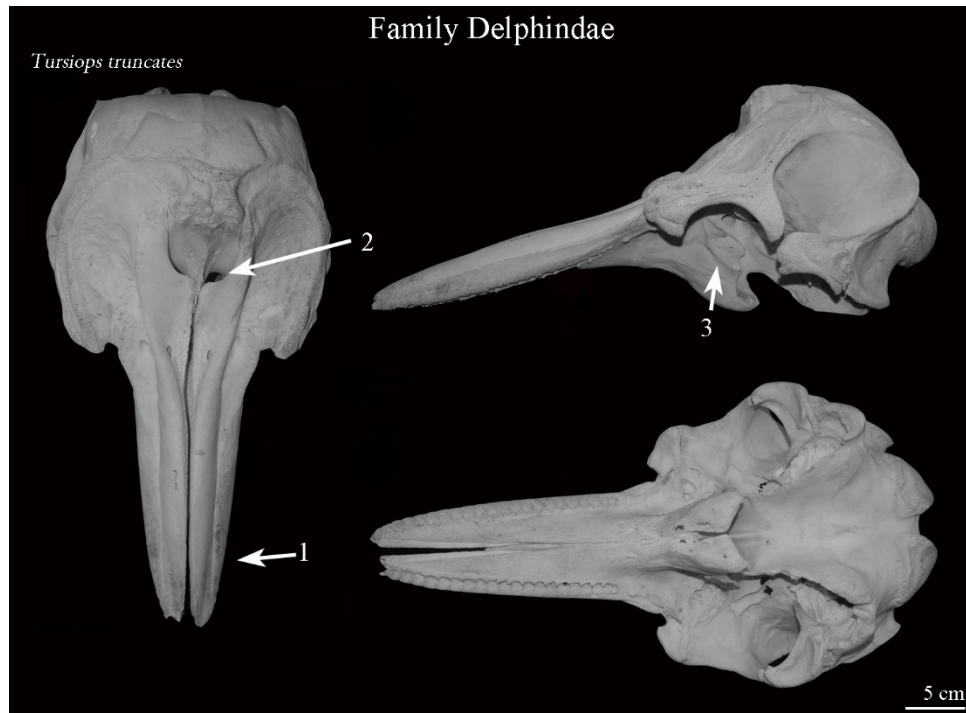


Figure 90: Cranial views of a bottle-nose dolphin (*Tursiops truncatus*).

### *Mandible*

The mandible of the bottle-nosed dolphin, *Tursiops truncatus* was unfortunately not present at the time of the data collection. The mandible is long and slender, projecting horizontally towards the anterior (Elbroch, 2006). The coronoid process is thick, with very little elevation. The condyle is robust and curved, projecting towards the posterior. Also, the angular process is small, creating a sharp corner towards the condyle (Elbroch, 2006).

## Post-cranial characteristics

### *Scapula*

The scapula of this family, as seen in Figure 91, is very large, with an exaggerated fan like appearance (Berta et al., 2006). The cranial border is flat (Fig. 91 1), curving sharply on the vertebral border. The body does not have a traditional spine but instead has two ridges (Fig. 91 2, 3) dividing the body into pre and post scapular fossae. The acromion process is an extension of the neck (Fig. 91 4) and the coracoid process is a blade like extension (Fig. 91 5).

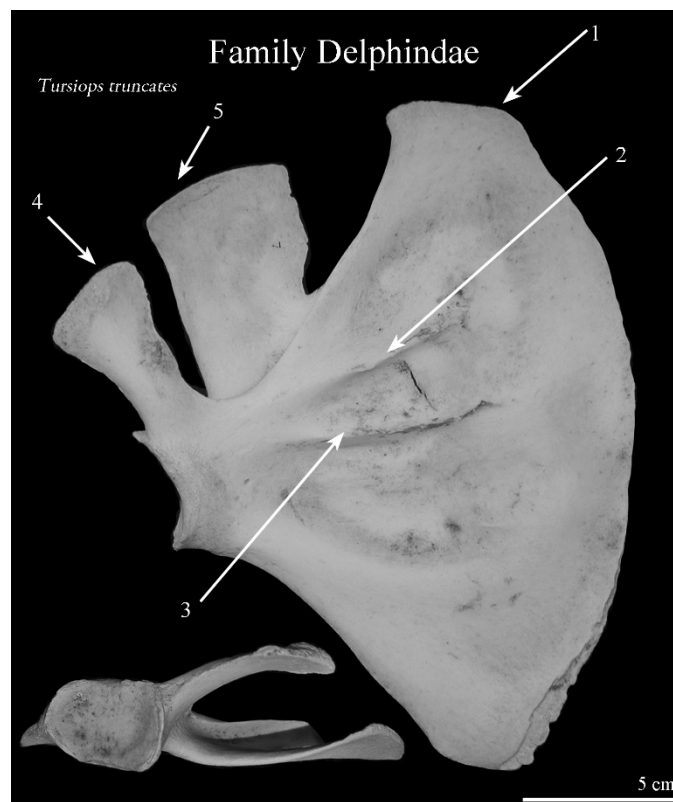


Figure 91: Anterior and lateral views of the left scapula of a bottle-nose dolphin (*Tursiops truncatus*).

### *Humerus, Radius, and Ulna*

This family only has forelimb skeletal elements. The humerus, as seen in Figure 92, is much reduced, dense, and still retains the distinctive rounded head (Fig. 92 1). The radius is dense, flat, retains a broad rounded head, and flares distally (Fig. 92 2). The radial styloid process is still present. The ulna is dense, flat, and missing the olecranon process (Fig. 92 3). The “semi-lunar” notch is only a notch with a developed coracoid process.

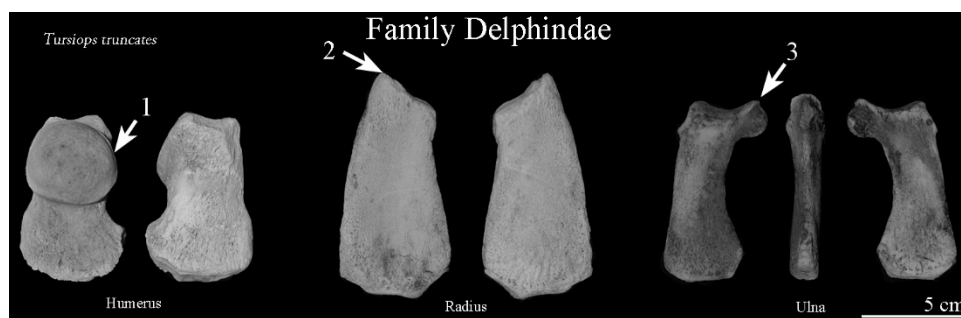


Figure 92: Anterior and posterior views of the left humerus and radius; lateral, anterior, and medial views of the left ulna of a bottle-nose dolphin (*Tursiops truncatus*).

## Class Reptilia

### Order Crocodylia

The order Crocodylia is comprised of three semiaquatic families; the Gavialidae, the Alligatoridae, and the Crocodylidae. The order is characterized by three notable modification of the basic archosaur skull: secondary palate for underwater breathing, the pterygoid and quadrate adhering to the braincase, and the closure of the otic notch (Romer, 1997). All members have homodont dentition. The following will be an outline of the skeletal characteristics of the family Alligatoridae.

### *Family Alligatoridae*

The family Alligatoridae can be distinguished by a rounded broad rostrum with an overbite of the upper dental arcade. The regional variant found in Florida is the Florida alligator (*Alligator mississippiensis*). The observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not provided then observations made of other families and species were used as a baseline to make specific observations of the family in question. This particular section used the information provided in Reynolds (1897), Olsen (1968), and Romer (1997) to infer much of the features of the cranial and post-cranial elements.

### Cranial characteristics

#### *Cranium*

The family Alligatoridae cranium, as seen in Figure 93, is long, broad, and flattened (Elbroch, 2006; Olsen, 1968; Romer, 1997). The cranium has a U-shaped maxillary and a premaxilla that projects towards the anterior aspect of the cranium (Olsen, 1968). The orbits are closed, oblong, positioned deeply posterior, and on the dorsal aspect of the cranium (Fig. 93 1). There are two oval shaped nares in the premaxillary (Fig. 93 2), a triangular shaped lower temporal fenestra located posterior to the orbit, and an oval upper temporal fenestra just medial to it (Fig. 93 3). Also, the jugal (zygomatic bones in mammals) are long, thick, and project sharply towards to the posterior (Fig. 93 4).



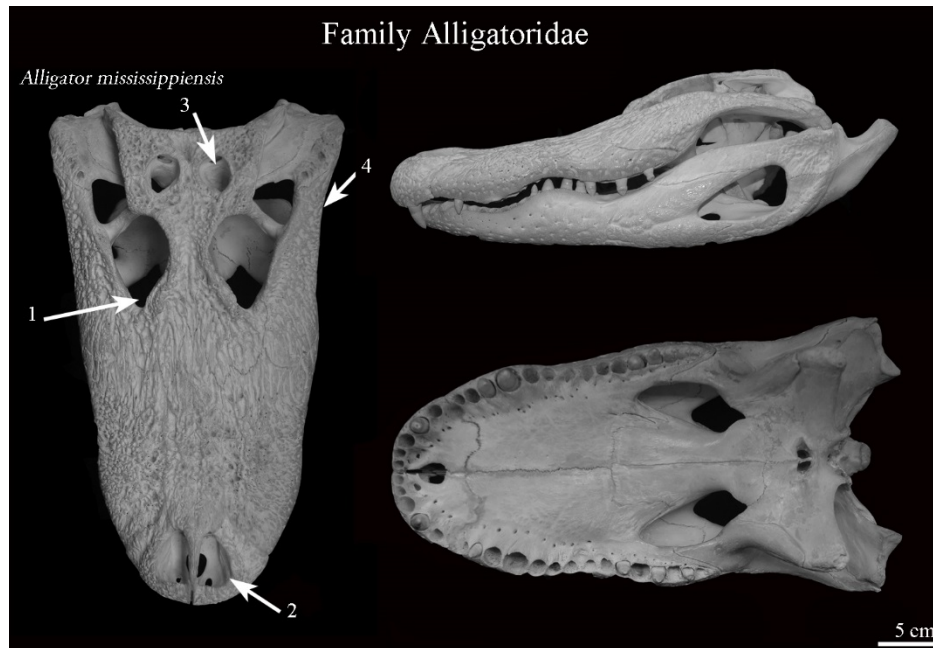


Figure 93: Cranial views of a Florida alligator (*Alligator mississippiensis*).

### *Mandible*

The mandible, as seen in Figure 94, is long, and thick with the body projecting anteriorly (Olsen, 1968). The angular bone is thick, curves posterior with a distinctive hooked projection, and positioned posterior to the splenial (small bone of the lower jaw positioned between the angular and supragular bone in reptiles, avians, and amphibians) (Fig. 94 1) (Reynolds, 1897). There is a large, oval shaped mandibular fossa (Fig. 94 2). The articular bone (Fig. 94 3) is thick, curves towards the posterior, and articulates with the cranium (Reynolds, 1897; Olsen, 1968).



Figure 94: Lateral views of the mandible of a Florida Alligator (*Alligator mississippiensis*).

### Post-cranial characteristics

#### *Humerus, Radius, and Ulna*

The post-cranial skeletal elements of the family Alligatoridae, as seen in Figure 95, are reduced, without exaggerated features. The humerus does not have the recognizable rounded humeral head due to the shape of the scapula (not available during collection) and the coracoid (separate element). There is a deltoid tuberosity (Fig. 95 1) and the distal end has some curvature reminiscent of the capitulum, however, the olecranon fossa is absent (Fig. 95 2). The radius has a well-developed radial head with a slight curvature to the edges (Fig. 95 3). Also, the shaft is slender and narrow with the distal portion resembling an isosceles triangle. The ulna is wide proximally and tapers distally (Olsen, 1968). There is no olecranon process nor is there a semilunar notch (Fig. 95 4) which corresponds with what is found in the humerus. Also, the head is bulbous and thick, the shaft is slender with a small curvature, and a small styloid process (Fig. 95 5).

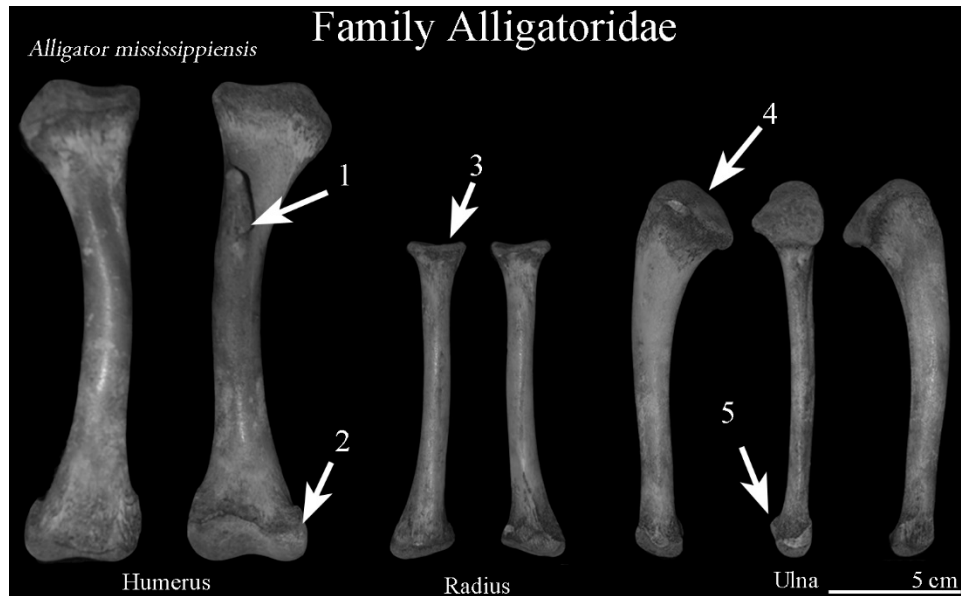


Figure 95: Anterior and posterior views for the left humerus and radius; lateral, anterior, and medial views for the left ulna of a Florida alligator (*Alligator mississippiensis*).

### *Femur, Tibia, and Fibula*

The femur, as seen in Figure 96, has a moderately large greater trochanter (Fig. 96 1) without a developed femoral head (Olsen, 1968). There is an intertrochanteric groove (Fig. 96 2). There is a well developed tuberosity just inferior to the trochanters (Fig. 96 3). The distal end has some condyle like definition (Fig. 96 4). The tibia is recognized by a wide flaring proximal end (Fig. 96 5). There is not a pronounced tibial tuberosity or crest; instead a small projected curvature. The distal portion of the tibia has a rounded projection (Fig. 96 6). Also, the fibula has a wide, square shaped head (Fig. 96 7), the shaft is slender and tapers distally, and the distal end of the fibula has a distinctly outlined articulation surface (Fig. 96 8).

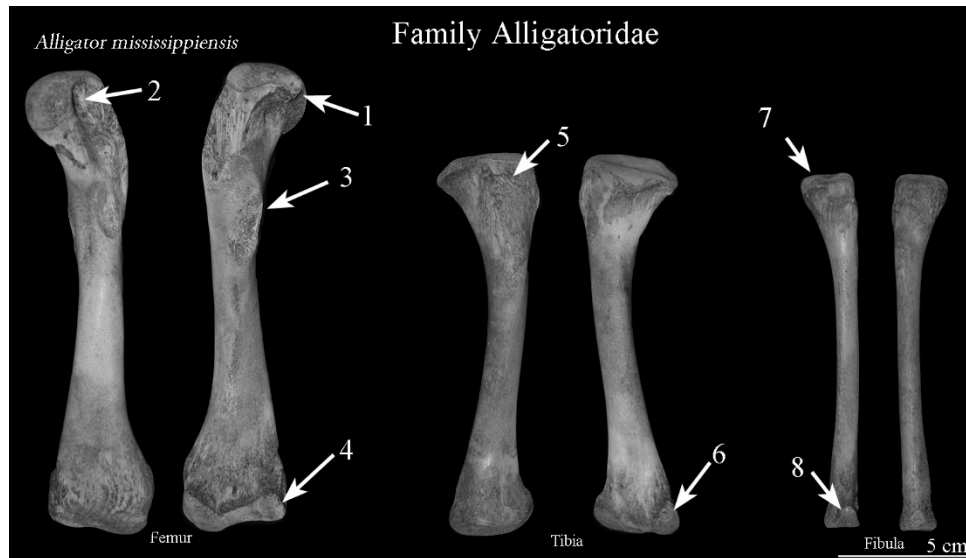


Figure 96: Anterior and posterior views of the left femur and tibia; lateral and medial views of the left fibula of a Florida alligator (*Alligator mississippiensis*).

### Order Testudines

The order Testudines is made up of turtles, tortoises, and terrapins; which are characterized by expanded ribs, carapace (shell), a beak-like maxilla, and a mandible lacking teeth (Sobolik and Steele, 1996). According to Romer (1997) this list can also include temporal regions that are complete without a true temporal fenestrae, reduced dermal roof, a parietal foramen, and the absence from the skull of postparietal, tabular, and lacrimal bones. The skeletal characteristics of the two families, Cheloniidae and Testudinidae, will be outlined below.

### *Family Cheloniidae*

The family Cheloniidae is comprised of hard-shelled sea turtles, who are almost entirely aquatic, characterized by an oval or heart shaped carapace, and flipper like appendages (Romer, 1997). This family are omnivores and have lost their ability to retract their head into their shell. The specimen used is the common Florida sea turtle (*Caretta caretta*). The observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not provided then observations made of other families and species were used as a baseline to make specific observations of the family in question. This particular section used the information provided in Reynolds (1897), Romer (1997) and Wyneken (2001) to infer much of the features of the cranial and post-cranial elements.

### Cranial characteristics

#### *Cranium*

The cranium, as seen in Figure 97, is triangular, smooth, and thick (Wyneken, 2001). The braincase is small and thick. The premaxilla is small and making up the most anterior portion of the rostrum (Fig. 97 1). The orbits are large, oval, and positioned anterolaterally (Fig. 97 2). The palate is v-shaped and lacks alveolar ridges (Wyneken, 2001). There is a long secondary palate formed from the vomer and palatines but no palatine fenestra (Romer, 1997). The supraoccipital is thick, narrow, and projects to a point posteriorly (Fig. 97 3) (Romer, 1997).

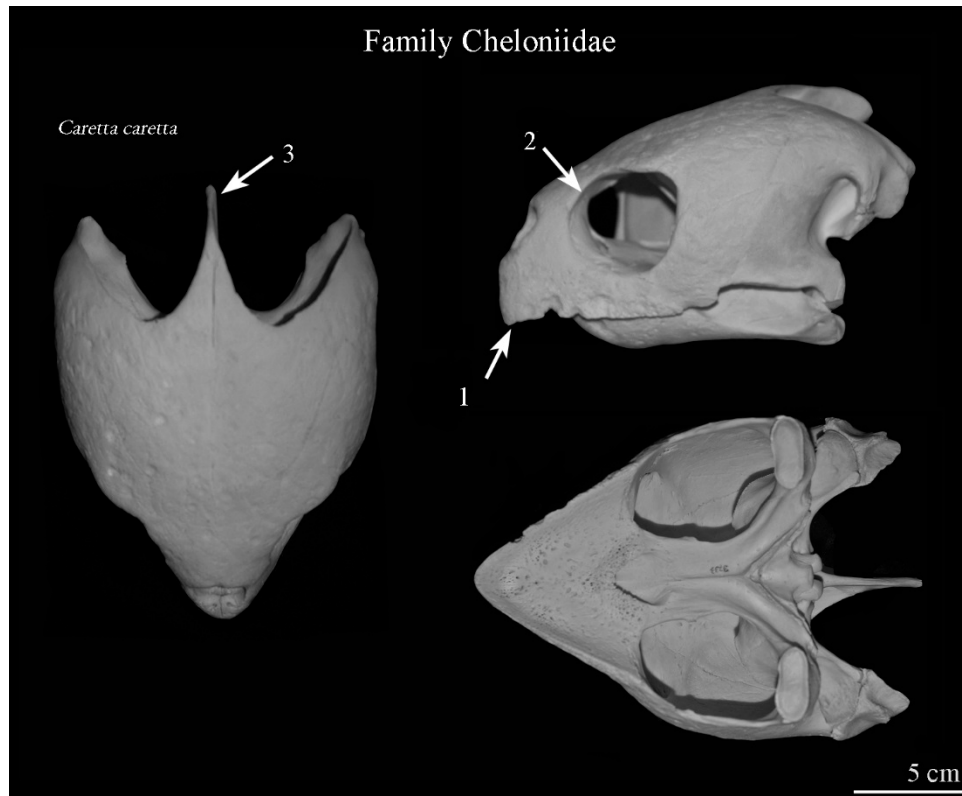


Figure 97: Cranial views of a sea turtle (*Caretta caretta*).

### *Mandible*

The mandible is thick and curves sharply towards the anterior to form a point (Wyneken, 2001). Both the surangular and the articular form the articulation with the cranium (Romer, 1997). The angular is small, rounded, and blunted. The dentary is large and forms the anterior portion of the mandible. In shape it is mostly flat with a porous texture that is pointed at the midline (Wyneken, 2001).

## Post-cranial characteristics

### *Humerus, Radius, and Ulna*

The skeletal elements of the family Cheloniidae, as seen in Figure 98, are flattened and have a smooth appearance. The humerus is characterized by an oval shaped head (Fig. 98 1) that is positioned below a large medial process, congruent with the greater tubercle in the mammalian class (Fig. 98 2) (Wyneken, 2001). The deltoid process is positioned just inferior to the humeral head (Fig. 98 3), emphasized by the fossa created by the medial process (Wyneken, 2001). There is also a distinctive notch on the medial aspect of the distal portion of the humerus (Fig. 98 4). The radius can be distinguished by a rounded radial head (Fig. 98 5) and flaring styloid process (Fig. 98 6). Also, the ulna lacks the distinctive olecranon process and semilunar notch, rather it has a rounded head (Fig. 98 7), slender shaft, and flares distally (Fig. 98 8).

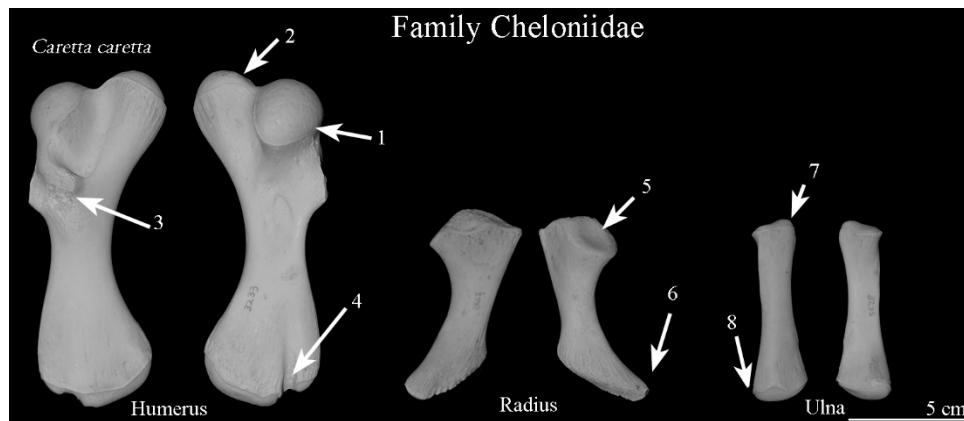


Figure 98: Anterior and posterior views of the left humerus, radius, and ulna of a sea turtle (*Caretta caretta*).

### *Femur, Tibia, and Fibula*

The femur, as seen in Figure 99, has a circular head (Fig. 99 1), situated between a large process (greater trochanter) that is just inferior to the highest point of the head, and a well-defined smaller process (Fig. 99 2) (lesser trochanter). There is a slight depression where the spiral line would be positioned in a human femur which gives the shaft an ‘hour glass’ appearance (Fig. 99 3) (Wyneken, 2001). The distal part of the femur flares and is rounded. The tibia lacks the traditional T-shape found in the mammalian class but does retain a raised tibial tuberosity (Fig. 99 4). The distal end of the tibia flares (Fig. 99 5). The fibula is thin and broad, has a tuberosity on the distal aspect, and has a flared distal end (Fig. 99 6).

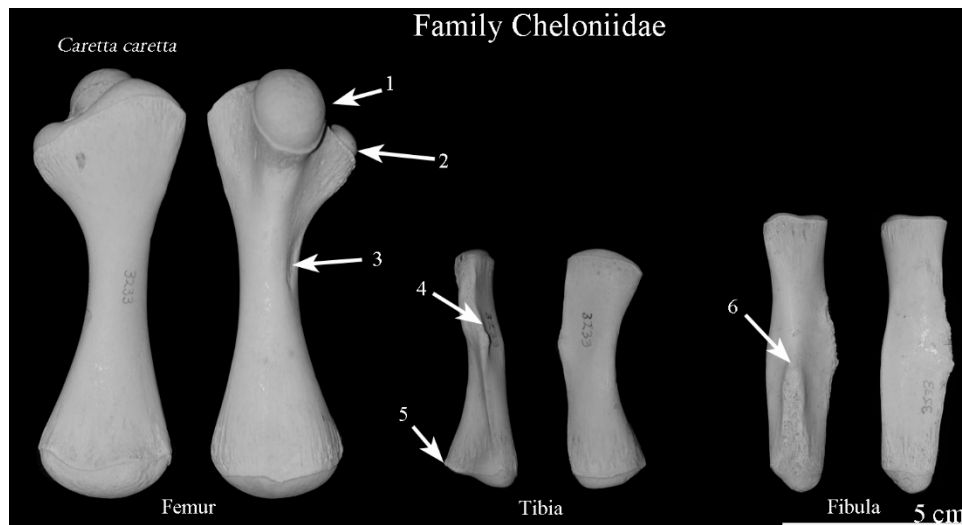


Figure 99: Anterior and posterior views of the left humerus, tibia, and fibula of a Sea turtle (*Caretta caretta*).

### *Family Testudinidae*

The family Testudinae are tortoises that are mostly herbivores. They are terrestrial with a domed shaped carapace (shell) and elephantine-like feet (Sobolik et al., 1996). The regional variation is the gopher tortoise (*Gopherus polyphemus*). The observations made for this section



have been inferred from multiple sources of information, if specific details of a feature were not provided then observations made of other families and species were used as a baseline to make specific observations of the family in question. This particular section pulled from Reynolds (1897), Olsen (1968), Sobolik et al. (1996), Romer (1997), and Adams and Crabtree (2012).

### Cranial characteristics

#### *Cranium*

The cranium, as seen in Figure 100, is triangular overall, short, with a wide and square shaped rostrum (Fig. 100 1) (Olsen, 1968; Sobolik et al., 1996). The braincase is very small and triangular and the orbits are closed, oval and are position anterolaterally. The temporal region generally has a small notch medial to the post-orbital process (Fig. 100 2), but no temporal fenestra (Romer, 1997). The supraoccipital extends to a point (Fig. 100 3).

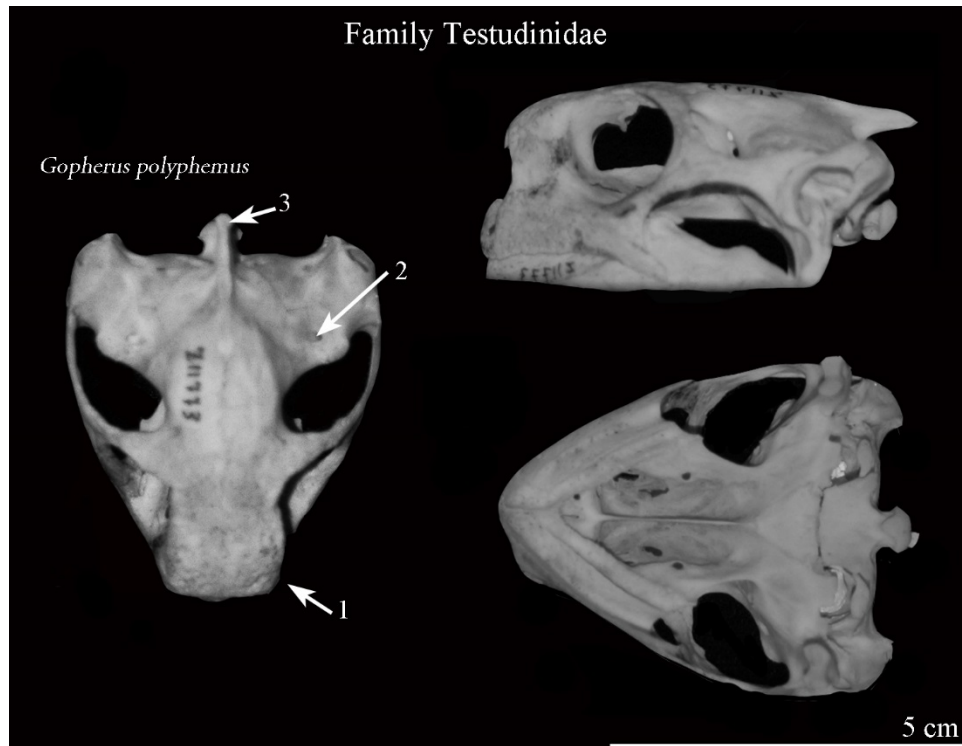


Figure 100: Cranial views for a Gopher tortoise (*Gopherus polyphemus*).

### *Mandible*

The mandible is long, wide, thick, projecting straight towards the anterior surface of the mandible. The dentary has a square shaped appearance, without the prominent curve typically exhibited by most omnivorous turtles. There are typically one or more ridges on the alveolar surface of the mandible (Romer, 1997)

### Post-cranial characteristics

#### *Humerus, Radius, and Ulna*

The humerus, as seen in figure 101, has a very round ‘mushroom’ shaped head (Fig. 101 1). The greater tubercle (Fig. 101 2) is positioned inferior to the humeral head while the lesser tubercle is positioned on the medial side (Sobolik et al., 1996). They join together to form a v-shape, while creating a deep intertubercular fossa. Also, the distal end has a well-developed medial epicondyle (Fig. 101 3), and an ectepicondylar foramen that is not visualized in this species (Olsen, 1968). The radius has a well-developed head that appears square shaped (Fig. 101 4). The shaft is short and narrow while the distal end has a fan-like flare (Fig. 101 5). The ulna proximal head does not have a well developed olecranon process instead there is a slight curvature where the semi-lunar notch would have been in mammals (Fig. 101 6). The shaft is flat with a slight curvature towards the distal end.

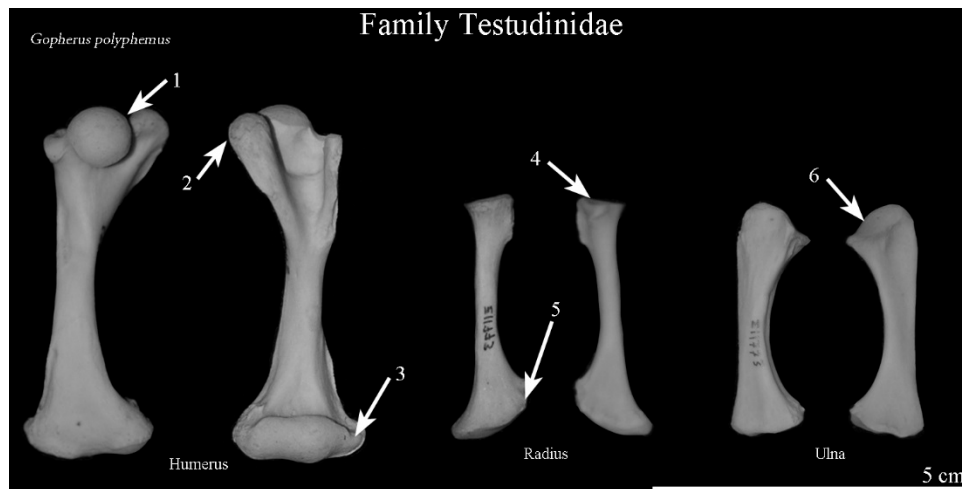


Figure 101: Anterior and posterior views of the left humerus, radius, and ulna of a Gopher tortoise (*Gopherus polyphemus*).

*Femur, Tibia, and Tibia*

The hind limb is characterized by shortened elements with overall reduced features. The femur, as shown in Figure 102, has a large, rounded, ‘mushroomed’ shaped head (Fig. 102 1) with a reduced intertrochanteric fossa (Sobolik et al., 1996; Romer, 1997). The shaft narrows before flaring distally (Sobolik et al., 1996). There is a slight supracondylar crest (Fig. 102 2) and developed condyles (Fig. 102 3). The tibia is small, but the tibial tuberosity is slightly developed (Fig. 102 4) giving it a classic T-shaped appearance, and there is a small medial malleolus (Fig. 102 5). The fibula is narrow with a slightly developed head and neck (Fig. 102 6), narrow shaft, and slightly flaring distally (Fig. 102 7).

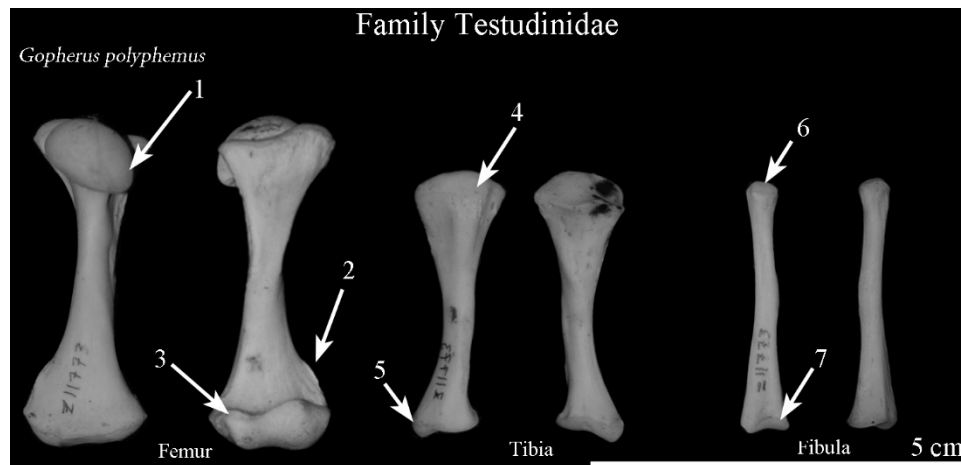


Figure 102: Anterior and posterior views of the left femur, tibia, and fibula of a Gopher tortoise (*Gopherus polyphemus*).

### Class Aves

The skeletal elements of the regional families of this class will be combined and described due to limited specimen availability. The observations made for this section have been inferred from multiple sources of information, if specific details of a feature were not provided

then observations made of other families and species were used as a baseline to make specific observations of the family in question. This particular section used a combination of resources to describe and sometimes infer the features of the three families described below, specifically Olsen (1972), Gilbert et al. (1996), France (2011), and Adams and Crabtree (2012).

### Order Ciconiiformes

This order is known for long-legged water birds such as herons, storks, ibises, and flamingoes. They are characterized by long bills that can range from pointed to curved.

#### *Family Ciconiidae*

The family Ciconiidae is characterized by a bill that is longer than the cranium. They are carnivorous and are found in wetlands. The species used to highlight this family characteristic is the Wood stork (*Mycteria Americana*).

#### Cranial characteristics

##### Cranium

Their bill, as seen in Figure 103, is long, rounded, and curved at the tip (Fig. 103 1). The cranium is rounded and smooth, and there is a well-defined suture between the nasal and frontal bones (Fig. 103 2) (Olsen, 1972). The zygomatic arch is thin, and projects posteriorly at approximately a 45 ° angle (Olsen, 1972). The orbits are large in relation to the cranium and open

(Olsen, 1972). There is also a long projecting orbital process (Olsen, 1972). The lacrimals are rounded and fused projecting inferior and defining the anterior portion of the orbit (Fig. 103 3) (Olsen, 1972). Also, there is a well-developed temporal fossa (Olsen, 1972).

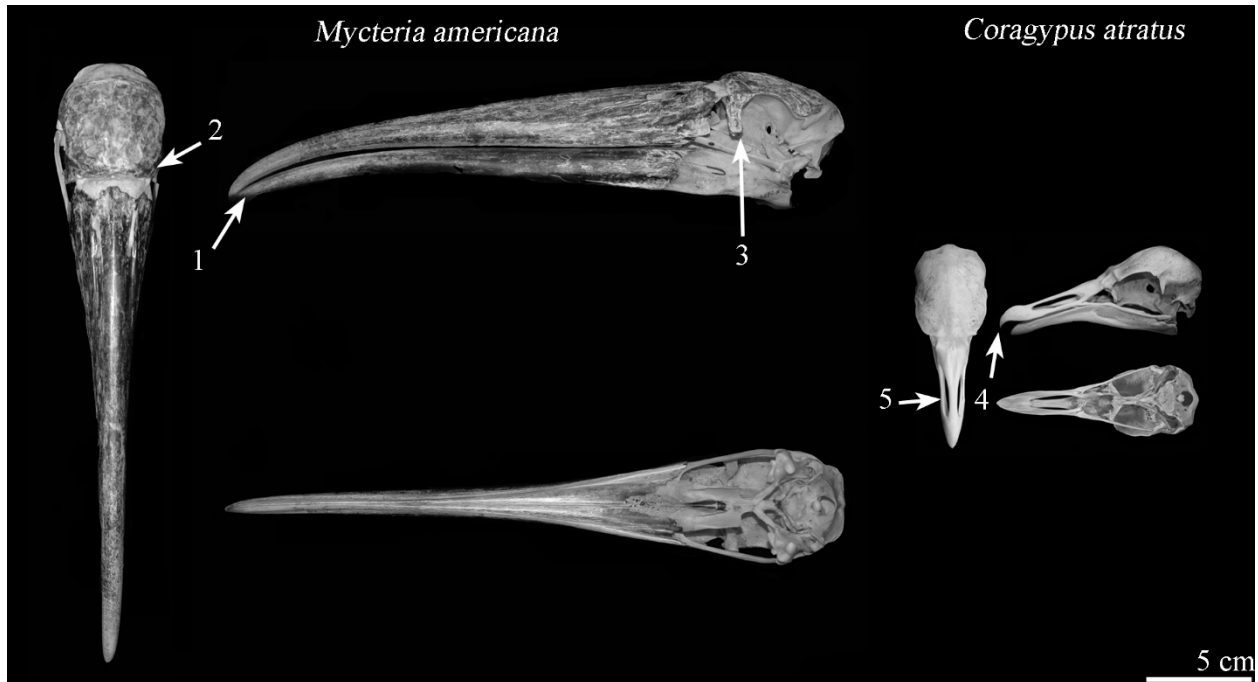


Figure 103: Cranial views of the wood-stork (*Mycteria americana*) and the black vulture (*Coragypus atratus*).

## Mandible

The mandible is rounded with the bill curving to a tip (Olsen, 1972). The posterior aspect has a mandibular foramen, and the articular is small and square shaped without a post-articular process (Olsen, 1972). The surangular rises just before the nasal bones and projects towards the anterior aspect of the mandible (Olsen, 1972).

## Post-cranial Characteristics

### *Humerus*

The humerus, as seen in Figure 104, is short with a fairly straight shaft (Gilbert et al., 1996). The humeral head is oblong, with a deep capital groove just inferior (Fig. 104 1) (Olsen, 1972; Gilbert et al., 1996). The bicipital crest is moderately projected (Fig. 104 2) and the bicipital furrow is moderately developed (Fig. 104 3) (Gilbert et al., 1996). There is a well-developed deltoid crest (Fig. 104 4) (Olsen, 1972; Gilbert et al., 1996). Also, the distal end has many prominent impressions and attachment sites for muscles and ligaments (Fig. 104 5) (Olsen, 1972; Gilbert et al., 1996).

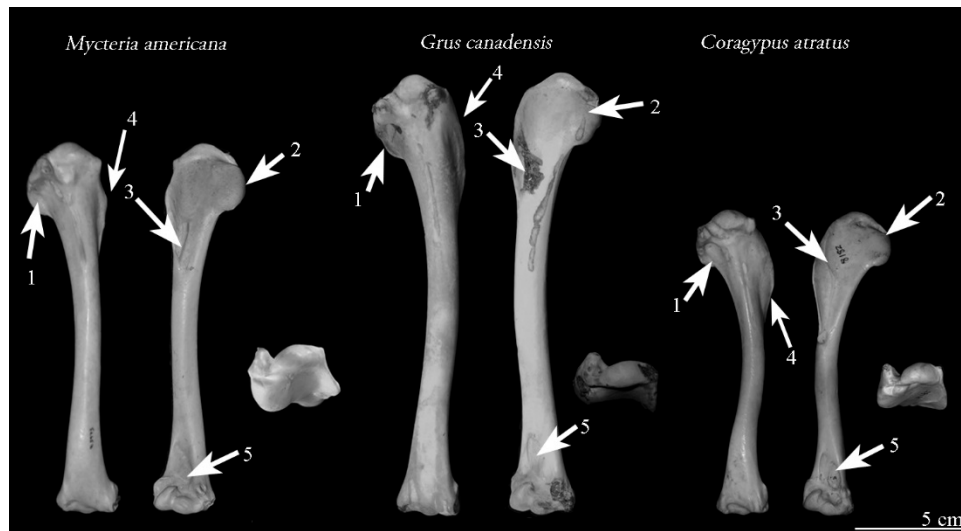


Figure 104: Anterior, posterior, and superior views of the left humerus for a wood stork (*Mycteria americana*), sand-hill crane (*Grus canadensis*), and black vulture (*Coragypus atratus*)

### *Radius and Ulna*

The radius and ulna, as seen in Figure 105, are joined together by ligament attachments during life but are not fused (Olsen, 1972). The radius is long and slender, with the distal end flaring wider than the shaft. The proximal end bows slightly just inferior to the radial head (Gilbert et al., 1996). The ulna has a triangular head, a long slender shaft, and a small curvature at the proximal end (median facet). Also, there are generally a single row of quill knobs along the curved shaft (Olsen, 1972; Gilbert et al., 1996). In this specimen they are slightly developed and are not readily apparent.

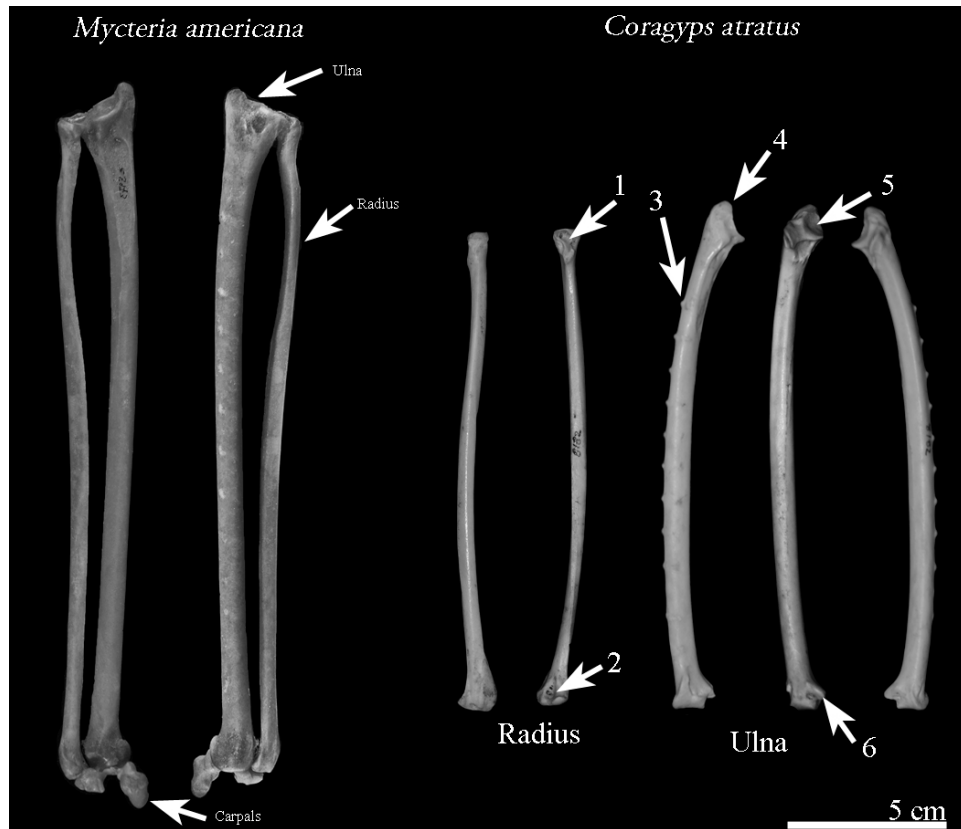


Figure 105: Anterior and posterior view of the fused left radius and ulna for a Wood-stork (*Mycteria americana*). Anterior and posterior views of the left radius; lateral, anterior, and medial views of the left ulna of the Black Vulture (*Coragyps atratus*)



## *Femur*

The femur of the *Mycteria americana*, as seen in Figure 106, is very short as is typically the case in avians (Gilbert et al., 1996). The femoral head is rounded, with only a small narrowing of the neck. The shaft is thick, with a small curvature and the distal end flares with a small curvature towards the medial side (Gilbert et al. 1996). The greater trochanter is positioned superior to the femoral head, has a moderately developed curvature (Fig. 106 1), and has a pneumatic fossa at the base (Olsen, 1972; Gilbert et al., 1996). There is a moderately developed intermuscular line (Fig. 106 2) and the lateral condyle is moderately developed (Fig. 106 3). Also, there is an oval shaped pneumatic foramen just inferior to the greater trochanter (Fig. 106 4).

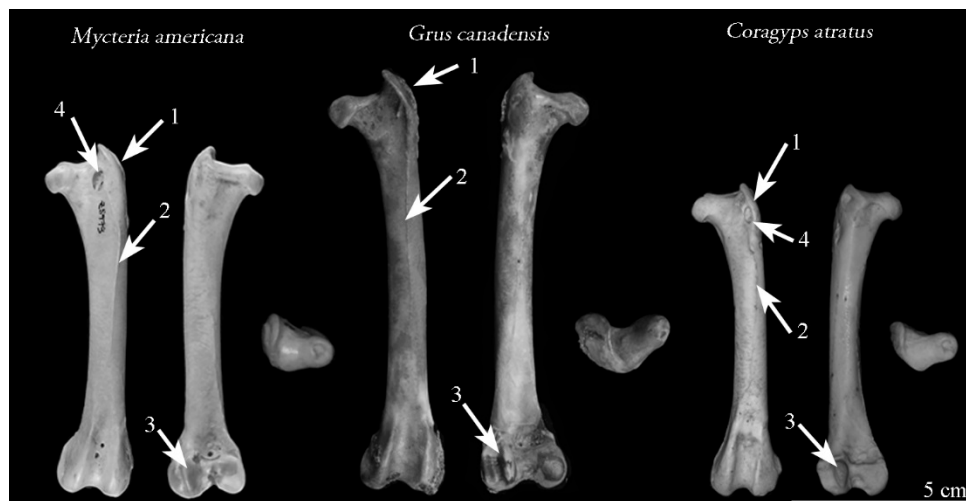


Figure 106: Anterior, posterior, and superior views of the left femur of a wood stork (*Mycteria americana*), sandhill crane (*Grus canadensis*), and black vulture (*Coragyps atratus*).

## *Tibiotarsus*

The tibiotarsus, as seen in Figure 107, is a fusion of the tibia and the proximal portion of the tarsus (Gilbert et al., 1996). The proximal aspect has a well-developed inner cnemial (crest-like prominence) crest (Fig. 107 1). The proximal end also has a circular articulation fossa flanked by the inner and outer cnemial crest (Fig. 107 2) (Gilbert et al., 1996). A reduced fibula is also connected at a high positioned fibular crest (Fig. 107 3) and the shaft is slender, straight, and narrow distally (Olsen, 1972; Gilbert et al., 1972). The distal aspect has a well-developed supratendinal groove that ends in a supracondylar fossa (Fig. 107 4) (Olsen, 1972). Also, there is a groove for a muscle attachment just superior to the lateral condyle (Fig. 107 5).



Figure 107: Anterior, posterior, superior, and inferior view of the left tibiotarsus of a wood stork (*Mycteria americana*).

## Order Gruiformes

The order Gruiformes includes cranes, rails, and allies. The family Gruidae is the regional variant photographed for this thesis. The characteristics of this family will be outlined below.

### *Family Gruidae*

The family Gruidae are large cranes with long legs. They are typically omnivores and migratory. The species specific to Florida is the sand hill crane the *Grus canadensis*.

### Cranial Characteristics

#### *Cranium*

The bill is longer than the cranium, projecting straight to a point, and is composed of the jugal, maxilla, and premaxilla (Olsen, 1972). The nostrils are long, taking up the majority of the rostrum (Olsen, 1972). The vomer is present as well as a well-developed occipital foramina (Olsen, 1972).

#### *Mandible*

The mandible is thin, projecting sharply anterior to form a point, and the articular process is small and hooked (Olsen, 1972). Also, the mandibular foramen is thin and oval (Olsen, 1972).

## Post-cranial Characteristics

### *Humerus*

The humerus, as seen in Figure 104, is longer than in the other two species with a slightly curved shaft. The humeral head (Fig. 104 1) is oblong with a shallow capital groove positioned just inferior (Olsen, 1972; Gilbert et al., 1996). The bicipital crest is positioned parallel to the entepicondylar prominence (Fig. 104 2) and the bicipital furrow has a ligament in place of the furrow (Fig. 104 3) (Olsen, 1972; Gilbert et al., 1996). The deltoid crest (Fig. 104 4) is positioned high and has a sloping angle towards the shaft (Olsen, 1972; Gilbert et al., 1996). The distal end has many prominent impressions and attachment sites for muscles and ligaments (Fig. 104 5) (Olsen, 1972; Gilbert et al., 1996).

### *Femur*

The femur of the *Grus Canadensis*, as seen in Figure 106, is longer than that of the other two species. The shaft is thick, round, and has less of a curvature. The distal end flares with a small curvature towards the medial side. The greater trochanter (Fig. 106 1) is positioned higher than the femoral head and is heavy with a sharp lip (Olsen, 1972). The neck of the femoral head has a sharp indentation (Olsen, 1972). Also, an intermuscular line is visible, oriented to the distal 1/3 of the shaft (Fig. 106 2), while the lateral condyle is well defined and oval shaped (Fig. 106 3) (Gilbert et al., 1996).

### *Tarsometatarsus*

The tarsometatarsus, as seen in Figure 108, is the fusion of the tarsal and metatarsal bones (Gilbert et al., 1996). The length can vary significantly between orders. The *Grus canadensis* is a long-legged water bird and therefore has a very long shaft. The proximal end has a hypotarsal ridge (Fig. 108 1) that is flanked by both an internal and external proximal foramen (Fig. 108 3) on the posterior side (Gilbert et al. 1996). The anterior side has a proximal foramina (Fig. 108 2) and the distal portion flares into three trochlea for digits: two (only reaches base of the fourth), three (longest), and four (Olsen, 1972; Gilbert et al., 1996). There is a dorsoplantar foramen (Fig. 108 4) near the fourth trochlea (Gilbert et al., 1996).

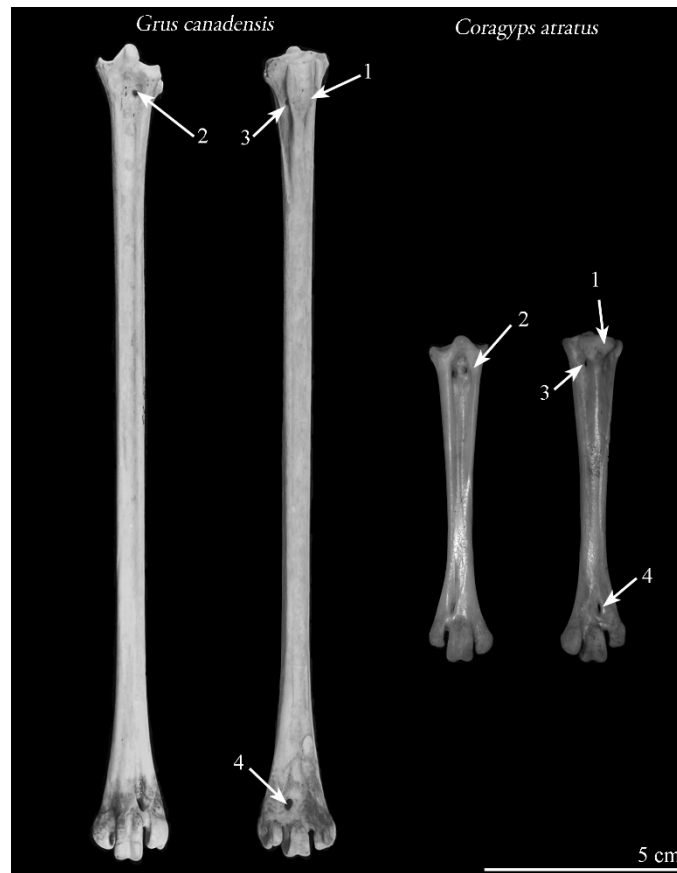


Figure 108: Anterior and posterior view of the left tarsometatarsus of a sand-hill crane (*Grus canadensis*) and a black vulture (*Coragyps atratus*).

### Order Falconiformes

The species that comprise the order Falconiformes are characterized by a hooked or strongly curved beak (Olsen, 1972). The species that comprise this order include vultures, hawks, and falcons. Most of them are carnivorous and are also known to eat carrion.

### *Family Cathartidae*

The family Cathartidae has a few distinctive characteristics that will be illustrated by the black vulture, *Coragyps atratus*.

### Cranial Characteristics

#### *Cranium*

The cranium, as seen in Figure of 103, is rounded with the rostrum angled slightly downward before projecting anterior (Fig. 103 4) (Olsen, 1972). The nares (Fig. 103 5) are perforated, large and oval located just behind the hook beak (Olsen, 1972). Also, the lacrimals are fused to the frontal bones, and the temporal fossae is small, and there is no vomer (Olsen, 1972).

#### *Mandible*

The mandible is thin, short, and the premaxilla covers the dentary. There are no mandibular foramen (Olsen, 1972). Also, is no posterior process, but instead a well-defined internal articular process is present (Olsen, 1972).

### Post-cranial characteristics

#### *Humerus*

The humerus, as seen in Figure 104, is short with a moderately curved shaft (Gilbert et al., 1996). The humeral head is oblong, with a deep capital groove (pneumatic) positioned just inferior (Olsen, 1972; Gilbert et al., 1996). The bicipital crest projects past the entepicondylar prominence (Fig. 104 2) and the bicipital furrow is well developed (Fig. 104 3) (Olsen, 1972; Gilbert et al., 1996). The deltoid crest (Fig. 104 4) is long, well rounded, and positioned high with a sloping angle towards the shaft (Olsen, 1972; Gilbert et al., 1996). Also, the distal end has many prominent impressions and attachment sites for muscles and ligaments that fuse to form one large oval shape (Fig. 104 5) (Olsen, 1972; Gilbert et al., 1996).

#### *Radius and Ulna*

The articulated example in Figure 105, provides additional features to be visualized. The proximal end of the radius has a triangular shaped capital tuberosity (Fig. 105 1) and the shaft has a moderate degree of curvature (Gilbert et al., 1996). The distal end flares and has an oval-shaped pneumatic foramina (Fig. 105 2) (Gilbert et al., 1996). The ulna is characterized by a deeply concave shaft lined with a single row of quill knobs (Fig. 105 3) that are well developed and there is a small olecranon process (Fig. 105 4) (Olsen, 1972; Gilbert et al., 1996). Also the ulna has a half-crescent shaped semi-lunar notch (Fig. 105 5) and the distal end has a well-developed styloid process (Fig. 105 6) (Gilbert et al., 1996).

#### *Femur*



The femur of the *Coragyps atratus*, as seen in Figure 106, is smaller and is slightly more curved than was seen in the previous two avian species described. The greater trochanter has thicker edges and is oriented nearly parallel with the femoral head (Fig. 106 1), and has, a pneumatic fossa at the base (Olsen, 1972; Gilbert et al., 1996). The intermuscular line is only just visible (Fig. 106 2) while the lateral condyle is well developed, approximately equal in size to the medial condyle, and “tear drop” shaped (Fig. 106 3) (Olsen, 1972; Gilbert et al., 1996). Also, there is an oval shaped pneumatic foramen just inferior to the greater trochanter (Gilbert et al., 1996).

#### *Tarsometarsus*

The tarsometarsus, as seen in Figure 108, is short in the *Coragyps atratus*. The hypotarsal ridge is concentrated more superiorly than the in *Grus canadensis* and projects to a greater extent (Fig. 108 1). The anterior side has a well-developed proximal foramen (Fig. 108 2) that results in a well-defined groove along the anterior surface of the shaft. The internal proximal foramen is larger than the external (Fig. 108 3), and the distal end flares into three trochlea for digits: two (shortest), three (longest), and four (Olsen, 1972; Gilbert et al., 1996). There is an elongated dorsoplantar foramen (Fig. 108 4) near the fourth trochlea (Gilbert et al., 1996).

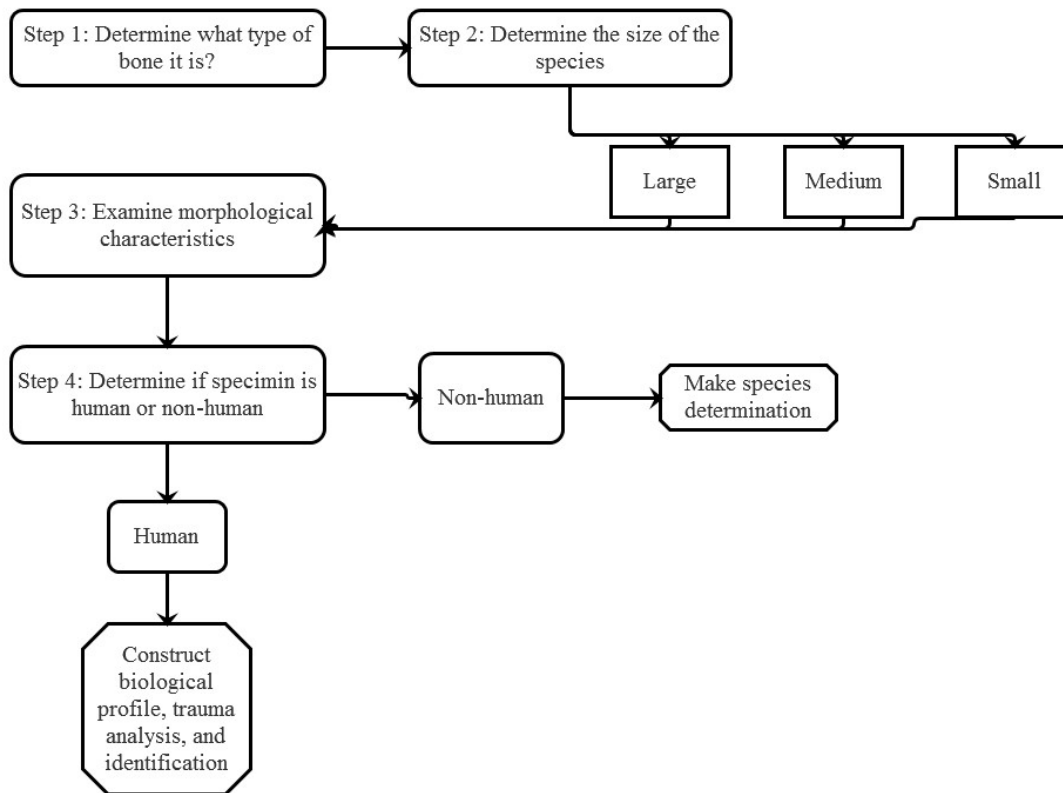
## **Chapter 5: Discussion**

### Guidelines for Species Identification

When skeletal remains are brought to a forensic anthropologist for identification their task is to determine whether the specimen has any medicolegal importance by determining if the remains are human or nonhuman (Schultz, 2012). This approach is adjusted depending on whether they are presented with a whole skeleton, a single skeletal element, or fragmentary remains. When presented with a whole skeleton the forensic anthropologist is provided with enough diagnostic information to provide an accurate species-specific identification. However, a single skeletal element can be more of a challenge when determining a species-specific non-human identification and may require use of both comparative osteological manuals and a comparative skeletal collection for reference (Schultz, 2012).

The approach to differentiating human and non-human remains should first begin with determining which skeletal element has been submitted for identification. The second step would be to determine the overall size of the species and if the specimen has reached full maturity. At this point there should be enough information to determine if the skeletal element is human or non-human. If the skeletal element is non-human then the next step involves determining its class, order, and family designation. The following section describes the cranial and post-cranial skeletal elements highlighting features that correspond with locomotion patterns and behavior. This information allows for class, order, and family designation to be determined. Finally using the region the specimen was found further aids in narrowing a genus and species identification. Figure 109 provides this basic guideline to aid in determining a species identification from a single complete bone.

Fragmentary remains can cause problems with identification and might only be visually diagnosed to class depending on the amount of diagnostic information remaining on the fragment. At the same time if the bone is too highly fragmented, other identification methods might be needed such as microscopic analysis, biomolecular methods and DNA analysis (Mulhern, 2009; Mulhern and Ubelaker 2012; and Byers, 2007).



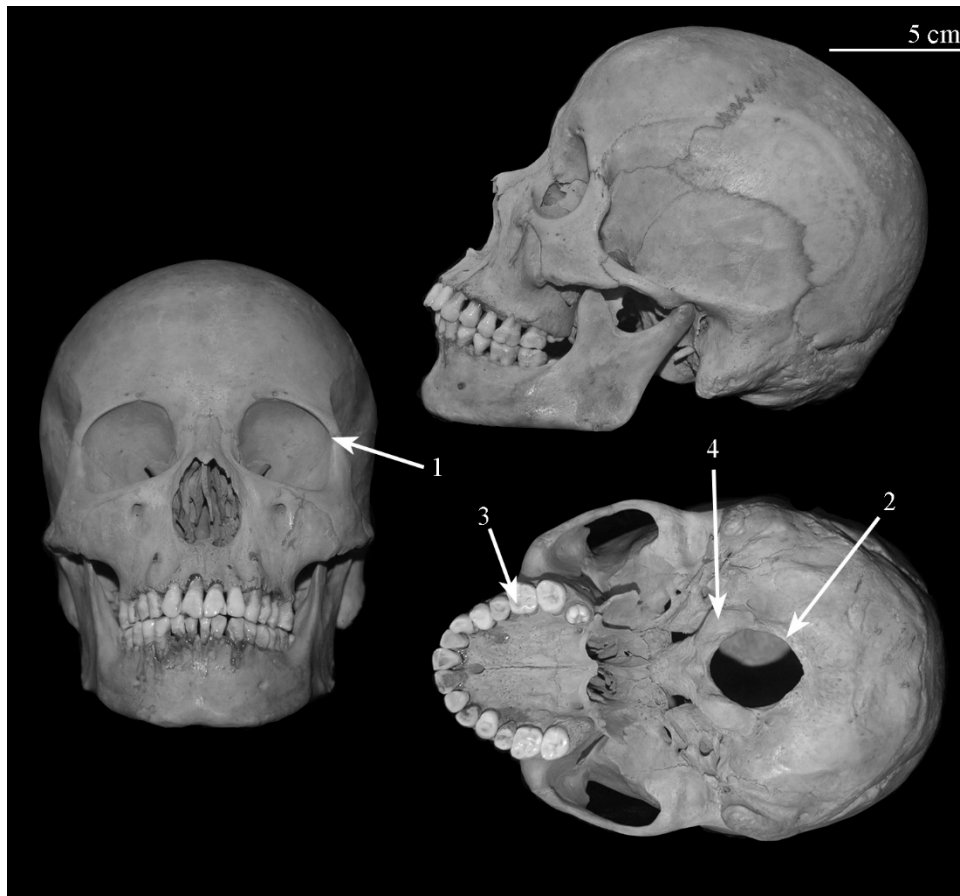
*Figure 109: Guidelines for determining species identification*

## Guidelines for a Species Identification

When an entire skeleton is available for diagnosis, the class and order can be determined by examining the axial and appendicular skeleton. The class of the specimen can be quickly determined by examining the cranium, shape of the vertebrae, and the density and weight of the bones.

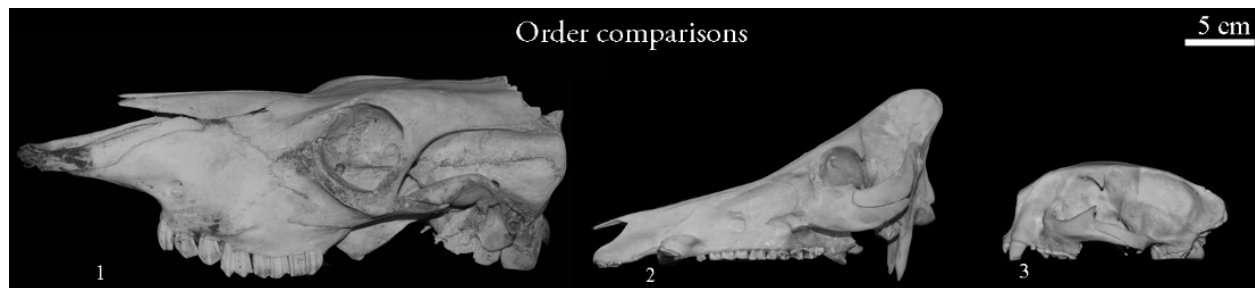
### *Cranium*

The cranium provides the most valuable diagnostic information used to make a species determination. For example Figure 110 is a human skull, from these views you can infer a great deal about their lifestyle. The orbital position can tell you if they have binocular or peripheral vision (Fig. 110 1). The position of the foramen magnum can tell you if they are bipedal or quadrupedal (Fig. 110 2). Dentition can be used to determine their subsistence pattern (Fig. 110 3). Finally, the presence of one or two occipital condyles can help with Class determination (Fig. 110 4).



*Figure 110: Anterior, posterior, and lateral views of a human skull*

The shape of the cranium, highlighted by the features contained within Figure 111, can provide information on Order classification. Appendix A and B, also provides a generalized example of the characteristics from the axial skeletal that can aid in species identification. The basic cranial features of the families commonly brought in for identifications in Florida are included in Appendix C.



*Figure 111: Order cranium comparisons of a cow (1), wild boar (2), and Florida panther (3).*

### Guidelines for Species Identification from a Single Post-Cranial Element

The order and family can also be determined by examining the post-cranial skeleton. The images and description in Chapter 4 highlight the diagnostic features of the families' common to Florida. Noting the presence of any fused, reduced, or elongated post-cranial skeletal elements can provide class information and provide insight into locomotion or other behaviors. The smaller details such as the length, shape, curvature, and the reduction or inflation of diagnostic features can be used to contrast between family, genus, and species classification.

When approaching an identification with only one skeletal element the maturity, size, and morphology of the specimen (see Fig. 109) are the main features that will be most helpful in determining a species identification. The first objective is to determine what skeletal element is being analyzed. Next the maturity of the specimen, determined by the presence of an unfused or missing epiphysis, combined with the species overall size can often eliminate the possibility of confusion between mature smaller mammals and human sub-adults (Dupras et al., 2012; Byers, 2007).

Larger specimens will require a comparison of the features of each elements. Often the development and shape of a skeletal element can determine if the specimen is human or not. Careful consideration should be given to species that assume a similar posture, locomotion, subsistence, and behavioral patterns as do humans. For instance bears assume a plantigrade locomotion pattern and occasionally a bipedal stance and as such have similar post-cranial elements. This can be seen with bear metapodials. With the claws removed these bones are very similar to human metapodials and have been the cause of confusion in past investigations. Another example of convergence can be seen in raccoons that also have opposable thumbs. They are capable of pronation and supination, and thus have a similar looking radius and ulna.

After the remains have been classified as non-human, a species identification profile can be compiled based on the information that skeletal element can provide. Each element provides a different set of information that can quickly determine class, order, and sometimes even family. The next several questions should be considered when reviewing the features of the different skeletal elements. Can you determine its locomotion pattern? Are they bipedal or quadrupedal? Do they have binocular or peripheral vision? What is their subsistence pattern?

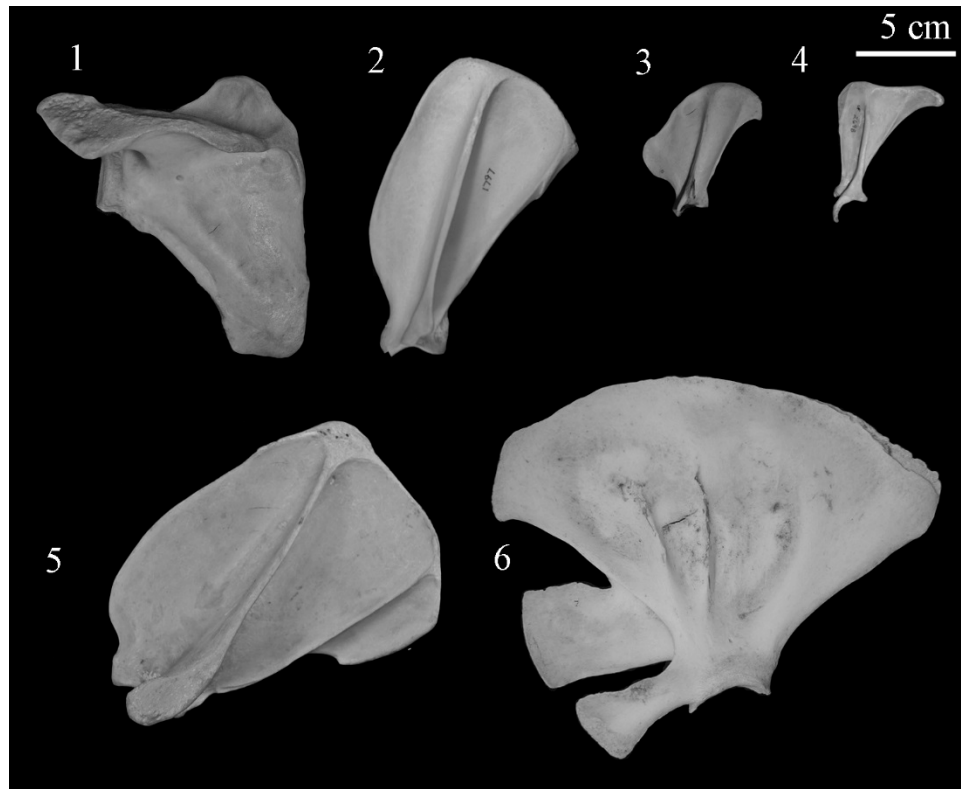
Each different skeletal element provides some insight into these questions, reducing the number of possibilities. From there noting the size of the bone can quickly divide the remaining possible species into generalized categories: large, medium, and small. Variation expressed between bone morphologies of different species are adaptive modifications and include changes in the length, diameter, and shape of each bone (Kent, 1992). The following section will discuss

the different skeletal elements and the features that can be used to determine a species identification.

### *Scapula*

The scapula can provide information on the type of movement and posture of the animal. This is based on the shape of the body, position of the spinous process, and the size and shape of curvature of the both the coracoid and acromion process. Figure 112 provides an example of several different shapes of the scapula among different species. Animals adapted for walking and running typically have a longer and narrower scapula; however, the orientation of the scapula varies depending on their locomotion pattern. For example those adapted for walking, with a bipedal stance, have a more horizontally oriented scapular blade in relation to the axis of the scapula (created by the articulation of the glenoid cavity and the humeral head) as seen by the human scapula (Fig. 112 1). Conversely those that are adapted for running, with a quadrupedal stance, will have a more vertically oriented scapular blade in relation to axis of the scapula, as seen by the dog scapula (Fig. 112 2) (Polly, 2007). Those adapted for digging, such as the armadillo (Fig. 112 4), or swimming, such as both the river otter (Fig. 112 3) or bottle-nosed dolphin (Fig. 112 6), also have a quadrupedal stance with a vertically oriented scapular blade and have a more triangular shaped scapula body to provide a better leverage for moving through a thicker medium than air (Polly, 2007).





*Figure 112: Lateral view of the left scapula showing body shape variations of a human (1), large dog (2), river otter (3), armadillo (4), bear (5), and bottle-nose dolphin (6). All are in anatomical position in accordance to their locomotion pattern.*

### *Humerus*

The range of motion and locomotion of the forelimb can be inferred by the size, shape, and position of the tubercles, tuberosities, and the head of the humerus. Figure 113 shows the different sizes and adaptive modification made to the humerus across three different classes. The position of the delotid tuberosity on the shaft can indicated the length of stride and degree of flexion and extension of an animals leg (Polly, 2007). The further the deltoid tuberosity is postioned down the shaft the stronger the amount of force can be applied (Polly, 2007). This type

of adaptation is typically seen in diggers and swimmers (Fig. 113 12) (Polly, 2007). Alternatively if the deltoid tuberosity is positioned closer to the humeral head, this allows for a shorter, more rapid, but overall less powerful strides (Polly, 2007). This is typically seen in those species adapted for running (Fig. 113 2, 5) (Polly, 2007). The condyles also have differences that can give insight into locomotion patterns. If both the trochlea and capitulum are the same size and have a 'hinge-like' appearance then this is an adaptation typically seen in those animals specialized for running, such as those found in the Order Artiodactyla and Order Perissodactyla (Polly, 2007). Conversely the capitulum is more developed in animals capable of supination, such as those found in humans, racoons, and bears (Polly, 2007).



*Figure 113: Composite image showing the difference sizes and shapes of the posterior view of the left humerus of a human (1), horse (2), cow (3), bear (4), goat (5), white-tailed deer (6), wood-stork (7), Florida alligator (8), sea turtle (9), wild boar (10), and the river otter (12).*

### *Radius and Ulna*

The radius and ulna can be either fused or unfused depending on the species, as shown in Figure 114. In species capable of pronating and supinating the manus (climbers) will generally

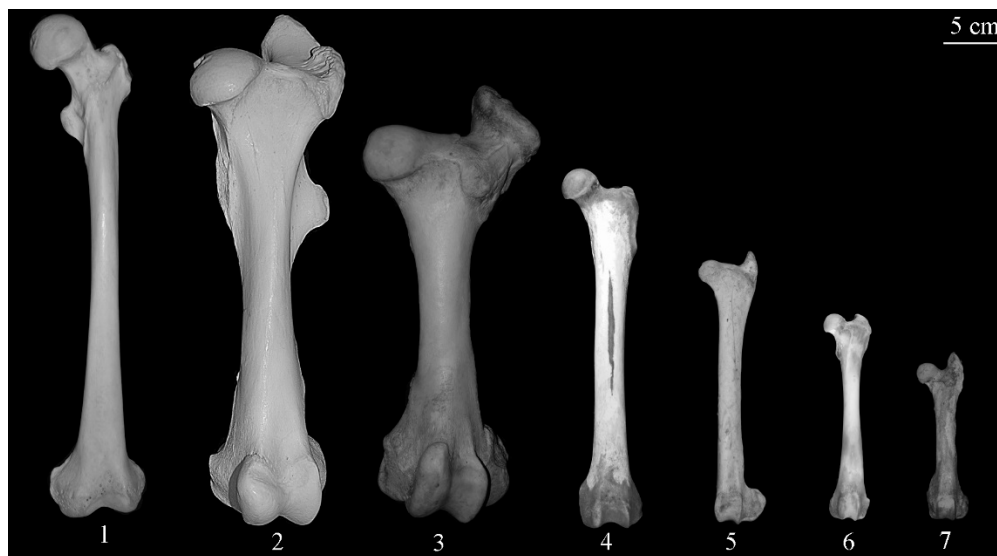
have a round radial head, such as is found in humans, bears, and raccoons (Fig. 114 2, 3). This adaptation makes supination possible (Polly, 2007). Those species adapted for running usually have restricted movement and a marked fusion between the radius and ulna, such as is found in the Order Artiodactyla and Order Perissodactyla. The length of the olecranon process affects forelimb extension; the longer processes are typically found in animals adapted to digging or swimming, such as the armadillo and the river otter, while shorter process are found in those adapted to running, such as the horse, cattle, and deer (Kent, 1992; Polly, 2007).



*Figure 114: Radius and Ulna of a horse (1), raccoon (2), and human (3). Note to scale to emphasize morphological variations.*

### *Femur*

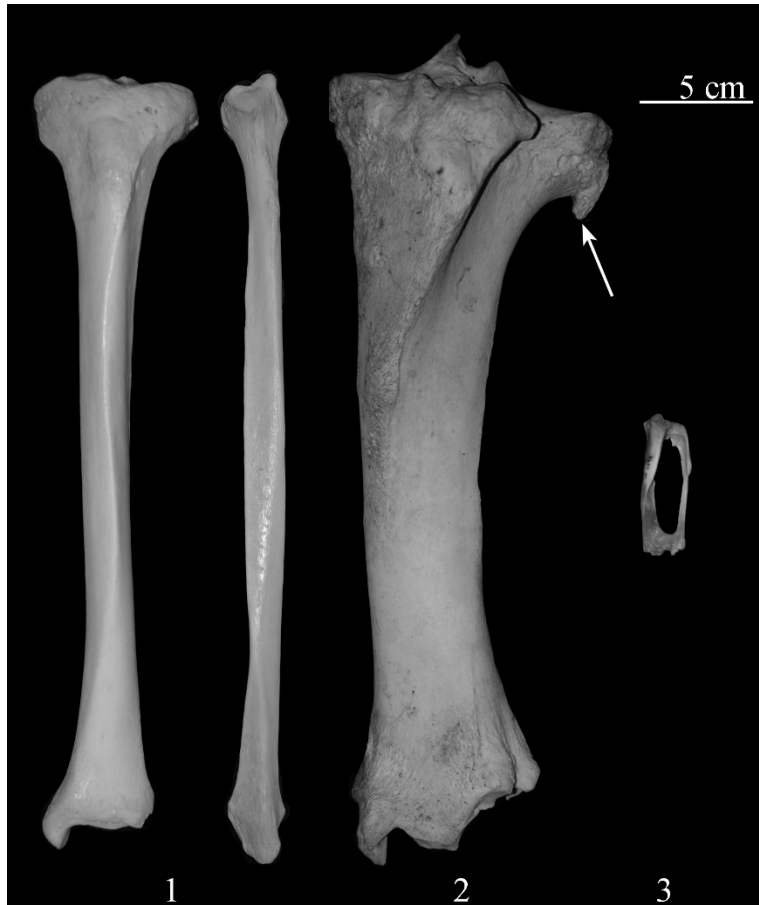
The femur, as seen in Figure 115, has several features that help to aid in identification. One feature is the length and orientation of the greater, lesser, and the inclusion of a third trochanter. The greater trochanter attaches the muscle that acts as the primary extensor of the hip. This is often well developed and long in animals adapted to running, such as the one found on the horse (Fig. 115 2), cow (Fig. 115 3), white-tailed deer (Fig. 115 5), dog (Fig. 115 6), and wild boar (Fig. 115 7) (Polly, 2007). The third trochanter, as seen best by the horse (Fig. 115 2), is well developed in animals adapted for running; it is one of the attachment sites for a powerful extensor muscle (Polly, 2007). The head of the femur projects more proximally in animals adapted for the walking and assuming a bipedal stance, such as the human (Fig. 115 1) and bear (Fig. 115 4) (Polly, 2007). This is due to the abducting motion that is characteristic for this type of locomotion (Polly, 2007). The patellar groove and surface can also indicate locomotion types (Polly, 2007).



*Figure 115: Composite image showing the difference in morphology and size of the left anterior view of the femur of a human (1), horse (2), cow (3), bear (4), white-tailed deer (5), large dog (6), and wild boar (7).*

### *Tibia and Fibula*

The tibia and fibula are subject to fusing depending on the animal's body mass and can be helpful when making a species identification (Polly, 2007). Figure 116, shows three different degrees of fusion. The human tibia and fibula show no signs of fusion (Fig. 116 1), the cow's tibia and fibula (Fig. 116 2) are fused but the fibula has been reduced to a small point, and the armadillo's (Fig. 116 3) proximal and distal ends are completely fused. Other features that can be used to differentiate between species for the tibia is the prominence of the tibial tuberosity, angle of the tibial crest, and the appearance of the medial malleolus. In the fibula the head, shaft, and distal end can be used to distinguish between species.

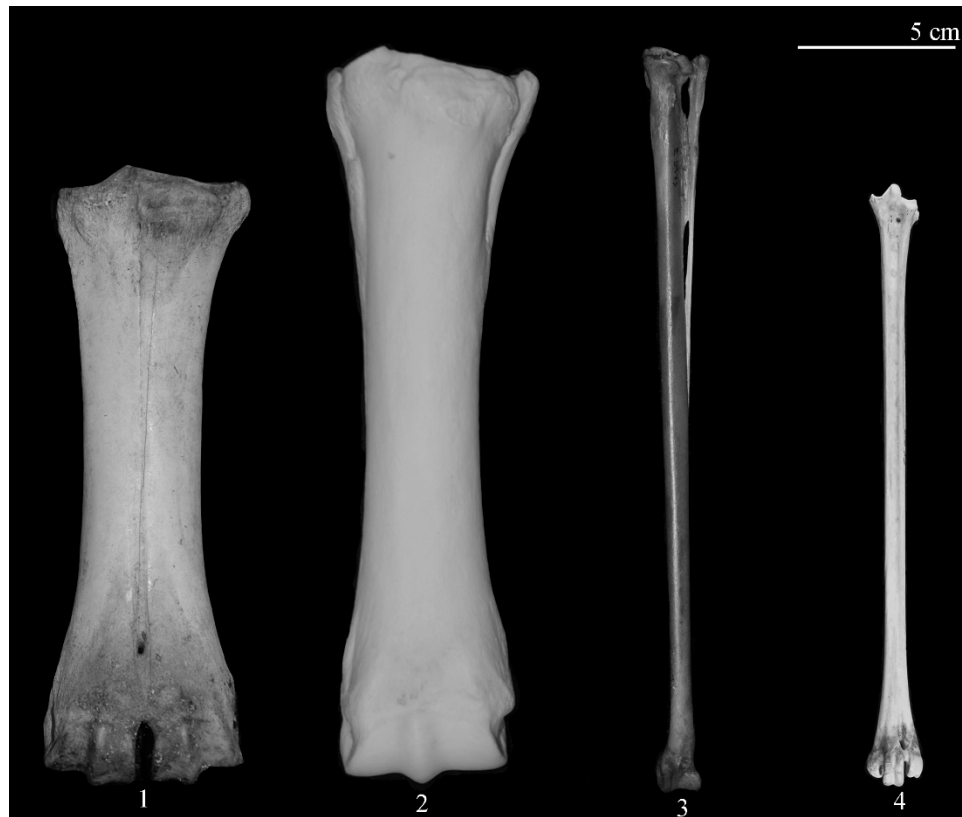


*Figure 116: Tibia and Fibula of a human (1), cow (2), and a armadillo (3). The arrow points to the remnant of the fibula in the horse.*

### *Other*

Presence of fused elements, shown in Figure 117, in the absence of pathology is a strong indicator that the specimen is not human. As for determining the species identification several types of bones are indicative of certain classes and orders. The fused metapodials depending on the number of articulations, can indicate two separate orders. Two condyles are found in the artiodactyls (Fig. 117 1), while one is found in the perissodactyles (Fig. 117 2). Fused element

are also included among the class avians, such as the tibiotarsus (Fig. 117 3) and the tarsometatarsus (Fig. 117 4).



*Figure 117: Metacarpal of a cow (1), metacarpal of a horse (2), tibiotarsus of a wood stork (3), and a tarsometatarsus of a stork (4).*

### Guidelines for Making a Species Identification with Fragments

When dealing with a fragmented or eroded pieces of bone the first step is to identify what class of bone it belongs to: short, long, flat, or irregular. This can be done by examining the thickness of the compact bone and the diploe. If any features of the original bone remains identification of the skeletal element might be possible. If you have a portion of the diaphysis the

medullary cavity can be used to differentiate between classes. The texture, thickness, and transparency of the fragment can also all be used to determine class.

When presented with highly fragmentary and eroded skeletal remains a number of laboratory test are available to the forensic anthropologist. However these tests can be expensive, time consuming, and are used only as a last resort. These methods of identification include gross morphological osteological comparison, microscopic analysis, biomolecular methods, and DNA analysis (Mulhern 2009, Mulhern and Ubelaker 2012, and Byers 2007).

#### Other Identification Methods

##### *Microscopic Analysis*

Microscopic analysis for human and non-human differentiation consists of evaluating histological microstructure variances unique to each species with the use of a scanning electron microscope or SEM (Mulhern, 2009, Gilchrist et al., 2001, Hiller and Bell, 2007). These variances include the number, size, density, and orientations of osteons (Mulhern, 2009). Mulhern (2009) notes the patterning of the different types of osteons and their overall configuration could be indicative enough for a species identification. For example a strong indicator of non-human bone is the presences of plexiform, or fibrolamellar, patterning which is identified by primary osteons forming rows or bands (Mulhern, 2009, Mulhern and Ubelaker, 2012, and Schultz, 2012). Another significant technique for human and non-human differentiation has been the comparison of the Haversian system diameter and Haversian canal diameter (Gilchrist et al., 2001; Hillier and Bell, 2007). These methods can be applied in highly fragmented remains with no distinguishable diagnostic features. The techniques are however



limited by what we know regarding the origin of the bone fragment because according to Gilchrist et al. (2001) variation can be seen between the same species, animal, and even different sections from the same bone.

### *Biomolecular Methods*

Another way to differentiate human and non-human remains is by a process called protein radioimmunoassay. This was originally developed by Lowenstein (1980) and later applied by Ubelaker et al. (2004) as a means of possible species-specific identification. This technique uses protein extracted from a very small bone sample and subjects it to rabbit antibodies that have already been exposed to the proteins (albumin) from different known species (Mulhern, 2009). During the exposure, the resulting antibodies from the species specific reaction then bind to the antigens from the bone sample (Mulhern, 2009). The result, which is measured with radioactive antibodies, is indicative of positive species identification (Mulhern, 2009). This identification is limited to the different species (human and non-human) the original rabbit serum was exposed to. Therefore, more exotic species identification would turn up negative and might lead to erroneous conclusions.

### *DNA Analysis*

DNA analysis is a viable option when identifying fragmented remains. Traditionally this technique has been used to identify individuals but has just as much potential to differentiate

species. Species determination using this method focuses on different gene ‘primers’ that are located in different areas of the DNA strand for different species (Gilchrist et al., 2001; Mulhern and Ubelaker, 2012). Interpretation of these results is based on a database of known species and is limited to only what has been placed in that database (Gilchrist et al., 2001; Mulhern and Ubelaker, 2012). It is a simple, cost effective test if the fragments are big enough for extraction and have not been subjected to degradation or contamination (Gilchrist et al., 2001; Mulhern and Ubelaker, 2012).

When faced with highly fragmentary skeletal remains a forensic anthropologist is responsible for weighing the pros and cons of these other identification methods. So if it is at all feasible it would be preferable to determine species from other gross characteristics of bone fragments such as the weight, thickness, and transparency (Mulhern, 2009). During an ongoing investigation potential problems can arise when these experts are not available or when samples are contaminated, lost or mislabeled (Dupras et al., 2012). These methods are best implemented when all diagnostic information has been removed from fragments, and only as a last resort due to cost and time constraints being a varying factor during an investigation.

### Conclusion

The purpose of this research was to compile a comprehensive comparative osteological guide of both the cranial and post-cranial elements of local Florida species to aid in differentiating among human and non-human remains, and further determining a species-specific identification when presented with non-human material. This research provides investigators

working in Florida with a resource that can be consulted during a medicolegal investigation that is not limited to one class of animal or one type of skeletal element.

This research has been organized and presented in a way to help provide context into both identifying features of specific species' and understanding the behaviors behind the variations exhibited between different species bone morphology. The limitation for this type of research is the attempt to extract the same amount of information for comparison between different species. Variations between each species' skeletal structure prevents a true standardization in overall presentation for each skeletal element. This has led to variation between the axis of each view, preventing in some cases the same amount of diagnostic information being presented. This is where an understanding of the underlying evolutionary principles affecting the biomechanical forces unique to each class, order, and family can bridge the gap of what has been recorded in a manual and the current specimen being examined. For example being familiar with the appearance of the adaptations for walking, digging, swimming, and running can be a helpful tool when reducing the possible species during an identification.

#### Future considerations

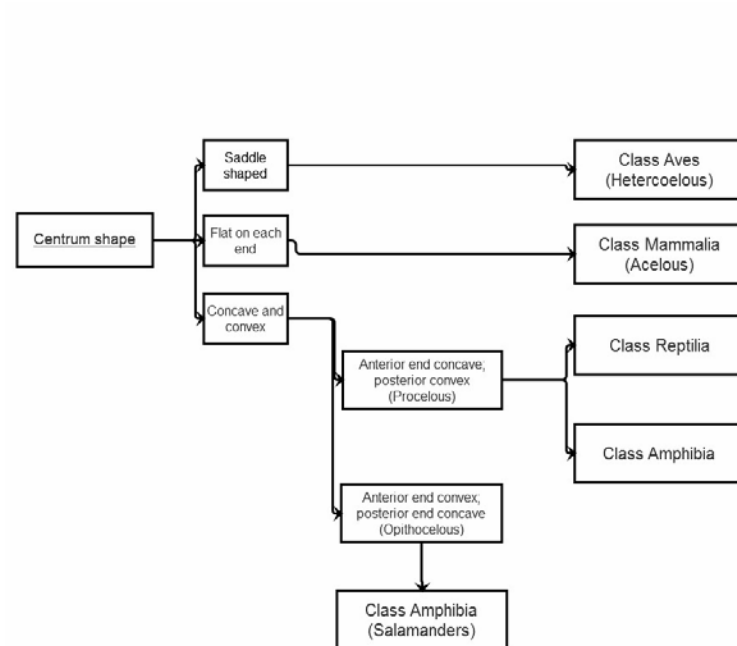
This research focuses on the species most commonly brought in for identification in forensic/ medicolegal contexts in the Central Florida region. While the species list is fairly comprehensive, future research should consider increasing the variation of dog samples, including a sheep, developing a broader representation of Florida's costal water birds, adding an adult specimen of the manatee, and incorporating the key deer. Next, the number of skeletal

elements should be expanded to include a section devoted to metapodials, especially a bear and human comparison. In addition, clavicles should be included for a comparison with the alligator's femur. All species vertebral elements, and a pelvis.

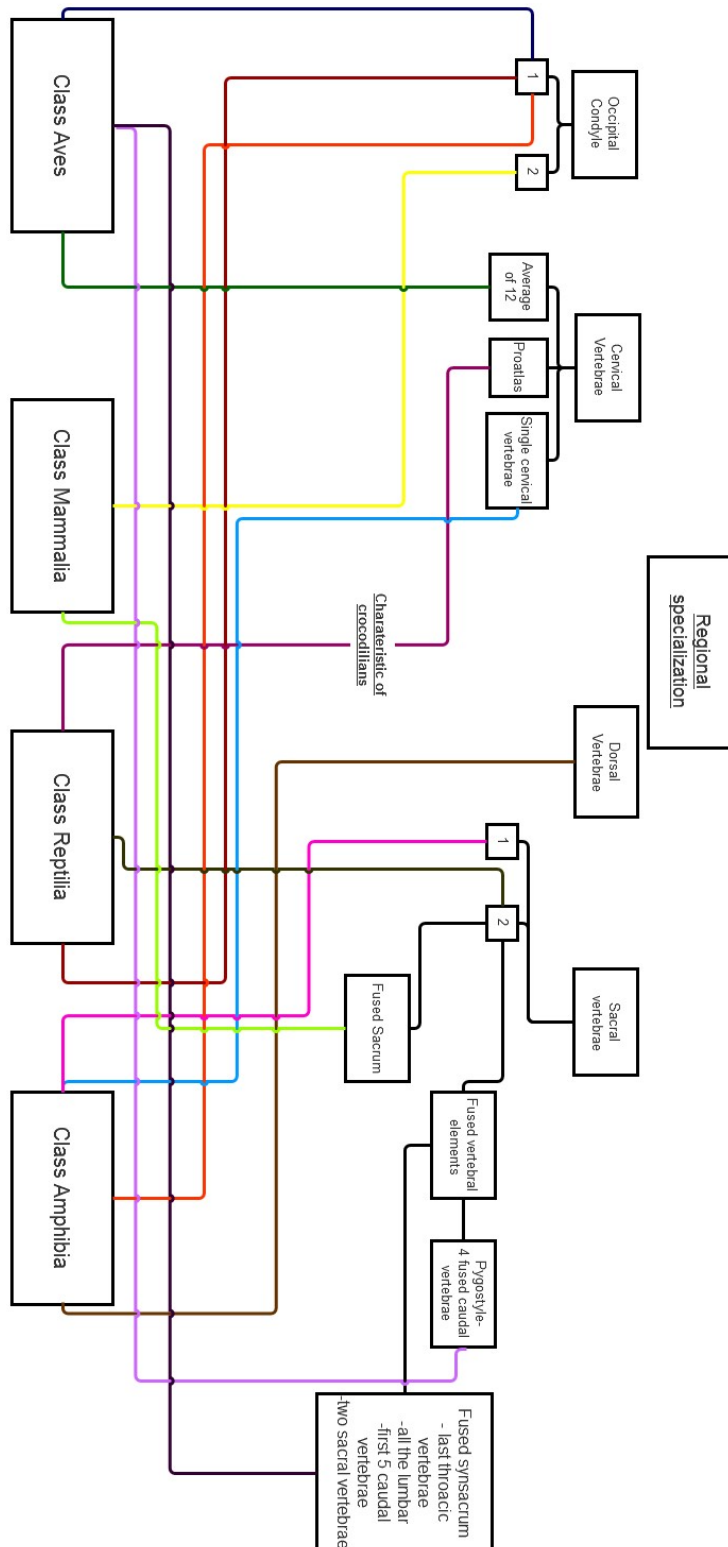
There were some exclusions from the original objective in this research that should be included in future research: sub-adults of both human and non-human remains, as well as a detailed analysis of fragmentary and butchered remains. Future research might also provide not just a singular representation of one species but several, as well a representation of both sexes. There were instances where the specimen might have been a very robust or gracile example of its species; thus, having a range of species within a certain family, class, or order would provide a broader understanding of species-specific skeletal structure variation.

## Appendix

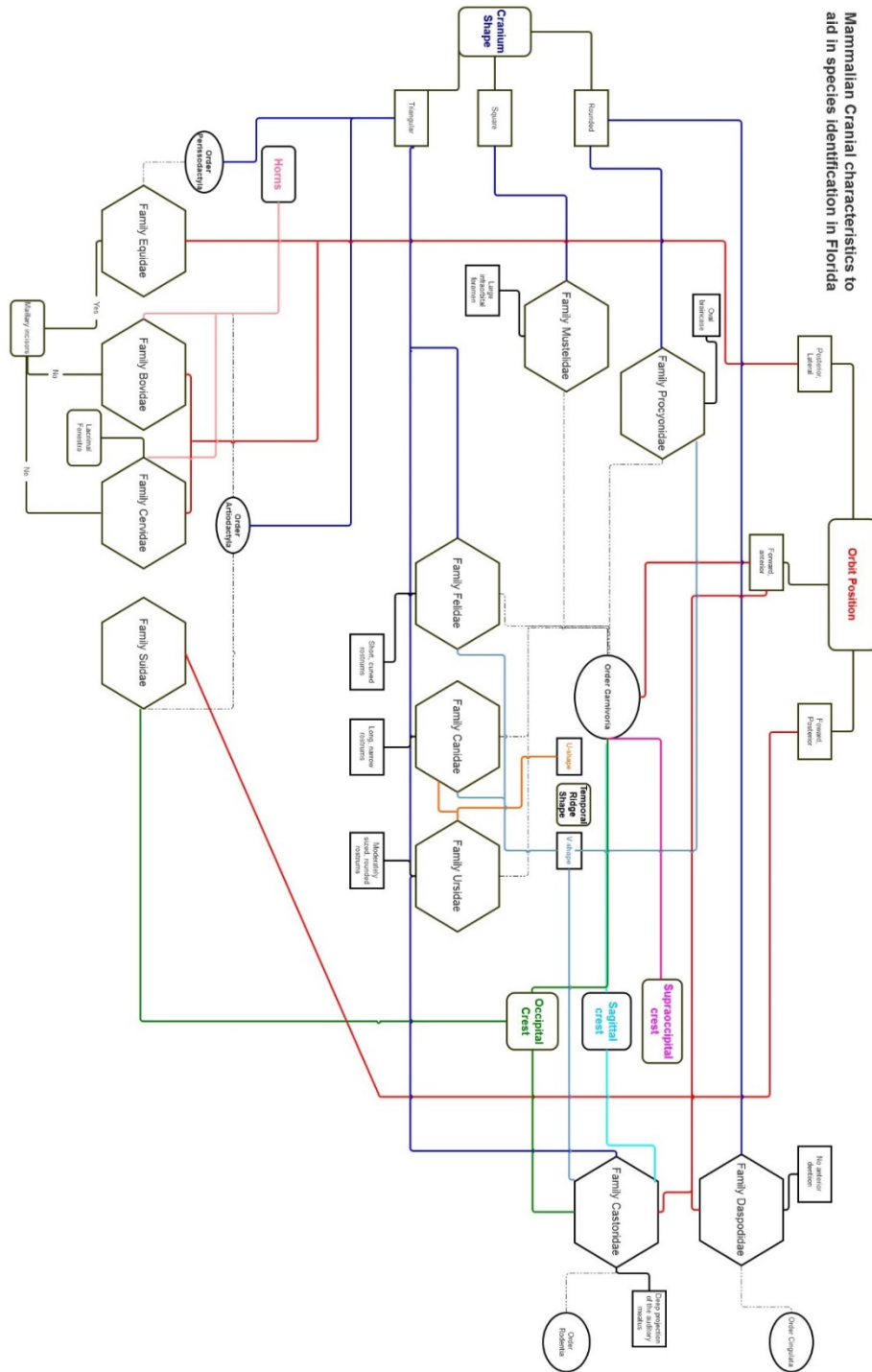
## Appendix A



## Appendix B



## Appendix C





## Appendix D

Florida Species provided by the Florida Fish and Wildlife Conservation Commission and edited by Dr. John Schultz, Mr. Irv Quitmyer, and Mr. Frank Logiudice					
<b>Birds</b>			<b>Land Mammals- Small</b>		
	Sand hill crane	<i>Grus canadensis</i>		Gray Fox	<i>Urocyon cinereoargenteu</i>
	Wood stork	<i>Mycteria americana</i>		Red Fox	<i>Vulpes vulpes</i>
	Black vulture	<i>Coragyps atratus</i>		Armadillo	<i>Dasypus novemcinctus</i>
	Turkey	<i>Meleagris gallopavo</i>		Beaver	<i>Castor canadensis</i>
	Domestic chicken	<i>Gallus domesticus</i>		Raccoon	<i>Procyon lotor</i>
<b>Land Mammals Large</b>				River Otter	<i>Lutra canadensis</i>
	Black Bear	<i>Ursus americanus</i>		Striped Skunk	<i>Mephitis mephitis</i>
	Wild Hog	<i>Sus scrofa</i>		Eastern Cottontail	<i>Sylvilagus floridanus</i>
	White hair deer	<i>Odocoileus virginianus</i>		Dog	<i>Canis lupus familiaris</i> Variations: -small -medium -large
	Coyote	<i>Canis latrans</i>		Cat	<i>Felis catus</i>
	Bobcat	<i>Lynx rufus</i>	<b>Marine Mammals</b>		
	Florida Panther	<i>Puma concolor</i>		Manatee	<i>Trichechus manatus</i>
	Cattle	<i>Bos primigenius</i>		Bottle Nose Dolphin	<i>Tursiops truncates</i>
	Horse	<i>Equus ferus</i>			
	Goat	<i>Capra hircus</i>	<b>Reptile</b>	Alligator	<i>Alligator mississippiensis</i>
				Sea Turtle	<i>Caretta caretta</i>
				Gopher Tortoise	<i>Gopherus polyphemus</i>

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