AN OSTEOLOGY OF THE WHITE-TAILED DEER

Odocoileus virginianus

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THESIS ABSTRACT

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Because of the absence of a comprehensive description of the osseous anatomy of the white-tailed deer, this study was undertaken. The external morphology of each bone is described utilizing the current nomenclature presented in *Nomina Anatomica Veterinaria*[39].

Bones obtained from five male and five female deer were studied. The skull is described as a whole and its features are characterized as seen from several views. Bones of the vertebral column are considered in regions with bones and features not characteristic of the series presented individually. The components of the appendicular skeleton are presented individually.

This thesis confirms the presence of a unique facial vacuity on the facial portion of the skull, a first carpal bone and vestigial second and fifth metacarpal bones.

The results report the presence of a single os cordis and distal sesamoid bones the presence of which had not been previously recorded. The condition of the fibula was examined and its variable status is reported.

Both the written description and the drawings should be useful to law enforcement officials and archeologists in identifying bones as those of the white-tailed deer.

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To all, I express my sincere thanks.

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I. INTRODUCTION

The purpose of this thesis is to present an accurate description of the osseous structures of the white-tailed deer (Odocoileus virginianus) using standardized anatomical nomenclature as found in Nomina Anatomica Veterinaria[39]. In general, the nomenclature presented in Nomina Anatomica Veterinaria[39] was adequate to describe the topographical features of the skeleton. All features were named according to their similarity to features of domestic mammals. There were no terms applicable to the features of the antlers, the pedicles, the subscapular ridge and groove, the interischial bone, the supraacetabular fossa, and the facial vacuity.

The descriptions of the individual features of the bones are composite descriptions and with few exceptions no attempt was made to describe differences between individuals. Comparative size of the bones of specimens was not considered.

In combining my interest in anatomy and wildlife, I selected the white-tailed deer for study. A review of the literature and personal communication with wildlife investigators indicated that complete anatomical information about the white-tailed deer was not readily available[7,19].

The economic importance of the white-tailed deer is difficult to evaluate, however the figures of the United States Department of the Interior are indicative of the value of the specie. In 1970, approximately seven million big game hunters spent over 950 million dollars for equipment, food, lodging, transportation, miscellaneous expenses, and licences[57]. In 1970 approximately 1.2 million deer were removed by hunting from the national deer herd. The herd was estimated at over eight million deer in 1970[56].

These figures indicate that the white-tailed deer is a valuable national resource which deserves careful management.

It is hoped that this work will serve as a useful tool for wildlife investigators, archeologists, law enforcement officials, and comparative anatomists. Osteology appears to be the traditional beginning of anatomical works and perhaps this thesis will become the first part of a more complete work.

II. REVIEW OF LITERATURE

The white-tailed deer has been subjected to scientific study for many years. The bibliographies of Taylor[54] and Harlow and Jones[18] provide evidence that a wide range of investigation has been conducted. Subjects which have captured the attention of numerous investigators include disease[25], parasites[28,41], taxonomy[40,60], management[1], behavior[2], aging[5,6,9,48,49,57], economics[26], reproduction[27,50], predators[30], anomalies[37,58,64,65], habitat[46], diet[46], and phylogeny[31]. From a structural standpoint, accounts of antler development[14,16,61,63] and structure[59,61,62], tooth structure[49] and measurements[6,20,48] and specific body measurements[42,45] have been frequently reported. The work of artists has been aided by structural accounts like that of Ellenberger et al[11]. The archeologist has been aided by the works of Schmid[47], Cornwall[8], and Lawrence[24].

The literature was not overburdened with precise descriptions of the macroscopic osseous anatomy of deer in general and the white-tailed deer specifically. Investigators reporting on structural features had to develop their own description of the normal anatomy. Blankenship et al.[4] and Mystkowska[36] found themselves in this situation with respect to the skeletal morphology of deer. This lack of anatomical information has been expressed by other investigators[7,19].

Information has been classified in this thesis according to its specificity. Important general information was obtained from works on comparative osteology in which statements pertaining to the order Artiodactyla, suborder Ruminantia and infraorder Pecora were applicable[13,43]. Other information provided structural accounts of the family Cervidae or deer other than the white-tail[36]. This literature was useful from a comparative standpoint and was utilized as an aid.

Because of structural similarities of the white-tailed deer to several of the domestic mammals and the availability of organized veterinary nomenclature, the works of Sisson and Grossman[52], Miller et al.[34], Koch[23], Barone[3], Nickel et al.[38], and May[32] provided considerable assistance. With few exceptions, the nomenclature utilized in this investigation is that presented in Nomina Anatomica Veterinaria[39]. For the sake of continuity, the results of the literature review are presented in a form similar to the results of this author's research.

It has been found that the bones of the skull of the deer include the occipitals, temporals, sphenoid, ethmoid, parietal[36], frontals, nasals, lacrimals[36,43], vomer[36], maxillae[36,43], intramandibulare[36] (incisive), palatines, pterygoids, zygomatics, mandibles[36], and hyoids[43]. An in depth description of these components has been presented by Mystkowska[36].

The dorsal surface of the male skull[12] has been characterized primarily as having bony outgrowths of the frontal bones[13,43]. These projections, called pedicles are described as forming the base on which antlers develop[13,16,43]. Reports indicated that antlers were deciduous structures[16,59] which developed under hormonal control[63]. They were reported to become increasingly complex with each annual regrowth[43]. Specific correlation between the number of tines[35] or beam diameter with age and vigor has not been generally agreed upon[6].

Antlers were reported to develop under a cover of velvet[62] which was skin richly supplied with blood vessels[59] and nerves[62]. Growth was found to occur at the tips of the tines and main beam[59]. After the shedding of velvet[35], the bare dead bone[35,43,59] of the antler was found to represent a rare instance where the continuity of the skin was naturally interrupted[16]. The stage of antler development was described as being accompanied by specific remodeling of the long bones of the deer[21,33] and during this phase, the antlers were reported to resemble neoplastic bone[35]. Ossification was reported to be intramembraneous[61]. The mature antler was found to consist of a corona[35] (coronet[8] or burr[12,16,61]) a main beam[22], and a variable number of points[35] or tines[8]. Tines have been named according to their position with the most proximal called the brow tine[8,22], the next the bez tine and the third the trez tine. Subsequent tines were not named[8].

At the appropriate season of the year, antlers have been reported to separate from the pedicle[16,43] and the skin grows over the exposed stump[61]. Abnormal occurrences such as antler formation in the female[65] and relationships between body injury and antler malformation have also been reported[29].

Fusion of the parietal bones[43] and parietal crests have been noted on the dorsal surface of the skull. The parietal crests diverged slightly and at no time formed a saggital crest[12]. The posterior ends of the nasal bones were not expanded[43].

A large lacrimal fossa[12,13,43] has been described on the lateral surface of the skull rostral to the rim of the large nearly circular orbit[43]. Immediately rostral to this fossa a facial vacuity[13,31] has been located. It was reported to be larger than the lacrimal bone[12] and located between the frontal, lacrimal, maxilla, and nasal bones[13,43]. This opening, also called the lacrimonasal interstice[12] or hiatus lacrimalis[36], has been reported to be covered by a thin membrane in living deer[13].

Caudal to the lacrimal fossa, the orbital rim was found to be interrupted by the double opening of the lacrimal canal[13]. A slightly concave glenoid facet was located rostral to the postglenoid process and foramen[43]. Ventral to this complex was the simple tympanic bulla and muscular process[13]. Above the long jugular process[13], a supramastoid foramen has been observed in the red deer[36].

The hyoid apparatus has been characterized as having short, stout keratohyoids and epihyoids. The stylohyoids were described as long and strong and having a prominent caudal process near the dorsal end[13].

The upper incisor teeth have been found to be resorbed before they cut through the gum, hence, there were no protruding teeth in the premaxilla[43]. Upper canines were usually absent[43,58] but have been reported[58]. The lower canines were incisiform in nature and were separated from the selenodont cheek teeth by a wide diastema[43]. Suggested terminology for the dental formula was $I\frac{0}{3}\ C\frac{0}{1}\ PM\frac{2}{2},\frac{3}{3},\frac{4}{4}\ M\frac{1}{1},\frac{2}{2},\frac{3}{3}$[12,44].

Seven vertebrae were present in the cervical region[43] and nineteen in the thoracolumbar area[13,43]. The sacrum was found to be composed of one large and several small vertebrae which were fused together. This complex was fused to the ilia and coccygeal segments[43]. Coccygeal vertebrae diminish in size caudally[13,43]. There were no accessory processes[13] reported.

Deep articular cavities for the occipital condyles were features attributed to the long atlas. Its transverse processes were flattened from dorsal to ventral and perforated by foramina which conducted the spinal nerve branches but not the vertebral artery[13]. The axis featured a spout like odontoid process[13,43] and the canal for the second cervical nerve was located near the cranial border of the laminae[36]. The axis along with the remaining cervical vertebrae were found to be opiscoelous[13,43].

The thoracolumbar segments were reported to be slightly opiscoelous. The high spines[43,66] of the thoracic vertebrae projected caudally in the cranial segments and cranially in the caudal region[43].

The slightly curved ribs of the cranial region were described as flattened as were the remainder of the series[13]. The sternum was found to contain seven segments[13,43]. Its first segment was rather narrow[13], and the remainder progressively wider and flatter[13,43]. The xiphisternum was reported to terminate caudally as a thin flat cartilagenous plate[43].

The high narrow scapula[13,43] was found to be marked by a prominent spine[31,43] with a distinct acromion[13,43]. A tuber spinae was reported as present but not prominent[4]. The triangular infraspinous fossa was found to be four times the size of the narrow supraspinous fossa. The subscapular fossa bore a caudally located subscapular ridge. Caudal to this ridge, the subscapular groove was found to contain a nutrient foramen near the junction of the middle and distal thirds. The scapular notch was reported to be similar to that of the ox[4]. When the imperfectly ossified scapular cartilage[13,43] was removed, it was found to reveal the straight dorsal border of the bone[43].

The humerus was described as being a stout, short bone[13,43]. The greater tuberosity was reported of overhang the bicipital groove[13,43], and the lesser tuberosity formed the medial wall of the undivided[4] groove. The neck was found to be poorly defined[4]. Reports indicate that the musculospiral groove was bordered cranially by a crest which bore a small[13], rough, slightly prominent deltoid tuberosity[4]. A teres tuberosity was reported on the medial side of the shaft. The medial condyle and epicondyle were larger and more developed than those on the lateral side[4].

The radius has been characterized as a long, slender bone[4], moderately curved[31] and enlarged at both ends[13,43]. It was found that the caudal edge of the proximal end was notched and medial to this notch was a small articular facet[4]. Features of the distal end are reported to include three obliquely oriented, smooth facets for articulation with the carpal bones. A smooth area for articulation with the ulna was identified at the lateral part of the caudal surface of the distal end[4].

The ulna was reported to be somewhat reduced in size[66] with most of its mass in the proximal end[4]. It has been found that its incomplete fusion with the caudal surface of the radius created small proximal and distal interosseous spaces[4]. The semilunar notch was reported to articulate with the medial condyle of the humerus. Distal to the notch, a facet has been found which articulated with the radius. It has been reported that lateral to this articulation a process, which has two smooth facets, fits into the proximal notch of the radius. The ulnar shaft was described as flattened. The enlarged styloid process was found to articulate with the radius and ulnar carpal bones[4].

Six bones were found to be present in the carpus[4]. Reports indicated that the four bones of proximal row were the radial carpal, intermediate carpal, ulnar carpal[4,43] and accessory carpal[4]. The medial of the two bones of the distal row were the fused second and third carpal units and the lateral bone was the fused fourth and fifth carpal units[13,66].

The axis of the manus was reported to pass between the third and fourth digits and the manus was symmetrical around this axis[4,13,43,66]. The large metacarpal bones (third and fourth) have been found to be fused along their axial surfaces[43]. A slight vascular groove was identified on the convex dorsal surface of the resulting bone. The palmar surface was described as being concave and the shaft smooth. Two foramina have been found on the caudal surface. The proximal foramen emerged on the proximal articular surface, and the distal foramen opened on the dorsal surface of the bone. The condyles were reported to be symmetrical and separated by a deep groove[4]. Accounts indicated that the second and fifth metacarpal bones were rudimentary[13,43] and flattened and have small distal condyles[4]. These bones were shorter than one half of the length of the shaft of the large metacarpal bone[31].

The weight bearing digits were found to be symmetrical and each digit has three phalanges[4]. The proximal end of the proximal phalanx was the larger and had a concave proximal articular surface. The shaft tapered to the distal condyle[4]. The middle phalanx was described as similar to the proximal, but only two thirds as long. The distal phalanx was characterized as being similar to a pyramid with its apex directed distally. Its axial surface bore a foramen near the proximal end[4]. The second and fifth digits each were reported to have three phalanges[4] which articulated with the small metacarpal bones[43]. Four sesamoid bones were located in a row at the metacarpophalangeal joint. The abaxial bones of this row are reported to be larger than the axial ones and were found to have a plantar eminence projecting distally[4].

The pelvis has been reported to be long[13,43,66] and narrow[43]. The flat ilium was found to narrow toward the acetabulum[43] and large ischial tuberosities were reported at the caudal end[13,66]. The acetabular bone was described as being fused with one of the other pelvic bones[13] and the presence of a supraacetabular fossa was reported[13,24,43]. The pelvic complex is described as being complimented by an interischial bone[53]. The presence of this bone has also been reported in the dog[17]. Several authors have indicated that determination of the sex of a deer from the carcass was important for forensic reasons[10,53]. The shape of the pelvic symphysis was advanced as a reliable criterion for this purpose[53,55]. The male symphysis was found to have a biconvex shape while the female symphysis was concave ventrally and convex dorsally[55]. Ischial suspensory tuberosities in the male and symphyseal ratios were also suggested as useful for sex determination[53].

It was found that a characteristic of the deer femur was the absence of the third trochanter[13,43]. The great trochanter was described as rising above the femoral head[13]. The lesser trochanter was not found to be prominent and the neck had no definite constriction[43].

Reports indicated that the patella was a well ossified[13,43], triangular bone having its base directed proximally[13]. Fabellae have not been found in the deer[13,43].

The fibula was characterized as being reduced in size[66] and represented by an unattached[13,43], small, short spine, and the lateral malleolus[13]. The lateral malleolus was a small bone located at the distolateral end of the tibia[43].

The second and third tarsal bones were found to be united as were the central and fourth[12,13,43,66]. The first tarsal was described as being distinct but small[13]. The proximal and distal ends of the tibial tarsal bone were reported to resemble pully-like grooves with the distal groove articulating with the fourth tarsal bone[43]. The fibular tarsal bone was found to articulate with the lateral malleolus of the fibula[43].

As in the manus, bones of the pes were found to be symmetrically oriented around an axis which passed between the third and fourth digits[43]. These digits were described as being well developed[13] and equal in size[13,66]. It has been reported that the large metatarsal bone had a well developed plantar furrow[31], and the second and fifth metatarsal bones absent[43]. The second and fifth digits were found to be represented by three small phalanges each[43].

The presence of an os cordis has been reported in sheep[80] and cattle[52]. Its presence in the deer has not been previously mentioned.

III. MATERIALS AND METHODS

When the white-tailed deer was selected as the species for this study, the entire scope of the project had not been determined. Because of availability, several deer were obtained prior to the time the research was started. Five male and five female deer were secured as the nucleus for the study. The generosity and hunting skill of students and friends provided numerous additional bones for study. Several of the earlier deer were embalmed with a solution of formalin, alcohol and phenol. They were emersed in a formalin solution for storage. The remainder of the deer that were collected were frozen for storage. Embalming several of the specimens proved to be a mistake and it turned the three day procedure of preparing a skeleton into a ten to twelve day procedure. Some of the bones from these specimens could not have been used for photography. All but one of the nucleus specimens were killed by gunshot and a number of bones were destroyed. In these cases, bones from a replacement collection were substituted so that the total number of bones examined represented ten skeletons.

All deer were aged according to the methods of Dahlberg[9] and Severinghaus[48]. Prior to cleaning, three of the deer were radiographed to provide a means for determining the presence or absence of bones and exact locations. The fibula, clavicle, os cordis, sesamoid bones, carpal bones, tarsal bones, metacarpal bones and phalanges of the minor digits were bones of this category.

Each specimen was trimmed of excess soft tissue and then boiled in a soapy water solution. The embalmed specimens were harder to clean so they were allowed to soften in the soapy water between boilings.

Three male and three female specimens were prepared in this fashion, and the initial observations made and recorded. The remaining specimens were utilized to clarify questions which arose during the initial observations. Dissection of these embalmed and thawed specimens was necessary to accurately describe several features. These specimens were then prepared as were the original deer. All bones were identified according to specimen.

The artists were provided with cleaned bones from which to prepare drawings. Frequent consultations were held with the artists to insure that correct drawings were prepared.

IV. RESULTS

Three of the male deer were found to be in the thirteen to seventeen month age class and one was four and one half years old. The exact age of the other male specimen was impossible to determine as the jaws were destroyed by gun-shot. The female specimens were six to seven months, thirteen to seventeen months, eighteen months, three years and four years of age.

Axial Skeleton

Head

The most complex group of bones encountered in the skeleton of the white-tailed deer was found in the head. Two notable features distinguished the skull of the deer from that of domestic mammals. The most obvious was the presence of antlers in male deer. The other feature was a large hiatus of bone (Figure 12) on the facial portion of the lateral surface of the skull. This opening was bounded by the nasal and lacrimal, frontal and maxilla bones was covered by a tough, paper thin membrane in freshly dissected specimens.

Dorsal Surface of the Skull
(Figures 2-9)

When viewed from above, the skull resembled a teardrop. The cranial part of the dorsal surface was formed by the occipital bone (Os occipitale), the fused parietal bones (Ossa parietales), and the paired frontal bones (Ossa frontales). The surfaces of these bones were generally smooth. The dorsal surface of the occipital bone resembled a trapezoid. Its caudal border was a sharp, slightly convex arc. Near the midline, this border was more gently rounded and formed the slight external occipital protuberance (Protuberantia occipitalis externa). On either side of this eminence, the nuchal line (Linea nuchae) extended lateral as the caudal border of the bone. The nuchal line then turned ventral and became associated with the lateral surface of the skull. The temporal line (Linea temporalis) marked the lateral extent of the dorsal surface of the occipital bone and it extended rostrally to meet the parietal margin (Margo parietalis). This margin was interdigitated and marked the rostral border of the occipital bone. The smooth surface of the bone was slightly convex and pitted by several small foramina.

The parietal bones were fused at the midline into a single bone. The lateral boundaries of the dorsal surface of this bone were the temporal lines which diverged rostrally. Immediately medial and parallel to the temporal lines, were shallow grooves. The frontal margin (Margo frontalis) of the parietal bone was interdigitated also and S shaped on each side of the midline. The surface of the bone was smooth and pitted by several small, irregularly placed foramina. A slight V shaped eminence was located near the midline and its apex was directed caudally.

The frontal bones formed the greatest portion of the dorsal surface of the skull. They were separated along the midline by the interfrontal suture (Sutura interfrontalis). This suture was rather straight anteriorly and interdigitating posteriorly. The nasal margin (Margo nasalis) was deeply notched and jagged. The straight edge adjacent to the facial vacuity was also jagged as was the junction of the frontal and lacrimal bone (Os lacrimalis). The rough, slightly concave supraorbital margin (Margo supraorbitalis) was obliquely oriented and formed approximately the middle one third of the lateral extent of the bone. Caudal to this margin, the zygomatic process (Processus zygomaticus) and the concave temporal line completed the lateral boundary. The surface of the bone was smooth and undulating and was slightly indented along the rostral end of the saggital margin (Margo saggitalis). The supraorbital groove (Sulcus supraorbitalis) was oriented in a rostrocaudal direction and extended caudally from the rostral end of the bone. The rostral end was wider and more shallow than the caudal end. From the deepest portion of the supraorbital groove, the supraorbital foramen (Foramen supraorbitalis) opened ventrally into the orbit.

In female specimens, a short ridge extended caudodorsal from the zygomatic process. In male specimens this ridge was enlarged and projected caudolaterally to form a cylindrical pedicle. The antlers were situated upon these pedicles. Differing degrees of development of mature antlers were observed, and they varied from a simple short spike to an ornate rack. Each antler consisted of a main beam with a coronal enlargement or burr. The burr was a knobby ring located at the most proximal end of the beam. Immediately distal to the burr the surface of the beam was rough and irregular. Some of these irregularities were small bumps and others were grooves or ridges. These ridges extended distally in a parallel fashion. In cross section, the main beam was nearly circular throughout its length. Considerable variation was observed in length, diameter, curvature and number of tines on different specimens. The main beam of a well developed antler first extended caudolateral and dorsal in a gentle curve. The dorsal curve continued and became anteromedial in direction. The main beam generally decreased in diameter from proximal to distal and terminated at a sharp point. Tines projected dorsally from the main beam at different intervals and were usually symmetrical with the tines of the opposite antler. The brow tine was located closest to the burr and the bez and trez tines were the second and third tines respectively. Additional tines were not encountered. When antlers were not present, the pedicle was rounded at its distal extreme.

The paired nasal bones (Ossa nasales) (Figure 2) and maxillae (Ossa maxillae) (Figure 10) formed the facial portion of the dorsal surface of the skull. Each nasal bone was long and narrow and its external face (Facies externa) was smooth and curved ventrolaterally away from the midline. The widest part of the nasal bone was adjacent to the large facial vacuity. The internasal suture (Sutura internasalis) was almost straight.

The portion of the dorsal surface formed by the maxilla was smooth as it extended ventrolaterally from the nasomaxillary suture (Sutura nasomaxillaris) and did not present any unique features.

Lateral Surface of the Skull
(Figures 10-12)

The cranial portion of the lateral surface of the skull was formed by the frontal, parietal, occipital, temporal, basisphenoid (Os basisphenoidale), presphenoid (Os presphenoidale), pterygoid (Os pterygoideum), palatine (Os palatinum), lacrimal, incisive (Os incisivum), and zygomatic (Os zygomaticum) bones.

Two separate divisions of the occipital bone were visable from the lateral side. One division formed a small slightly concave triangle at the extreme caudodorsal point of the skull. The dorsal border of this triangle was the temporal line and the caudal border was formed by the nuchal line. The other border was the occipitosquamous suture (Sutura occipitosquamosa). The ventral portion of the occipital bone was the jugular process (Figure 11) (Processus jugularis). This process was rather large and extended ventrally below the caudoventral aspect of the temporal bone. The jugular process was triangular and its lateral surface was concave from rostral to caudal. From its wide dorsal origin, the process curved slightly toward the midline and terminated as a rough, blunt tip. The caudal border of the process was slightly flattened. The thinner rostral border ended dorsally near the styloid process (Processus styloideus). Immediately caudal to this junction was the stylomastoid foramen (Foramen stylomastoideum).

The petrosal (Pars petrosa), tympanic (Pars tympanica), and squamous (Pars squamosa) parts of the temporal bone comprised a major portion to the lateral surface, (Figure 10).

The elongated mastoid process (Processus mastoideus) (Figure 11) and the styloid process of the petrosum were visable from the lateral side. The mastoid process extended from the lateral surface of the jugular process dorsally between the occipital bone and the squamosum. Its dorsal end contributed to the formation of the nuchal line and its larger ventral end was rough and irregular. The caudal border was rather straight and the rostral border irregular and interdigitating. The styloid process was a blunt spur situated in a concavity of the lateral surface of the tympanic bulla (Bulla tympanica)(Figure 11).

The tympanic part of the temporal bone formed the dorsal, rostral and ventral portions of the external acoustic meatus (Meatus acusticus externus). From this tubular canal, the bone extended ventromedial and widened at the bulb like tympanic bulla. The surface of the bulla was pitted and irregular. Projecting rostroventral from the medial side of the bulla was the spike like muscular process (Processus muscularis) (Figure 11). Immediately above the tympanic bulla was the large caudally directed retroarticular foramen (Foramen retroarticulare).

The squamous portion of the temporal bone was its largest portion. Its large perpendicular part had a smooth convex surface and was bordered dorsally by the occipital and parietal bones. Caudal to this plate was the mastoid process, and rostral to it were the parietal and sphenoid bones. These borders varied from smooth to irregular and interdigitating. The ventral portion of the squamosum was flaired laterally. The temporal crest (Crista temporalis) formed the caudal one third of this flaired edge and extended from the caudal edge of the zygomatic process (Processus zygomaticus) (Figure 11). The caudal edge of the temporal crest turned ventrally behind the external acoustic meatus. Ventral to the crest was the retroarticular foramen and the tympanum. A caudoventral extension of the squamosum formed the caudal portion of the external acoustic meatus.

The zygomatic process projected laterally from the middle one-third of the ventral edge of the bone. It was flattened from dorsal to ventral and formed a thin shelf which extended lateral and rostral to terminate above the temporal process (Processus temporalis) of the zygomatic bone. These two processes created the zygomatic arch (Arcus zygomaticus). The zygomatic process tapered to a blunt rostral tip.

The ventral surface of the zygomatic process, near its origin at the perpendicular part of the bone was convex rostrally and concave caudally. The concavity was the mandibular fossa (Fossa mandibularis) which articulated with the condylar process (Processus condylaris) of the mandible (Mandibula). The slightly rounded caudal border of this fossa was directed caudoventrally as the distinct retroarticular process (Processus retroarticularis). Its caudal edge was the rostral portion of the retroarticular foramen. The rostral edge of this horizontal shelf was sharp. The perpendicular portion of the squamosum extended rostral to this shelf and formed the lateral side of the pterygoid crest (Crista pterygoidea).

The parietal bone contributed a narrow strip to the lateral portion of the skull. This strip was bounded dorsally by the temporal line and the frontal margin (Margo frontalis). It was ventrally bounded by the squamosum. The lateral surfaces of the temporal and parietal bones formed a convex temporal fossa (Fossa temporalis).

The aforementioned supraorbital margin, the zygomatic process and the pedicles of the frontal bone were also visable on the lateral surface. The frontal bone also formed a considerable portion of the concave medial wall of the orbit. The ethmoid foramen (Foramen ethmoidale) was small and located near the rostroventral edge of the bone.

The basisphenoid bone formed the lateral and medial sides of the large foramen orbitorotundum (Foramen orbitorotundum). The oval foramen (Foramen ovale) was located caudal to foramen orbitorotundum. The basisphenoid contributed to the dorsal part of the pterygoid crest. The narrow pterygoid process (Processus pterygoideus) covered most of the caudal border of the pterygoid bone.

The pterygoid bone was visable both dorsal and ventral to the pterygoid process of the basisphenoid bone. The dorsal part was a flat plate which extended dorsomedial to the pterygoid crest. Only the ventral portion of this plate joined the palatine bone leaving an oblong fissure above. The hamulus (Hamulus pterygoideaus) (Figure 12) was rather blunt and projected ventrally beyond the palatine and basisphenoid bones.

The wings (Ala) (Figure 12) of the presphenoid bone extended dorsolaterally from the base and formed the caudal portion of the orbit. The optic canal (Canalis opticus) was oval and situated in the wing at the apex of the orbit. From this region, the wing continued as a fingerlike extension into an excavation in the ventral margin of the frontal bone. A longer projection extended rostrally between the temporal and palatine bones to the caudal border of the lacrimal bone. Slightly rostral to the optic canal, this projection was depressed into a smooth fossa which was pitted by several small foramina. Ventral to this fossa, the slight orbitosphenoid crest (Crista orbitoshinoidale) extended rostrally in a gentle dorsal then ventral curve which ended at the rostral tip of the bone.

The palatine bone formed the greatest portion of the medial wall of the pterygopalatine fossa (Fossa pterygopalatina). This perpendicular plate (Lamina perpendicularis) was smooth surfaced and slightly convex from dorsal to ventral.

The zygomatic bone (Figure 13) completed the rostral extent of the zygomatic arch and the caudoventral rim of the orbit. The temporal process (Processus temporalis) projected caudally below the zygomatic process of the temporal bone. It terminated caudally at a bladelike tip.

The frontal process (Processus frontalis) (Figure 12) was a caudodorsal projection from the arch which met the zygomatic process of the frontal bone at an interdigitating junction. This process was compressed from medial to lateral. The infraorbital margin (Margo infraorbitalis) was a sharp edge and comprised approximately the ventral one third of the orbital rim (Aditis orbitae). The orbital rim was almost a perfect circle. Below the infraorbital margin, the distinct facial crest (Crista facialis) extended from the zygomatic arch rostrally to be continued on the maxilla.

The lacrimal bone formed approximately the rostral one sixth of the orbital margin. The orbital face (Facies orbitalis) of the bone was smooth and concave. The two large lacrimal foramina (Foramina lacrimalia) entered the bone near the rim of the orbit. A spike like projection separated these two foramina. Rostral to these foramina was the concave external lacrimal fossa (Fossa lacrimalis externa). Above this fossa, a rounded ridge formed the caudoventral margin of the facial vacuity.

No special features of the nasal bone were observed on the lateral view.

The facial surface (Facies facialis) (Figure 12) of the maxilla was irregular, but smooth, and formed more of the lateral surface than any other bone of the skull. All of the upper teeth were embedded in the maxilla and the impressions of their roots were visable near the jagged ventral border of the bone. The roughened maxillary tuberosity (Tuber maxilla) was located caudal to the third molar. The facial crest was not prominent on the maxilla and it terminated rostrally at the slight, smooth surfaced facial tuberosity (Tuber faciale). Dorsal to the most rostral cheek tooth at the level of the facial tuberosity, was the large infraorbital foramen (Foramen infraorbitale) (Figure 12). The surface of the maxilla, rostral to the infraorbital foramen, extended from the nasal bone to the hard palate and was gently convex from dorsal to ventral.

The most rostral bone of the skull was the incisive bone (Figure 13) which presented a convex smooth lateral surface. In lateral profile, the bone was somewhat triangular. The dorsal margin was gently concave and the ventral margin almost straight. The caudal margin was irregular as it articulated with the maxilla.

The hard palate was almost straight as viewed from the lateral side. The facial vacuity was shaped like a teardrop and the internal structure of the turbinate bones was visable through it.

Ventral Surface of the Skull
(Figures 13-16)

The large rather circular foramen magnum (Foramen magnum) (Figure 14) separated the smooth surfaced occipital condyles (Condylus occipitalis). The ventral surface of each condyle was somewhat oval and obliquely oriented in a rostromedial to caudolateral direction. Its caudolateral border curved in a gentle convex arc and formed a distinct margin with the perpendicular surface of the condyle. The condyles were separated at the ventral midline by an intercondylar notch. At the dorsal border of the foramen magnum, was the nuchal tubercle (Tuberculum nuchale) (Figure 14) which was slightly indented at the midline. Lateral to each condyle, the ventral condylar fossa (Fossa condylaris ventralis) (Figure 14) formed a deep, smooth surfaced depression which was bordered laterally by the jugular processes. Immediately rostral to the occipital condyles, the base (Pars basilaris) of the occipital bone was expanded laterally as a crested tubercle. The base tapered somewhat rostrally and at the junction with the basisphenoid bone were the two roughened muscular tubercles (Tuberculum musculare).

Lateral to the basilar portion of the occipital bone was an elongated foramen complex (Figure 14). The foramen lacerum (Foramen lacerum) was located at the rostral end of this complex. It was squarely bounded by the basisphenoid bone. This opening tapered caudally to the narrow petro-occipital fissure (Fissura petrooccipitalis) which joined the jugular foramen (Foramen jugulare). The jugular foramen was situated deep to the caudolateral end of the tympano-occipital fissure (Fissura tympanooccipitalis).

The muscular process of the temporal bone was concave on its medial side and with the basisphenoid bone formed the musculotuberal canal (Canalis musculotubarius). Rostral to this canal was the large oval shaped oval foramen (Foramen ovale). The base of the basisphenoid was convex from side to side with a slight ridge at the midline. The junction of the basisphenoid bone with the presphenoid bone was transverse and straight. Extending ventrally from this junction, the flat medial wall of the pterygoid bone tapered to the hamulus. The choanae (Choanae) (Figure 14) were oblong from dorsal to ventral and were separated at the mid-line by the thin crest (Crista vomeris) of the vomer (Vomer) which extended caudally beyond the junction of the bases of the pre and basisphenoid bones. The caudal edge of the crest of the vomer bone slanted dorsoventrally and its caudoventral angle was the more rostral of its two angles. The dorsal edge of the vomer bone flaired laterally creating the wings (Ala vomeris) which formed the roof of the choanae.

Rostral to the oval foramen the foramen orbitorotundum was obscured from view by the pterygoid process of the basisphenoid. This foramen was formed by the basisphenoid on the lateral and medial sides and the presphenoid at the rostral margin. This foramen was irregularly oval in shape. The optic canal was obscured by the pterygoid bone and presented no special features.

The ventral surface of the horizontal lamina (Figure 14) (Lamina horizontalis) of the palatine bone was smooth and flat and was interrupted only by the major palatine foramen (Foramen palatinum majus). This foramen was small, caudally directed, and located near the rostral margin of the horizontal lamina. The caudal margin of the lamina extended caudolateral from the midline in a slight concave arc to its junction with the pterygoid bone. The greatest portion of the hard palate was formed by the maxilla. The flat surface of the hard palate slanted ventrolaterally to the alveolar process (Processus alveolaris) and the interdental margin (Margo interalveolaris). A narrow strip of maxilla extended caudally between the palatine bone and the alveoli (Alveoli dentales) of the molar teeth (Dentes molares) and it terminated at the pterygopalatine fossa.

The alveolar process contained twenty one alveoli (Figure 16) which were arranged in the following manner: 1) The roots of the most rostral postcanine tooth extended into three alveoli with one being lateral and two medial; 2) The roots of the next two posteriorly positioned postcanine teeth each extended into three alveoli with two being lateral and one medial; 3) The three most posterior postcanine teeth each had four roots and their respective alveoli were situated with two medial and two lateral.

Just caudal to the last postcanine tooth, was the small maxillary tuberosity (Tuber maxillae) which had a dorso-ventral groove which varied in size.

The rostral end of the maxilla was deeply notched on its medial side and formed the caudolateral boundary of the palatine fissure (Fissura palatina) (Figure 15). Lateral to this notch, the rostral extremity of the maxilla was jagged as it articulated with the incisive bone.

Each incisive bone provided an arch like extension from the maxilla and completed the lateral, rostral and medial borders of the palatine fissure. The palatine face (Facies palatine) of the body (Corpus ossis incisivi) was the widest portion of the ventral surface of the incisive bone. The nasal process (Processus nasalis) was wider than the palatine process (Processus palatinus). The medial edge of the body was slightly notched and with the notch of the opposite member created a distinct interincisive fissure (Fissura interincisive) (Figure 15). The rostral end of the septal groove (Sulcus septalis) of the vomer bone was visable at the caudal end of the palatine process and in some specimens, formed a caudomedial part of the palatine fissure.

Caudal Aspect of the Skull
(Figures 17 and 18)

The large foramen magnum was the central feature of the caudal view. It was symmetrical on each side but not uniformly circular. It was flanked on either side by the smooth surfaced occipital condyles. The caudal surface of each condyle was gently convex with distinct and rather straight medial and lateral margins. A distinct rounded margin separated the caudal surface from the ventral surface of the condyle. Dorsal to each condyle, the surface of the dorsal condylar fossa (Fossa condylaris dorsalis) was rough and slightly concave. The supramastoid foramen was situated above this fossa at the junction of the occipital bone and mastoid part of the temporal bone.

Two foramina were located just internal to the foramen magnum on each side. The opening of the condylar canal (Canalis condylaris) was the larger and more caudal of the foramina. A thin ridge separated the condylar canal from the smaller, more rostrally placed hypoglossal canal (Canalis n. hypoglossi).

Dorsal to the foramen magnum, the external occipital crest (Crista occipitalis externa) was represented by a short rough irregular eminence. Each choana was compressed from medial to lateral and was narrower near its dorsal edge. The pterygopalatine fossa was deep and lacked a definite floor. Three openings were located at the rostral end of the fossa. The smallest and most ventral of these was the caudal palatine foramen (Foramen palatinum caudale). It was situated entirely within the palatine bone. The next dorsal and slightly lateral opening was the maxillary foramen (Foramen maxillare). The borders of this foramen were created by portions of the maxilla, the lacrimal and palatine bones. The maxillary foramen was triangular in shape with its lateral angle continued laterally as a slit.

The sphenopalatine foramen (Foramen sphenopalatinum) was the most dorsal of the three foramina. It was essentially formed in the palatine bone with a small dorsomedial portion completed by the presphenoid and lacrimal bones.

Lateral to the sphenopalatine foramen, the lacrimal bone protruded caudally forming the lacrimal bulla (Bulla lacrimalis) which was rather flat on its dorsal surface. The ventral surface of the bulla extended into a fissure which separated it from the maxillary tuberosity.

The Hyoid Apparatus (Figure 19)

The hyoid apparatus (Os hyoideum) was a configuration of nine individual bones joined in such a way as to provide support for the trachea. Each bone of the configuration was paired except the basihyoid bone (Basihyoideum).

The thyrohyoid (Thyrohyoideum) bone was the most caudoventral bone of the series. It was second in length, compressed from medial to lateral, and expanded at each end. The ventral expansion was the larger of the two. The bone was slightly arched with concavities on the medial and dorsal margins. The ventral expansion of the thyrohyoid bones articulated with the ends of the transversely oriented basihyoid bone.

The basihyoid bone was short and slightly arched with concavities on the dorsal and caudal sides. At the midline, the lingual process (Processus lingualis), projected rostroventrally as a small roughened eminence.

The keratohyoid (Ceratohyoideum) bone was positioned immediately rostral to the basihyoid bone. It was compressed from medial to lateral and expanded at each end. The dorsal margin was concave as was the lateral side. The ventral and medial sides were convex. A slight angular projection extended from the ventral margin of the bone.

The epihyoid (Epihyoideum) bone was the shortest of the configuration. It was flat from medial to lateral and expanded at each end with the dorsal expansion being slightly the larger.

The stylohyoid bone (Stylohyoideum) was the largest bone of the series. Like the other paired bones, it was compressed from medial to lateral. The bone was long with nearly parallel sides except for caudal eminences located near each end. The ventral eminence was a small laterally projecting angle. The stylohyoid angle (Angulus stylohyoideus) was the larger irregularly shaped proximal eminence.

The hyoid apparatus attached proximally to the styloid process of the petrosum by the tympanohyoid cartilage (Tympanohyoideum).

Mandibles (Figure 20)

Each mandible was long and compressed from medial to lateral. Each was joined with the opposite member at the mandibular symphysis.

The horizontal portion or body (Corpus mandibulae) tapered in width and height rostral to its junction with the ramus (Ramus mandibulae). The incisive portion (Pars incisiva) was small and expanded laterally. It contained the three lower incisor teeth (Dentes incisiva) and the canine tooth (Dentes canini). The canine tooth was incisive in morphology and was situated next to the lateral incisive tooth. The single root of each of these teeth extended into a single alveolus. The symphyseal surface was rough and irregular.

The lateral surface of the molar portion (Pars molaris) of the body was marked at the rostral end by the large mental foramen (Foramen mentale). Caudal to this foramen, the body narrowed from dorsal to ventral. It then became wider toward the postcanine teeth which were set in the most massive part of the bone. The first postcanine tooth was set in a single small alveolus. The two roots of each of the remaining postcanine teeth were set in a large caudal alveolus and a smaller rostral one.

The body was nearly straight when viewed from the ventral surface. Both sides were smooth and slightly convex from dorsal to ventral. The ventral margin (Margo ventralis) was gently convex from cranial to caudal and terminated caudally at the vascular notch (Incisura vasorum facialium).

The vertical portion or ramus had its greatest dimensions near the ventral edge. The angle (Angulus mandibulae) formed approximately one third of a circle and it extended slightly caudal and ventral to the body and ramus. It was smooth and rather concave on the lateral side at the masseteric fossa (Fossa masseterica) and convex on the medial side.

The rostral border of the ramus was grooved as it joined the body. This groove was widest at its ventral end.

The medial surface of the ramus was depressed at its middle forming the pterygoid fossa (Fossa pterygoidea). Near the ventral end of this fossa was the large mandibular foramen (Foramen mandibulae). The narrow mylohyoid groove (Sulcus mylohyoideus) extended from the caudal end of the mandibular foramen cranioventrally across the medial surface of the ramus.

Above the pterygoid fossa, at the caudal surface of the ramus, the condylar process (Processus condylaris) extended toward the midline. The smooth surfaced articular head (Caput mandibulae) was transversely oriented on a somewhat narrower neck (Collum mandibulae). The articular area was directed dorsally and was convex from rostral to caudal and concave from medial to lateral.

The rounded mandibular notch (Incisura mandibulae) formed the angle between the condyloid process and the coronoid process (Processus coronoideus).

The coronoid process was thin and blade like and it curved caudodorsally from the ramus. The margins of the coronoid process were nearly parallel, and the caudal margin was thinner than the rostral margin. The process terminated dorsally as a gently rounded tip.

Vertebrae

Cervical Vertebrae (Figures 21-30)

There were seven cervical vertebrae (Vertebrae cervicales). The first two differed from each other and from the remainder of the series. The vertebral bodies (Corpus vertebrae) of the second through the seventh vertebrae decreased in length so that the seventh was approximately two thirds the length of the second. The spinous processes (Processus spinosus) of the third through the seventh projected craniodorsally and, proceeding caudally, became longer and more bladelike. Transverse foramina (Foramina transversarium) were present in all cervical vertebrae except the seventh.

The atlas (Figure 23) lacked a spinous process and a distinct body. The large transverse processes (Processus transversus) were flattened into wide, flairing, wing like eminences. Each wing was the lateral extension of a lateral mass (Massa lateralis) which when united with the dorsal arch (Arcus dorsalis) and ventral arch (Arcus ventralis) created the vertebral foramen (Foramen vertebrale). The transverse process was thickest at its caudal tip. It was dorsoventrally pierced by the alar foramen (Foramen alare). The dorsal opening of this foramen varied from round to resembling the figure 8. The alar foramen was joined by the lateral foramen (Foramen vertebrale laterale) which entered from the vertebral canal. It was joined by the transverse foramen which was the more caudal of the openings in the dorsal surface of the transverse process. The alar foramen opened ventrally into the atlantal fossa (Fossa atlantis).

Each lateral mass had a cranial articular surface (Fovea articularis cranialis) and a caudal articular surface (Fovea articularis caudalis). The cranial articular surface was a smooth cup like depression which articulated with the occipital condyle. The smooth caudal articular surface was flattened and extended partially into the vertebral foramen. Neither the cranial nor caudal articular surface was connected with the surface of the opposite side.

The dorsal arch was thinner than the ventral arch and was notched at the caudal midline. The dens (Dens) of the axis (Axis) articulated with the ventral arch at the smooth concave fovea dentis (Fovea dentis). The dorsal arch had a roughened dorsal tubercle (Tuberculus dorsalis) on its craniodorsal surface. A similar ventral tubercle (Tuberculus ventralis) was found on the ventral arch, however, it was situated more toward the caudal end of the bone.

The axis was composed of a large body, a prominent arch (Arcus vertebrae) and several processes. The dens resembled a half cylinder and it projected from the cranial end of the body of the axis. The dorsal aspect of the dens was deeply concave. Its ventral aspect (Facies articularis ventralis) was a smooth, convex curve that blended with the flairing cranial articular surface of the cranial extremity (Extremitas cranialis). The caudal extremity (Extremitas caudalis) flaired slightly and the articular surface formed the gently concave vertebral fossa (Fossa vertebrae). Dividing the caudal three fourths of the ventral surface into two deep fossae was a prominent ventral crest (Crista ventralis). This crest terminated caudally as a roughened tubercle.

From each side of the body, the transverse processes projected caudolaterally and tapered to a rounded tip. Each process, in its proximal portion, contained a craniocaudally directed tunnel called the transverse foramen. This tunnel was connected cranially with the lateral foramen.

The vertebral arch was thin and each side was pierced by the lateral foramen near the cranial edge. Projecting dorsally from the top of the arch was the bladelike spinous process. It extended the entire length of the arch. The dorsal edge of the process was thickened and the thickness increased caudally.

The caudal articular processes (Processus articularis caudalis) angled away from the caudodorsal edge of the arch. Their articular surfaces were directed ventrolaterally in a gentle 90° twist.

The remaining cervical vertebrae differed from one another primarily in the size of their components and were representative of the typical vertebral form. All had distinctive bodies with a convex cranial extremity or head (Caput vertebra) and a concave caudal extremity. The third, fourth and fifth vertebrae had prominent ventral crests.

The transverse processes of vertebrae three through six featured double projections. These were designated the dorsal and ventral tubercles (Tuberculus dorsale et ventrale); however, this did not accurately describe their positions on the articulated specimen. The ventral tubercle was positioned cranial or ventral and was the more bladelike of the two. The dorsal tubercle was pointed and extended caudolaterally on the third vertebra. Thereafter, the dorsal tubercles were blunter and directed lateral.

Transverse foramina became progressively larger in diameter on the third through the sixth vertebrae. The caudal articular processes of the second through seventh segments were similar but became more laterally placed progressing caudally. The cranial articular processes

(Processus articularis cranialis) extended craniolateral from the junction of the laminae (Lamina arcus vertebra) and pedicle (Pediculus arcus vertebrae) (Figure 28) and their articular surfaces were directed dorsally.

The caudal extremity of the seventh cervical vertebrae (Figure 29) presented on either side of the vertebral fossa, a fovea (Fovea costalis caudalis) in which the heads (Caput costae) of the first ribs (Os costale) articulated.

The cranial and caudal borders of the pedicles were notched. The cranial vertebral notch (Incisura vertebralis cranialis) together with the larger caudal vertebral notch (Incisura vertebralis caudalis) of the adjacent vertebra formed the intervertebral foramen (Foramen intervertebrale).

<u>Thoracic Vertebrae</u> (Figures 31-37)

The thoracic vertebrae (Vertebrae thoracicae) were thirteen in number and were characterized by long spinous processes and articulation with the ribs. From cranial to caudal the spines of the vertebrae first increased and then decreased in length with the third or fourth being the longest. The spines of the first ten or eleven thoracic segments were inclined caudally and the eleventh or twelfth was anticlinal (Vertebra anticlinalis). The distal end of each spine was slightly expanded.

The thoracic vertebral bodies were compressed dorsoventrally. The third and fourth segments were the widest of the group. The ventral surface of the bodies appeared pinched from side to side and created the distinct ventral crest. A nutrient foramen (Foramen nutricium) (Figure 36) pierced the ventrolateral aspect of each body on one side or the other. These foramina varied considerably in position.

The cranial and caudal extremities of the thoracic vertebral bodies were expanded. The caudal fossa and associated cranial convex head observed in the cervical region was continued in this region. Peculiar to the cranial and caudal extremities of this region, however, was the addition of fovea which received the heads of the ribs. Fovea were situated lateral to the vertebral extremities. The caudal extremity of the thirteenth vertebra did not possess this character, and there was no rib head at this position.

Transverse processes extended laterally from the junction of the bodies and pedicles. They were largest on the first and smallest on the last thoracic vertebrae. A cranioventrally directed articular surface (Fovae costalis transversalis) was present on the transverse processes of the first ten segments. These articular surfaces were inconsistant on the eleventh and twelfth vertebrae and were not seen on the thirteenth. The transverse processes of the first thoracic vertebra were continuous with the cranial articular processes which faced dorsally. Mamillary processes (Processus mamillaris) were identified on all thoracic vertebrae. They were associated with the transverse processes on the first eleven vertebrae and with the cranial articular processes of the last two vertebrae. No accessory processes (Processus accessorius) were observed.

From rather stout pedicles, the laminae slanted caudally and joined at the midline. The spinous processes extended from this junction. The cranial articular processes were enlarged and projected craniolaterally from the pedicles on the first thoracic vertebra. Each had a large flat craniodorsally directed articular surface. The caudal articular process morphologically appeared the same as those described for segments two through ten.

The cranial and caudal articular processes of vertebrae two through ten were similar. The cranial articular processes were paired flattened areas located on the craniodorsal aspect of the laminae. The caudal articular processes were likewise paired flattened areas but were located on the caudoventral aspect of the laminae. They all were oval in shape.

The cranial articular processes of the eleventh vertebra were the same structurally as those on the middle thoracic vertebrae. The remaining articular processes resembled a tongue and groove arrangement with the groove being created by a prominent hook shaped cranial articular process. This process projected cranially from each lamina and the articular surface was directed medially. Each tongue was a separate caudal projection from the laminae and its articular surface faced ventrolaterally. Intervertebral foramena were formed similar to those in the cervical region.

Lumbar Vertebrae (Figures 38-40)

The lumbar vertebrae (Vertebrae lumbales) were six in number and all were similar in structure. They were characterized by large bladelike spinous processes and long flat transverse processes.

A distinct ventral crest was present on the ventral surface of the bodies. The cranial and caudal extremities were distinctly flaired, and the caudal extremity was wider than the cranial. Each lumbar vertebra was wider than the one preceeding it. One or more nutrient foramina entered the bodies ventrally; however, a single foramen for each vertebra was the usual case. Each vertebral body was more dorsoventrally compressed than the one preceding it.

The transverse processes projected craniolaterally from the junction of the body and pedicle. Each was gently arched ventrally. All were wing like and flaired at the tips. They became progressively longer from the first through the fourth segments and then became shorter. The transverse processes of the last lumbar segment were sickle like and pointed at the distal ends.

The cranial and caudal articular processes were similar in arrangement to those described for the last thoracic segments; however, each articulation was more laterally placed than the preceeding one. Mamillary processes were present on all cranial articular processes.

Spinous processes were widest in the lumbar region. The distal ends were flaired with a prominent cranial projection. They did not differ appreciably in height.

Sacrum (Figures 41-43)

The sacrum (Os sacrum) was formed by the fusion of the four sacral vertebrae. It had a dorsal surface (Facies dorsalis), a pelvic surface (Facies pelvina), a base (Basis ossis sacri), an apex (Apex ossis sacri) and two lateral parts (Pars lateralis).

On the midline of the dorsal surface was the median sacral crest (Crista sacralia mediana) which was formed by the fused spinous processes of the four vertebrae. This crest was complete in the adult, forming a gentle arch cranially although it was almost straight caudally. The distal end of the crest was thickened and, in some specimens, was slightly indented at the fusion points. The incomplete fusion of the spinous processes of the first and second segments left an oval fissure between the two. A similar opening was seen between the last two spines in some specimens.

Intermediate sacral crests (Crista sacralis intermedia) were located on either side of the medial sacral crest. They were formed by the fusion of the mamilloarticular processes of each side. Their dorsal surfaces were irregular and in some specimens incomplete. They extended from the lateral parts of the first segment with which they blended caudally to the craniolateral aspect of the last sacral segment.

The three pairs of dorsal sacral foramina (Foramena sacrale dorsalia) had single or double openings. When single, they opened medial to the intermediate crest. When double, one opened medial and one lateral to the crest. The cranial articular processes of the first sacral vertebra, although a part of the intermediate sacral crest, were more closely associated with the pars lateralis and will be described with that structure. There were no caudal articular processes on the last segment.

From the intermediate sacral crest, there was a flat ventrolateral slope which extended to the lateral sacral crest (Crista sacralis lateralis). This crest was formed by the fused distal ends of the transverse processes. The transverse processes of the fourth sacral vertebra were swept caudally and were rather pointed. The lateral crests marked the lateral boundary of the pelvic surface.

The transverse processes of the first sacral vertebrae were the pars lateralis of the sacrum. These massive structures projected from the junction of the pedicles and body of the vertebra. Laterally, they expanded forming angular wings (Ala ossis sacri). The ventral portion of the lateral surface of each wing articulated with the ilium at a cresent-shaped, smooth, auricular surface (Facies auricularis).

From the craniomedial surfaces of the pars lateralis extended the cranial articular processes which were similar to those of the lumbar region.

The pelvic surface was T shaped and concave. The fusion points of the vertebrae were evidenced by three transverse lines (Linea transversae). Three pair of large, oval pelvic sacral foramina (Foramena sacralia pelvinae) were situated on either side of the midline. One pair was located just cranial to each transverse line. Single nutrient foramina entered the ventral surface of the bodies at irregular intervals.

The base of the sacrum or cranial part, presented a large dorsoventrally compressed, oval, cranial extremity. Its ventral ridge was the sacral promontory (Promontorium) which was almost straight and not well defined.

A cranial view of the sacrum revealed the triangular opening of the sacral canal (Canalis sacralis). This canal traversed the entire length of the sacrum, and in cross section the canal was triangular in shape.

At the apex of the sacrum, the caudal extremity was slightly indented at its center. It articulated with the first coccygeal vertebra.

Coccygeal Vertebrae (Figures 44-45)

The number of coccygeal vertebrae (Vertebrae coccygeae) varied from thirteen to fifteen segments in the specimens examined. Each vertebra of the series was characterized by being smaller and less complex than the vertebra preceding it.

The first two to four segments resembled a typical vertebra of other regions having a complete arch and spinous process. Thereafter, the arches were incomplete dorsally. The progressive decrease in width of the bodies was not accompanied by a decrease in length until the eighth or ninth vertebra. From the fifth vertebra caudally, the bodies were centrally pinched with the caudal extremity being smaller than the cranial one. Reduction in size continued with successive vertebrae and the most caudal of the series was a slender rod having only the cranial end slightly enlarged.

Hemal processes (Processus hemalis) consistantly extended from the cranioventral extremity of the third through the sixth segments and were found on the next adjacent vertebrae in several specimens. At no time did they form an arch.

The caudally placed transverse processes were distinct through the fifth or sixth segments and thereafter remained as part of the expanded caudal extremity.

On the coccygeal vertebrae with a complete arch, the paired craniodorsal projections resembled cranial articular processes. They had slight facets resembling articular surfaces and distinct mamillary processes however they did not articulate. No caudal articular processes were observed on this series. As the arches became incomplete, the facets disappeared and all that remained were two dorsal projections. These mamilloarticular processes were evident through the ninth or tenth segments. The vertebral foramena were generally circular.

Ribs (Figures 46-49)

All specimens had thirteen pairs of ribs (Costae) of which eight articulated with the sternum (Costae vera). The ribs varied in size and shape but none was modified greatly from the typical rib form. Each rib consisted of a proximal ossified portion (Os costale) and a distal cartilagenous portion (Cartilago costalis). The cranial ribs of the series were straighter and flatter than the caudal ribs which were arched and rounder in cross section.

The first ribs were the shortest of the series. Progressing caudally, the ribs increased in length to the eighth or ninth and where they became progressively shorter. The fifth rib was the widest of the series.

The acuity of the costal angle (Angulus costae) was greatest in the first rib and it decreased progressively thereafter. The proximal extremity of each rib was expanded and had several articular facets at the points of articulation with the vertebrae. Each rib had a distinct head (Caput costae) which presented an articular surface (Facies articularis capitis costae). This articular surface had two convex to flat facets which were divided by a narrow groove. At these facets, the rib articulated with the cranial and caudal costal fovea of the vertebrae.

The head of each rib was situated at the proximal end of the neck (Collum costae). The neck was of less diameter than the head and irregular in cross section. Caudally, the necks became progressively compressed dorsoventrally. The dorsal edge of the neck was pinched into a slight crest (Crista colli costae).

The tubercle (Tuberculum costae) was a dorsally situated eminence at the junction of the neck and body (Corpus costae). The tubercle of the first rib was largest and thereafter the tubercles became progressively smaller. A definite tubercle was not observed on the last two ribs. There it was represented by a slightly roughened area. Each tubercle had a concave articular facet (Facies articularis tuberculi costae) which articulared with the transverse process of the adjacent vertebrae.

The rib bodies were generally flattened from medial to lateral. The greatest width of each rib was in the distal one-third. The costal groove (Sulcus costae) was noticeable on the caudomedial borders of the third through the twelfth ribs in the proximal two-thirds of their bodies. A similar groove was present on the proximal craniolateral aspect of the fifth through the thirteenth ribs. It varied in length and extended distally one-third the length of the rib.

The ribs joined the costal cartilages at the costochondral angle and then proceeded distally to join the sternum or the next rib. The costal cartilages tapered slightly to this junction.

Sternum (Figure 50)

The sternum (Sternum) consisted of seven osseus segments or sternebrae (Sternebrae). Their arrangement on the floor of the thoracic cavity created a gentle S shape when viewed from the side. The cranial two sternebrae were noticeably compressed from side to side while the remaining five were progressively compressed from dorsal to ventral. Each segment was also compressed in its middle when viewed from the side or above. At the junction of adjacent sternebrae, were the costal grooves (Incisura costales) into which the distal ends of the costal cartilages terminated. The costal cartilages of the sternal ribs terminated in this fashion except the first and seventh. The costal cartilage of the first rib joined the cranial end of the first sternebra or manubrium (Manubrium sterni) at two dorsally located articular facets. The distal end of the seventh joined the sternum at a separate articular facet located near the caudolateral angle of the sixth sternebra.

Both ends of the manubrium were enlarged. The cranial enlargement bore the previously described facets and a blunt cranioventral projection. A slight line marked the dorsal midline of the bone. The second segment was also enlarged at both ends. The cranial enlargement was compressed from side to side and the caudal one from dorsal to ventral.

The third, fourth, fifth and sixth segments were similar and varied only in the dimension of their features. In cross section, they were trapezoid in shape and caudally each was successively wider than the preceding segment. They also became progressively thinner from dorsal to ventral caudally. The caudal expansion of each was wider than its cranial expansion and wider than the cranial expansion on the next caudal segment. The ventral surfaces were slightly concave and the dorsal surfaces marked by a slight midsaggital line. The caudal expansion of the sixth sternebra was the widest of the series and had a separate articular facet for the costal cartilage of the seventh rib.

The flat xiphoid process (Processus xiphoideus) was the longest of the sternebrae and was tongue like in appearance. It was centrally pinched from side to side.

The caudal expansion was smooth and slightly concave on its dorsal surface. From this expansion extended the plate like xiphoid cartilage (Cartilago xiphoidea). The xiphoid process lacked a distinct dorsal line but did have a mid-ventral line.

Appendicular Skeleton

Pectoral Limb

Scapula (Figures 51-52)

The scapula (Scapula) of the deer had two faces, three borders and three angles. Viewed laterally, the scapula appeared to be a tall inverted isosceles triangle, the apex of which pointed ventrally. The most prominent feature of the scapula was the spine (Spina scapulae).

The costal face (Facies costalis) was gently concave and smooth except for two rough areas (Facies serrata). The smaller caudodorsal portion of the serrated face was completely separated from the larger craniodorsal portion. Both areas were irregular in shape. Separating the large smooth subscapular fossa (Fossa subscapularis) from the thickened caudal border (Margo caudalis) was a large ridge. Immediately caudal to this subscapular ridge was a long shallow subscapular groove. A nutrient foramen was located in this groove near the caudal border at the junction of the proximal two-thirds and distal one-third.

The lateral face (Facies lateralis) was divided by the spine into cranial and caudal areas, each of which was triangular in shape. The cranial area or supraspinous fossa (Fossa supraspinata) occupied about one-fourth of the area of the lateral face. The supraspinous fossa was bounded cranially by the thin, rather straight cranial border (Margo cranialis). The fossa blended caudally with the convex surface of the spine.

The caudal area or infraspinous fossa (Fossa infraspinata) was large, smooth and slightly concave. It blended cranially with the concave surface of the spine and was bounded caudally by the caudal border. Both fossae were bounded dorsally by the rough dorsal border (Margo dorsalis). The scapular cartilage (Cartilago scapulae) extended proximally from the dorsal border.

The spine of the scapula extended from the dorsal border to the neck (Collum scapulae) and was curved caudally. Near the middle of the edge of the spine was the inconspicuous, roughened tuber spinae (Tuber spinae scapulae). The spine terminated ventrally as a roughened, beaklike acromion (Acromion) which was not very prominent. The stout neck had in addition to the cranial and caudal borders, a slight ridge which was nearly parallel to the caudal border and situated at the caudolateral surface of the neck.

The cranial angle (Angulus cranialis) was the least prominent of the three angles. The caudal angle (Angulus caudalis) was slightly thickened. The ventral angle (Angulus ventralis) was large and formed the glenoid cavity (Cavitas glenoidalis) and the scapular tuberosity (Tuberculum supraglenoidale). The glenoid cavity was a smooth concave depression, pitted at its craniomedial edge by a slight glenoid notch (Incisura glenoidalis). Extending from the cranial aspect of the ventral angle was the scapular tuberosity which with the medial projecting coracoid process (Processus coracoideus) created a hook.

Humerus (Figures 53-55)

The humerus (Humerus) was composed of a shaft and two extremities. When viewed from the either side, the humerus resembled a tall S.

The proximal extremity presented a large, caudally placed, dome shaped head (Caput humeri). The central area of the head was a gentle arc, and it was more rounded toward the edges. The head flattened as it joined a slightly depressed fossa, craniolaterally and the minor tubercle (Tuberculum minus), craniomedially. The articular surface of the head was smooth and directed caudolaterally.

Projecting from the craniolateral aspect of the proximal extremity was the stout, fingerlike major tubercle (Tuberculum majus). It extended dorsomedially to overhang the intertuberal groove (Sulcus intertubercularis). The greater tubercle was separated into a large cranial part (Pars cranialis) and a smaller caudal part (Pars caudalis). Cranial and ventral to these eminences was a cresent-shaped crest (Crista tuberculi majoris). Situated on the medial side of the proximal extremity was the smaller, lesser tubercle. It was separated from the greater tubercle by the intertuberal groove. Like the greater tubercle, the lesser tubercle had cranial and caudal parts and a slight crest (Crista tuberculi minoris).

From the expanded proximal extremity, the bone narrowed distal to the head and lesser tubercle creating a neck (Collum humeri). The body (Corpus humeri) was long with almost parallel sides. On the lateral surface (Facies lateralis) was a small tuberosity (Tuberositas teres minor) and a slight anconeal line (Linea m. tricipitas) which terminated distally at the deltoid tuberosity (Tuberositas deltoidea). The deltoid tuberosity was represented only by a small roughened area. From this eminence extending distally around the cranial surface (Facies cranialis) was a slight humeral crest (Crista humeri). The musculospiral groove (Sulcus m. brachialis) occupied the greater part of the lateral surface and was flat to concave proximally and convex distally. The medial surface (Facies medialis) was generally smooth except for a small, roughened teres tuberosity (Tuberositas teres major) which was located in the proximal one half of the shaft. From it, a slight ridge extended proximally to the crest of the minor tubercle.

The cranial surface (Facies cranialis) was marked only by the humeral crest which emerged from the lateral side.

After its appearance at the deltoid tuberosity, the crest extended distal and medial down the cranial surface of the bone. The caudal surface (Facies caudalis) was transversely rounded and was pitted by a nutrient foramen on the lateral side in the middle one-third of this surface.

The distal extremity was characterized by surfaces for the associated prominences and fossae of the radius and ulna.

The humeral condyle (Condylus humeri) was composed of a trochlea (Trochlea humeri), the olecranon fossa (Fossa olecrani), and the radial fossa (Fossa radii). The trochlea was a cranially placed transverse projection and its diameter was not constant. Its greatest diameter was on the medial side and a smooth ridge separated the small, lateral one third from its larger medial two thirds. Smooth parallel grooves flanked each side of this ridge. Immediately caudal to the trochlea and between the epicondyles was the deep cuplike olecranon fossa. The radial fossa was a wide roughened depression which was located in a transverse plane proximal to the trochlea on the cranial surface.

Extending proximally from the lateral and medial ends of the condyle were the lateral epicondyle (Epicondylus lateralis) and the larger medial epicondyle (Epicondylus medialis). Each was represented caudally by a prominent crest. The lateral crest (Crista epicondyli lateralis) was smaller than the medial crest which extended further distally than did the lateral one. Viewed caudally, these crests converged just proximal to the olecranon fossa.

Radius (Figures 56-58)

The major long bone of the antebrachium was the radius (Radius). It was a long bone expanded at each end, and in lateral profile, it appeared as a gentle arc with the convex surface directed cranially.

The proximal extremity or head (Caput radii) had a cupped, undulating, articular surface (Fovea capitis radii). The medial portion of this surface was somewhat rounded and much wider in dimension than the lateral portion. The undulations corresponded with the trochlea of the humerus with which it articulated. The lateral aspect of the caudal border of the articular surface was marked by a deep notch in which the medial coronoid process of the ulna projected. In the middle of the caudal edge of the head, was a pointed projection. In the articulated specimen this projection extended between the medial and lateral coronoid processes of the ulna (Processus coronoideus medialis et lateralis). The smooth caudal surface of the head was not continuous and varied from one, to three separate surfaces.

Distal to the head, the neck (Collum radii) narrowed to the nearly parallel medial and lateral borders (Margo medialis et lateralis). The greatest narrowing occurred on the lateral side beginning at a small eminence located just distal to the medial side of the articular surface.

A small, oval, roughened area, located on the craniomedial surface of the neck was the only evidence of a radial tuberosity (Tuberositas radii). On the caudal aspect of the neck was located an inverted triangular, roughened area where the radius articulated with the ulna. The shaft (Corpus radii) was compressed craniocaudally and had medial and lateral borders, and a cranial and a caudal surface (Facies cranialis et caudalis). The arc of the bone contributed to the cranial face being convex in both dimensions while the caudal face was correspondingly concave. Along the middle two-thirds of the lateral margin of the caudal surface was a groove in which the shaft of the ulna articulated. A nutrient foramen pierced the radius near the proximal end of this groove. At the distal end of the caudal face, marking its junction with the distal extremity, was an irregular transverse ridge (Crista transversa).

The expanded distal extremity or trochlea (Trochlea radii) was a group of irregularities. Corresponding with the carpal bones were three, smooth, oblique articular areas (Faces articularis carpea) of unequal size. The medial area was the larger while the lateral was the smaller.

Forming the medial edge of these articular faces was the most distal eminence of the bone called the medial styloid process (Processus styloideus medialis). The lateral side of this sharp projection was slightly roughened. The styloid process of the ulna (Processus styloideus) articulated with the caudolateral surface of the trochlea distal to the transverse line at a slightly flattened area.

On the cranial face of the distal extremity of the radius were two nearly parallel ridges which extended proximally along the long axis of the bone. They created a smooth muscular groove. Another shorter muscular groove was located on the lateral surface of the distal extremity.

Ulna (Figures 59-60)

The ulna (Ulna) was the longer bone of the antebrachium and it was completely separate throughout its length from the radius. The most distinctive feature of the ulna was that the greater part of its mass was concentrated in its proximal extremity. The ulna articulated with the humerus proximally nearly the entire length of the surface of the radius and the carpal bones distally. The radius did not articulate with the ulna at the proximal and distal interosseus spaces (Spatii interosseum antebrachii proximale et distale).

The large proximal extremity of the ulna or olecranon (Olecranon) was flattened from medial to lateral with the cranial and caudal margins being rather acutely rounded. The enlarged proximal projection (Tuber olecrani) of the olecranon was marked on each side with irregularities. Its greatest enlargement occurred in the proximal caudal region. The medial and lateral sides of the distal portion of the olecranon were smooth. Projection from the craniodistal portion of the olecranon was the beak shaped anconeal process (Processus anconeus). The distal surface of the anconeal process was smooth and contributed to the formation of the trochlear notch (Incisura trochlearis). This convex arc completed approximately one-third of a circle and was directed cranioventrally. The articular surface of the notch was convex from medial to lateral and articulated with the trochlea of the humerus.

The distomedial end of the trochlear notch terminated as the medial coronoid process which had a small cranially directed articular facet. The lateral coronoid process was separated from, and larger than the medial one. It had a small articular facet on each side.

The body or shaft (Corpus ulnae) of the ulna was slender, tapered and flattened from medial to lateral. The flattened portion of the shaft changed to a distinct triangular shape near the distal end.

The medial and lateral faces (Facei lateralis et medialis) were flat, and the caudal border (Margo caudalis) was concave and sharp. The cranial border was convex and sharp except for the roughened middle portion which marked the area of articulation of the shaft of the ulna with the radius. From the middle of the shaft distally, a longitudinal vascular groove marked the lateral face adjacent to the caudal surface of the radius.

The distal extremity or head (Caput ulnae) was enlarged as a three-sided structure. The cranial face was notched to accommodate the transverse crest of the radius. Immediately distal to this notch was the irregularly smooth area of articulation with the caudolateral surface of the radius. The head terminated distally as a pointed styloid process (Processus styloideus), the ventral surface of which was smooth (Facies articularis carpea) and articulated with the ulnar carpal bone.

Manus (Figure 71)

Carpus (Figures 61-64)

The carpus (Carpus) was the most proximal part of the manus (Skeleton manus) and was composed of six or seven bones arranged in two rows. The four bones constituting the proximal row were the radial carpal (Os carpi radiale), the intermediate carpal (Os carpi intermedium), the ulnar carpal (Os carpi ulnare) and the accessory carpal (Os carpi accessorium) bones. The distal row consisted of two or three bones. No evidence of the first carpal bone (Os carpale I) was found in several specimens. The large medial bone of the distal row was the fused second and third carpal bone (Ossa carpale II et III). The remaining bone of the distal row was the hamate. The hamate best represents the fused fourth and fifth carpal units.

The carpal bones articulated with the radius and ulna proximally and with the large metacarpal bone distally.

The radial carpal bone was the most medial bone of the proximal row. It was compressed from medial to lateral and six sides were identified. The dorsal, medial and palmar surfaces were rough and did not articulate with any other bones. The smooth proximal surface articulated with the radius and bore a concave plantar depression. A pointed projection marked the plantar aspect of this surface. The distal surface articulated with the fused second and third carpal bones and was also smooth. It bore a depression similar to that found on the proximal surface. Separate proximal and distal transverse articular ridges were found on the lateral surface which articulated with the intermediate carpal bone. A rough depressed groove separated these articular areas.

The intermediate carpal bone was located between the radial and ulnar carpal bones of the proximal row. It articulated proximally with the radius and distally with the proximoaxial surfaces of the two large bones of the distal row. The intermediate carpal had six sides. The proximal surface was smooth and undulating and the distal surface had a slight ridge which marked its partial extension between the two large bones of the distal row. The dorsal and palmar surfaces were rough and irregular. The medial surface had two elongated articular facets which corresponded to those found on the lateral surface of the radial carpal bone. The lateral surface was also marked by two articular facets, one of which was located at the proximo-dorsal corner and was flat. The other facet bordered the distal edge and was S shaped.

The ulnar carpal bone was the most irregular bone of the carpus. It was situated on the lateral side of the proximal row and articulated proximally with the radius and ulna, caudally with the accessory carpal, and distally with the hamate. The proximal surface of the ulnar carpal was grooved and curved gently toward the palmar lateral side creating a convex surface. A distal concave articular surface existed at the junction with the hamate. A stout eminence projected from the palmar distal region, and on its palmar surface was an oval facet which articulated with the accessory carpal bone. The medial surface was rough except for a flat, proximally located articular facet. The arrangement of the articular facets at the intercarpal joints (Articulationes intercarpeae) between these three bones of the proximal row created oval fissures on each side of the intermediate carpal bone (Figure 61).

The accessory carpal bone articulated with the caudal portion ulnar carpal. It was an irregularly shaped bone and enlarged at the palmar extremity. Its single articular facet was convex and located at the dorsal surface. The remainder of the surface of the bone was rough and irregular. In the articulated carpus, the accessory carpal bone projected in a palmar-medial direction.

When present, the small pea-shaped first carpal bone was located at the distolateral corner of the palmar surface of the fused second and third carpals. A smooth articular surface was present on the first carpal at this junction. On one carpus, the first carpal appeared to be partially fused to the second and third.

The large medial bone of the distal row was the fused second and third carpal bones. It was compressed from proximal to distal and had six sides. The dorsal surface was slightly roughened and convex while the medial surface was rough and irregular. The proximal surface was smooth and concave before and convex behind. The entire length of the proximal surface was marked by a laterally located ridge. The smooth proximal surface was continuous with the medial side of the palmar surface. The articular facets of the lateral surface were interrupted by a depressed roughened area. The distal surface was smooth and rather flat except for a depressed roughened area which extended medially from the lateral edge. From the mediopalmar corner of the distal surface, projected a slight hook. The fused second and third carpal bone articulated proximally with the radial and intermediate carpal bones, laterally with the hamate bone and distally with the large metacarpal bone. The first carpal bone articulated with the palmar surface.

The lateral bone of the distal row was the hamate. It articulated proximally with the intermediate and ulnar carpal bones, distally with the large metacarpal bone, and medially with the fused second and third carpal bones. The hamate bone was an irregular, wedge shaped bone whose surface was marked by articular facets and roughened areas. The distal surface was rather flat and smooth and the dorsolateral surface was convex and rough. The articular facets of the medial surface corresponded with those of the hamate bone. The proximal surface was smooth and continuous with the palmar surface in an undulating fashion.

Metacarpus (Figures 65, 66, 67, 71, 73)

The metacarpus (Metacarpus) was composed of three individual bones. The large metacarpal or cannon bone (Os metacarpale III et IV) was formed by the fusion of the third and fourth metacarpal bones. This fusion was complete along their lengths except at the distal end. The other two bones of the region were the small distal ends of metacarpals two and five (Os metacarpale II et V) which flanked the palmar abaxial surfaces of the distal end of the large metacarpal bone.

The slightly expanded proximal end or base (Basis) of the large metacarpal bone articulated with the distal row of carpal bones. This articular surface (Facies articularis) was divided into two smooth areas. The medial area was the larger of the two and was separated from the lateral one in the palmar region by a rough depression. Extending distally into the bone from the depression was a vascular canal (Canalis metacarpi proximalis) which terminated on the palmar surface (Facies palmaris) of the shaft less than one centimeter from the articular surface. A rough tubercle projected from the medial aspect of the dorsal surface of the base.

Features of the shaft or body (Corpus) included the dorsal (Facies dorsalis) and palmar surfaces, and the medial and lateral borders (Margo medialis et lateralis). The dorsal surface was very straight and was marked by a faint dorsal longitudinal groove (Sulcus longitudinalis dorsalis) which extended the entire length of the shaft. The dorsal surface was convex from medial to lateral. At its distal extremity, the shaft had a vascular opening (Canalis metacarpi distalis) which continued into the depth of the bone and emerged at the distal end of the palmar surface.

The medial and lateral borders were rather straight with a slight abaxial deviation at each end. The palmar surface was concave from medial to lateral in the proximal three-fourths and rather straight distally.

The distal extremity (Caput) of the large metacarpal bone was enlarged and had two nearly identical articular trochlea. Each trochlea resembled a half cylinder, and they were oriented end to end in a transverse plane. A ridge divided each articular surface into axial and abaxial portions with the axial portion having a greater diameter. The two trochlea were separated on the midline by a deep fissure (Incisura intertrochlearis). A shallow fossa was located at the abaxial end of each trochlea. Above these fossae were small rough eminences.

The two small metacarpal bones of each limb were situated at the palmar abaxial sides of the distal one-third of the large metacarpal bone. They were flat and bladelike. The distal extremities of these bones were enlarged and terminated distally as a semicircle which articulated with the proximal phalanx (Phalanx proximalis) of the second and fifth digits. This articulation occurred at the level of the proximal extent of the intertrochlear fissure of the large metacarpal bone. The small metacarpal bones tapered proximally and terminated in a point.

Digits (Figures 68-74)

The digital portion of the manus consisted of two major digits (Ossa digitorum manus) flanked by two minor digits. Each digit was composed of three phalanges, but only the major digits had sesamoid bones. The third and fourth were the major weight bearing digits and they were symmetrical. The minor second and fifth digits were also symmetrical.

The proximal phalanx (Phalanx proximalis) of a major digit was the largest bone of the digit. From its expanded proximal base (Basis phalangis proximalis) the body (Corpus phalangis proximalis) tapered to a slightly expanded trochlea (Trochlea phalangis proximalis).

The proximal surface (Fovea articularis) of the proximal phalanx was smooth and articulated with a trochlea of the large metacarpal bone. The phalangeal articular surface was concave with a midsaggital groove. The axial side of the fovea articularis was deeper than the abaxial side. At the palmar aspect of each side of the articular surface were small articular facets which articulated with the smooth distal surfaces of the proximal sesamoid bones (Ossa sesamoidea phalangis proximalis). Distal to these facets, the proximal palmar surface was a roughened area which extended around to the axial and abaxial surfaces.

The distally located trochlea had a smooth convex articular surface which was midsagitally grooved. The smooth areas on either side of the groove were nearly equal in size. Each end of the trochlea was depressed with the axial depression being somewhat deeper. The trochlea articulated with the proximal end of the middle phalanx (Phalanx media).

The middle phalanx had an expanded base (Basis phalangis mediae) at its proximal end, and a lesser expansion (Trochlea phalangis mediae) at its distal end. The body (Corpus phalangis mediae) was compressed from medial to lateral and connected the two expansions. The middle phalanx was about two-thirds the length of the proximal phalanx.

The proximal articular surface (Fovea articularis) of the base was concave except for a slight midsaggital ridge. Palmar to this surface was a rough area, from which protruded a small axial eminence and a larger abaxial one. Between these, was a slight distally extending groove. Protruding from the proximal dorsal portion of the base was a small rough entensor process (Processus extensorius).

The body of the middle phalanx tapered distally and was triangular in cross section. The apex of the triangle projected dorsally.

The articular surface of the trochlea was marked by an oblique groove. The area abaxial to this groove was larger than the axial area. A cuplike depression was found at the axial end of the trochlea. This bone articulated with the proximal and distal phalanges (Phalanx distalis) and the distal sesamoid bone (Os sesamoideum distale).

The distal phalanx resembled a pyramid having three sides and a base. The nearly straight dorsal margin (Margo dorsalis) and axial solar borders converged at the apex (Apex) with the slightly curved solar border (Margo solearis). The slightly convex abaxial or parietal surface (Facies parietalis) was triangular. Several small foramina were observed in the region of its palmar angle. A single foramen was located near the apex. A slight groove extended between these two areas. The surface of the sole (Facies solearis) was also triangular and was rather flat and smooth except for the flexor tubercle (Tuberculum flexorium) at the palmar edge. The axial surface (Facies axilaris) bore two prominent foramina which connected to create a canal within the bone. One opening was close to the extensor process (Processus extensorius) while the other was closer to the apex. The later opening was continued toward the apex as a groove.

Smallest of the surfaces of the third phalanx, was the smooth articular surface (Facies articularis) which was concave except for a slight ridge which crossed it obliquely. A small extensor process extended from the dorsal edge of this surface. At the distal edge of the articular surface was a small elongated facet (Facies articularis sesamoidea) where the distal phalanx articulated with the distal sesamoid bone (Os sesamoideum distale).

The phalanges of the second and fifth digits were reduced in size compared to the weight bearing digits. The proximal phalanx was the longer of the three and it articulated with the minor metacarpal bone. It was compressed from side to side and expanded at each end. The narrow articular surfaces of the extremities were slanted obliquely and the proximal surface was concave and the distal surface convex.

The middle phalanx was about one half the length of the proximal phalanx. It too was expanded at each end and compressed from medial to lateral. A slightly concave articular surface marked the proximal extremity and at its palmar surface was a small eminence. The convex distal articular surface was larger than the proximal surface.

The distal phalanx was similar in shape to that of the major digits but much reduced in size. Its parietal face was slightly convex while the axial face was convex. Each side had two foramina which were not consistant in their placement.

Sesamoid bones
(Figures 71, 72, 75, 76)

Each major digit had two proximal sesamoid bones (Ossa sesamoidea proximalia) which articulated primarily with the condyle of the large metacarpal bone associated with that digit. The medial pair were almost identical to the lateral pair. The bones of each pair were about equal in size but varied somewhat in shape. The articular surfaces (Facies articularis) were smooth and concave from proximal to distal. This smooth surface continued slightly inward on the flexor surface (Facies flexoria). The palmar aspect of the flexor surface of each bone was flattened and diverged away from the axis of each digit. On the articulated specimens, the two bones created a groove for the flexor tendons.

The surfaces (Facies m. interossei) facing the muscle interosseus were slightly convex. A small articular facet at the distal margin of the base of each bone marked its articulation with the proximal phalanx.

An eminence projected distally from the palmar margin of the base of each abaxial sesamoid bone creating a slight hook.

The distal sesamoid bone (Os sesamoideum distale) was a very small slightly elongated bone which tapered at each end. The articular surface (Facies articularis) was smooth and corresponded with the trochlea of the middle phalanx with which it articulated. The flexor surface was convex in all dimensions.

Pelvic Limb

Os coxae (Figures 77-80)

The ossa coxarum was created by the two os coxae (Os coxae) which were joined at the midline. This union occurred along the ventral portions of the respective os coxae. The long axis of the two os coxae were nearly parallel to each other and to the long axis of the body. Each os coxae was an elongated bone expanded at each end. The component bones of each os coxae, the ilium (Os ilium), the ischium (Os ischii), the pubis (Os pubis) and the acetabular bone (Os acetabulum) were fused into a single structure. On four specimens, a separate interischial bone was found. This was a Y shaped bone located at the ischiadic symphysis (Symphysis ischiadica).

The ilium was the most cranial bone of the os coxae. It was enlarged at each end with the greatest expansion at the cranial end. This cranial expansion or wing (Ala ossis ilii) was flattened creating a lateral gluteal surface (Facies glutea) and a medial sacropelvic surface (Facies sacropelvinae). The gluteal line (Linea glutea), which was a stout ridge, divided the gluteal surface into dorsal and ventral portions. The thickness of the wing was greater ventral to the gluteal line. This portion of the wing terminated cranially at the thickened tuber coxae (Tuber coxae) which extended from the cranial most extent of the gluteal line ventrolaterally to the acute cranial ventral iliac spine (Spina iliaca ventralis cranialis). At this point the tuber coxae met the ventral border of the wing.

Dorsal to the gluteal line, the wing was thinner and resembled a trapezoid with the gluteal line forming the base. The cranial border of this area was a thin concave arc which extended dorsomedially to the somewhat thickened cranial dorsal iliac spine (Spina iliaca dorsalis cranialis).

The thin, irregularly convex tuber sacrale (Tuber sacrale) was terminated at the caudal dorsal iliac spine (Spina iliaca dorsalis caudalis) as it joined the greater sciatic notch (Incisura ischiadica major). The iliac crest (Crista iliaca) was composed of the tuber sacrale, the tuber coxae and the intervening border.

The sacropelvic surface of the wing was slightly convex and varied from smooth to rough. At its caudoventral region a small cresent shaped rough area, the auricular surface (Facies auricularis) was identified and it corresponded to the shape of the auricular surface of the wing of the sacrum. This area was rougher than the remainder of the sacropelvic surface (Facies iliaca) and was easily identified. Caudoventral to the wing, the ilium narrowed to a stout shaft or body (Corpus ossis ilii). This portion was somewhat compressed from medial to lateral and expanded in all directions caudally. The central compression created distinct medial and lateral faces. The gently concave greater sciatic notch formed the dorsal border of the shaft of the ilium, and became sharper as it continued caudally as the ischiatic spine (Spina ischiadica). The ventral border of the ilium was rather straight and not as sharp as the greater sciatic notch. At the caudal end of this border was the deep elongated fossa. The iliopectineal line (Linea arcuata) varied in appearance from a distinct line to a slightly roughened area which crossed the medial face of the body from dorsal to ventral. Cranial to this line, the shaft was convex, and caudal to it, the shaft was slightly concave. The lateral face of the ilium and ischium bore the caudal continuation of the gluteal line and several ridges which appeared to radiate from the acetabulum (Acetabulum). The ilium articulated caudally with the ischium and ventromedially with the pubis. The ilium formed the caudolateral one-third of the lunate surface (Facies lunata) of the acetabulum. On one specimen the articulation of the ilium with the ischium was grossly visible.

A distinct acetabular bone was not recognized.

Like the ilium, the ischium was also an elongated bone expanded at each end. The cranial expansion articulated with the ilium and contributed to the formation of the acetabulum. The major part of the caudal expansion was the prismatic tuber ischii (Tuber ischiadicum). The body (Corpus ossis ischii) was oriented in a cranial caudal direction. It was compressed from medial to lateral with the dorsal border being thin, and the ventral border somewhat thicker. The lateral face was slightly concave and marked by the ridgelike radiations from the acetabulum. The medial or pelvic face was smooth and concave except for the region adjacent to the obturator foramen (Foramen obturatorum). From the caudoventral aspect of the body, projecting toward the midline, was a winglike ramus (Ramus ossis ischii). This ramus extended to the midline where it met the ramus of the opposite member at a roughened face (Facies symphysialis). The ramus was smooth on each side, and from its craniomedial extent, projected a tongue like eminence. The ischium formed the lateral, caudal and part of the medial borders of the obturator foramen. The ischiatic table (Tabula ossis ischii) was gently concave and smooth. The dorsal border of the ischium was concave in its middle but became convex proceding toward the extremities. The cranial convexity contributed to the formation of the ischiatic spine. The central concavity or lesser sciatic notch (Incisura ischiadica minor) extended caudally to the dorsal angle of the tuber ischii.

The tuber ischii was large and consisted of three individual projections. The dorsal projection was the most acute, the lateral projection most isolated, and the medial projection the most blunt. From the medial projection the ischiadic arch (Arcus ischiadicus) extended cranioventral to the midline. The ventral surface of the ischium was marked by a roughened arclike crest which was located at the junction of the body and the wing. The caudoventral portion of the acetabular articular surface of the ischium was partially undermined by a deep groove.

The pubis was craniomedially situated and was composed of a thick, central portion or body (Corpus ossis pubis), a flattened caudally projecting branch (Ramus caudalis ossis pubis), and a thicker laterally projecting branch (Ramus cranialis ossis pubis). The pubis was dorsoventrally compressed and thickest at the midline where it articulated with the opposite pubis bone. The caudal ramus was fused with the wing of the ischium. At the midline was a roughened articular face (Facies symphysialis) where it joined the member of the opposite side. The cranial ramus was stouter and projected craniolateral from the body. It terminated by fusing with the ilium and ischium and by contributing approximately one-third to the circumference of the acetabulum. The cranial border of the cranial ramus or pectin (Pectin ossis pubis) was a gentle, concave arc which extended laterally to the irregular, rough iliopectineal eminence (Eminentia iliopubica). A notable difference was observed in the size of the cranial ramus when comparing the os coxae of the male and female. In the female the cranial ramus was not as massive, and the pectin was represented as a sharp border. The cranial edge of the more massive cranial ramus of the male was flattened with recognizable dorsal and ventral borders. The ventral edge of the symphysial face was concave in the female. The pubis became the craniomedial portion of the obturator foramen. The foramen was regularly oval with its long axis directed from craniolateral to caudomedial. At the craniolateral end of the obturator foramen was an indentation which varied in depth among the specimens examined. This variation ranged from an indentation of approximately one-half circle to complete separation in some specimens. This indentation extended craniodorsally as the obturator groove (Sulcus obturatorius) on the medial side of the ischium.

The acetabulum was situated at the midpoint of the length of the os coxae. It was a deep, cup-shaped, articular formation. At the bottom of this cup was the acetabular fossa (Fossa acetabuli) which was a rough, irregular excavation. This excavation extended caudally and completely undermined a portion of the lunate face of the acetabulum. It was continuous with the acetabular notch (Incisura acetabuli). The lunate surface varied in width and the greatest widths were near the craniodorsal and caudodorsal portions. The rim of the acetabulum was irregularly marked by two slight indentations. One was located at the dorsal region and the other in the craniomedial region of the rim. A slight roughened eminence was noted directly above the dorsal notch.

When the two os coxae were united at the symphyses, the acute angle of the ischiadic arch became evident. The Y shaped interischial bone was situated at the apex of the acute angle. The bone extended cranially along the ventral surface of the ischiadic symphysis and symphyseal crest (Crista symphysialis). The interischial bone continued foreward to the level of the middle of the obturator foramen. In some specimens, the interischial bone was completely fused to the ischii.

Femur (Figures 81-83)

The femur (Os femoris) was a long bone expanded at each end. The distal expansion was the larger and more complex of the two. The shaft was generally cylindrical and formed a slight arc, the convex surface of which was directed cranially. The femur articulated proximally with the acetabulum of the os coxae and distally with the tibia and patella. The expanded proximal extremity was composed of the head (Caput ossis femoris), trochanters, and their associated ridges and depressions. The head resembled a hemisphere, and its surface was smooth. It projected craniomedially from the proximal extremity. The medial aspect of the articular surface was marked by an irregular shaped fovea (Fovea capitis). The smooth dorsal surface of the head extended laterally toward the greater trochanter (Trochanter major) complementing the hemispherical shape. The head was suspended on the neck, (Collum ossis femoris) the diameter of which was less than the head. The greater trochanter was a large eminence on the proximal extent of the lateral aspect of the femur. The greater trochanter curved dorsally and its dorsal edge was marked by a slight notch (Incisura trochanterica). The lateral surface of the greater trochanter was irregularly convex and slightly roughened. The deep trochanteric fossa (Fossa trochanterica) was situated between the greater trochanter, and the neck and was most visable from a caudal view (Figure 82). At its deepest extent, the trochanteric fossa was rough, irregular and pitted by several nutrient foramina. Extending disto-medially in a slight concave arc from the proximocaudal aspect of the greater trochanter was the intertrochanteric crest (Crista intertrochanterica). This crest extended ventral to the level of the trochanteric fossa, and terminated at the blunt trochanter minor (Trochanter minor). The trochanter minor was located on the caudal surface of the humerus and was pyramidal in shape. Its surface was rough and slightly rounded. A slight ridge extended proximomedially from the trochanter minor toward the head. The intertrochanteric line (Linea intertrochanterica) was a slightly roughened line which originated on the cranial surface of the neck and extended distally to the medial surface ventral to the trochanter minor. It terminated at the rough face (Faces aspera) on the caudal surface of the body (Corpus ossis femoris). The cylindrical body had its smallest diameter near the middle. A large nutrient foramen entered the dorsal surface in the proximal one-third. The surface of the body was generally smooth except for the facies aspera. This face was located along the lateral edge of the caudal surface and extended from the junction of the proximal one-third and middle one-third. It continued distally to the lateral supracondylar tuberosity (Tuberositas supracondylaris lateralis). The facies aspera was bounded on the lateral side by the lateral lip (Labium laterale) and on its medial side by the medial lip (Labium mediale). This roughened area occupied approximately the lateral one-third of the caudal surface of the shaft. The supracondylar tuberosities (Tuberositas supracondylaris lateralis et medialis) were located at the level of the junction of the proximal three-fourths and the distal one-fourth of the bone. The lateral supracondylar tuberosity was larger, rougher and more proximally located than the medial one. These tuberosities were separated by a smooth ridge which extended distally from the caudal surface of the shaft. Immediately distal to the lateral supracondylar tuberosity was the concave supracondylar fossa (Fossa supracondylaris). The popliteal surface (Facies poplitea), was an area on the caudal surface just proximal to the condyles, and its surface was pitted by a nutrient foramen. Distal to this foramen was the S shaped intercondylar line (Linea intercondylaris) which extended from the proximal end of the lateral condyle (Condylus lateralis) toward the lateral surface of the medial condyle (Condylus medialis). Distal to the intercondylar line was the intercondylar fossa (Fossa intercondylaris) which was a somewhat oblique excavation situated between the medial and lateral condyles. This fossa extended cranially to meet the groove of the trochlea

(Trochlea ossis femoris). The intercondylar line separated the popliteal surface from the intercondylar fossa.

The femoral condyles were two knoblike eminences located at the caudodistal region of the femur. The condyles were oriented in a slightly oblique fashion extending from proximolateral to distomedial. The lateral condyle was the larger of the two, and its surface was interrupted by two irregular depressions. The caudal depression (Fossa m. poplitei) was irregularly oval and located on the lateral side of the condyle. The cranial depression or extensor fossa (Fossa extensoria) was irregularly shaped and located at the junction of the lateral condyle and the lateral lip of the trochlea. The extensor fossa was slightly roughened and blended caudally with the smooth articular surface of the condyle. The articular portion of the medial condyle was more isolated than that of the lateral condyle. The medial epicondyle (Epicondylus medialis) was located on the medial side of the medial condyle. The lateral epicondyle (Epicondylus lateralis) was larger than the medial and was located on the lateral side of the lateral condyle above its articular surface. The trochlea was a pully like structure, which when viewed laterally, completed about one-third of a circle. The articular surface was smooth and concave from medial to lateral. The medial trochlear ridge was longer and wider than the lateral ridge. The lateral trochlear ridge was sharp along its edge.

Patella (Figures 84-85)

The patella (Patella) was the only sesamoid bone of the stifle joint. It was located in the distal tendon of the quadriceps femoris muscle (M. quadriceps femoris) and articulated with the femur at the trochlea. The patella was a short irregularly shaped bone which resembled an inverted pyramid. The flattened proximal surface or base (Basis patellae) resembled a long oval and was slightly convex from side to side. Several nutrient foramina pitted the slightly roughened surface of the base. The distal end of the patella tapered in all dimensions to the apex (Apex patellae). The apex was wider from medial to lateral than from cranial to caudal.

The caudal articular surface (Facies articularis) was an irregular rectangle with its long axis oriented from proximal to distal. This surface was convex from medial to lateral and slightly concave from proximal to distal. The smooth articular surface covered the entire caudal surface of the bone except for a small area near the apex and a medially projecting eminence near the base.

The cranial surface (Facies cranialis) was undulating, and its central portion was elevated into a large eminence which was situated slightly to the medial side. Close to the base, a smooth slightly convex area was observed at both the medial and lateral side. One or more nutrient foramina pitted the cranial surface at random positions.

Tibia (Figures 86-89)

The tibia (Tibia) was the major long bone of the crus and was the only weight supporting bone of the region. It articulated proximally with the femur and distally with the tibial tarsal bone (Talus) and the distal extremity of the fibula (Fibula). The tibia was enlarged at each end with the proximal enlargement being the greater. In lateral profile (Figure 86) the tibia was slightly curved with the convex surface of the curve being directed caudally. The proximal surface of the tibia was somewhat triangular with two large articular areas located at each of the caudal angles of the triangle. These two areas constituted the proximal articular face (Facies articularis proximalis) and the lateral articular area was the larger of the two. The areas were irregularly shaped, convex from cranial to caudal, and concave from medial to lateral. The articular area of the medial condyle (Condylus medialis) was somewhat flatter than the lateral and both articular areas were inclined caudally. The axial margins of each articular area were elevated to form the medial and lateral intercondylar tubercles (Tuberculum intercondylare medial et laterale). These tubercles collectively were the intercondylar eminence (Eminentia intercondylaris) and it was the most proximal extent of the tibia.

Between the medial and lateral articular surfaces was a rough region which could be divided into three areas. The central intercondylar area (Area intercondylaris centralis) was located directly between the intercondylar tubercles. Cranial to this central area, was the slightly depressed cranial intercondylar area (Area intercondylaris cranialis), and caudal to the central area was the caudal intercondylar area (Area intercondylaris caudalis). It too was concave and extended slightly toward the medial side of the bone.

Both articular areas were positioned on a large boney eminence or condyle. The lateral condyle (Condylus lateralis) was the larger and more distinct of the two. From its caudolateral aspect, projected a rough eminence from which the proximal extremity of the fibula extended. The free margins of both condyles tapered toward the body. These tapering sides were roughened proximally and became smooth as they blended with the body.

The popliteal notch (Incisura politea) was located between the two condyles on the caudal surface, and from its depth projected a distal hanging, smooth surfaced eminence.

The smooth surfaced extensor groove (Sulcus extensorius) interrupted the triangular shape of the proximal surface on the lateral side. The remainder of the proximal surface was rough, irregular, and pierced by one large nutrient foramen. In some specimens, several foramina were present in this area.

The body of the tibia (Corpus tibiae) tapered from the proximal extremity and was somewhat triangular in the proximal one-half. It was oval to quadrilateral in the distal one-half.

The proximal half of the body presented three faces and three margins. The cranial margin (Margo cranialis) or tibial crest extended distally from the rather smooth tibial tuberosity (Tuberositas tibiae). The proximal one-half of this margin was rough and straight, while the distal one-half was smooth and slightly concave. The tibial tuberosity was situated at the junction of the cranial margin and the proximal surface. It was irregularly oval, smooth surfaced, and convex from medial to lateral. A slight transverse groove divided its proximal one-third from its distal two-thirds. The medial margin (Margo medealis) extended distally from the medial condyle and was not as acutely rounded as the other two margins. The lateral margin (Margo lateralis) extended distally from the lateral condyle. It was rather sharp proximally, and was pierced by a large nutrient foramen at the level of the junction of the proximal one-third and the distal two-thirds of the bone.

The medial face (Facies medialis) was gently convex and irregularly roughened. The lateral face (Facies lateralis) was deeply concave. The caudal face (Facies caudalis) was slightly concave and marked by the popliteal line (Linea m. poplitea) which was a slight ridge extending from the popliteal notch distally along the proximal one-third of the bone.

The craniolateral and caudomedial margins of the distal one-half of the shaft were more acute than the other margins. The craniolateral margin terminated distally as a slightly roughened eminence. The other two margins were gently rounded.

The caudomedial aspect of the shaft was marked by a shallow groove. The distal end of the body expanded evenly to the distal extremity.

The major articular surface of the distal extremity or cochlea (Cochlea) consisted of two parallel grooves which were separated by a broad ridge. The grooves were concave from cranial to caudal and were obliquely oriented. The medial groove was longer and narrower and was at its cranial end bounded by the medial malleolus (Malleolus medialis). The sharp pointed medial malleolus was the most distal extent of the tibia. The cranial edge of the cochlea extended further distally than did the caudal edge. At the lateral edge of the lateral groove of the cochlea, two small articular facets were present at the articulation of the tibia and the lateral malleolus (Malleolus lateralis) of the fibula. The more caudal of these articular facets was larger and oval shaped. Its caudal region was concave and its cranial region convex. The cranial region extended into the fibular notch (Incisura fibularis). The fibular notch separated the two facets and from it a groove extended proximally to the surface of the shaft.

Several nutrient foramina randomly entered the cranial surface of the distal extremity. On the caudal face of the distal extremity, was a wide dorsoventral groove.

Fibula (Figure 90)

The fibula (Fibula) was the lateral bone of the crus and consisted of two or three separate components. The proximal extremity or head (Caput fibulae) was fused to the tibia at the caudolateral aspect of the lateral condyle. It was a distally hanging spike which resembled an arrow head and was only a few millimeters long. A fibular body (Corpus fibulae) was present in several of the specimens. In other specimens, no evidence of an ossified body was found. When present, the body resembled a flat toothpick and was situated at the lateral margin of the tibia in a tendinous band. The band extended from the fibular head to the lateral malleolus. The body was variable in length and somewhat larger at the proximal end. It tapered to a point at its distal end. In one specimen, the distal end of the shaft of the fibula was fused to the shaft of the tibia.

The lateral malleolus was a separate bone located on the lateral side of the distal extremity of the tibia. It articulated with the tibia, the tibial tarsal bone, and the fibular tarsal bone. The lateral malleolus was an irregularly shaped bone having three separate articular areas (Facies articulares malleoli). The cranial, lateral, and caudal surfaces were rough and irregular. The malleolar groove (Sulcus malleolaris) was a very slight depression on the lateral face. The proximal articular face articulated with the tibia and had at its middle a short spike which extended proximally into the fibular notch of the tibia. The medial articular face articulated with the tibial tarsal bone. This face was smooth and undulating and had a broad ridge caudally and a slight groove cranially. The distal articular face articulated with the fibular tarsal bone and was also undulating on its surface. It was convex before and concave behind.

Pes (Figures 72, 74, 76, 91-97)

Tarsus (Figures 91-94)

The tarsus (Tarsus) was a complex of irregularly shaped bones which formed the proximal unit of the pes (Skeleton pedis). The middle unit of the pes was the large metatarsal bone, and the distal unit was the digital complex. The tarsal complex articulated proximally with the tibia and fibula and distally with the large metatarsal bone (Os metatarsale III et IV). The tarsus consisted of five individual bones some of which represented the combination or fusion of two more primative tarsal components. The bones of the proximal row were the fibular tarsal bone (Calcaneus) which was the largest bone of the tarsal complex and the tibial tarsal bone (Talus) which was the next smaller bone. The middle row consisted of a single bone (Os centroquartale) which represented the fusion of the central and fourth tarsal bones. The portion of this bone which was formed by the fourth tarsal bone extended into and represented nearly one-half of the distal row. The central and fourth tarsals articulated with the bones of the proximal and distal rows and the large metatarsal bone. The other bones of the distal row were the medially placed first tarsal (Os tarsale I) and a larger bone which represented the fusion of the second and third tarsal bones (Os tarsale II et III).

The surface of the tibial tarsal was complex and articulated proximally with the tibia and fibula, distally with the central and fourth, and with the fibular tarsal on its plantar surface. The bone resembled two cylinders united side by side. The proximal cylinder or body (Corpus tali) had a smooth surfaced articular trochlea (Trochlea tali proximalis). This trochlea, when viewed from either side resembled a semicircle. It had a large, lateral trochlear ridge, a somewhat smaller and more acute medial trochlear ridge. A gentle groove separated the two. A crescent shaped smooth articular surface which articulated with the medial malleolus was observed on the medial side of the medial trochlear ridge. A smooth crescent shaped lip which articulated with the lateral malleolus was present on the lateral side of the lateral ridge. Toward the center of this semicircle, this smooth articular surface became a depressed groove which also articulated with the lateral malleolus. Near the center of the semicircle was a small sharp point.

The trochlear groove was roughened on its dorsal side. This roughened area extended distally into a depression on the dorsal surface of the neck (Collum tali). The neck was concave on the dorsal and lateral surfaces, and convex on its plantar and medial surfaces. The plantar surface was a smooth articular area (Facies articulares calcanei) which was convex from proximal to distal and concave from medial to lateral. It articulated with the fibular tarsal bone. The lateral edge of this surface was gently rounded while the medial edge was sharp. Distal to the lateral edge was a groove (Sulcus tali) which extended distomedially across part of the plantar surface of the bone and terminated on one or more nutrient foramina.

The head (Caput tali) was formed by the distal enlargement or cylinder of the bone. The articular surface of the head was formed into a trochlea (Trochlea tali distalis) which had two ridges of approximately equal size. These were separated by a slight groove.

In addition to the previously mentioned articular areas, the lateral surface of the bone had two crescent shaped articular facets. One was located at the plantar edge of the neck and the other was at the distal edge. Both articulated with the fibular tarsal bone.

The fibular tarsal bone was an elongated bone which was slightly expanded at its proximal end and greatly enlarged at its distal end. The distal expansion articulated with the tibial tarsal bone, the lateral malleolus and the combined central and fourth tarsal bones. The expanded proximal end or tuber calcis (Tuber calcanei) was irregular in shape and its proximal plantar aspect was marked by a smooth groove. The shaft was slightly compressed from side to side and rough on its plantar aspect. The sustentaculum tali (Sustentaculum tali) was an irregularly shaped eminence which projected from the medial side perpendicular to the long axis of the bone. The plantar aspect of the sustentaculum was slightly grooved (Sulcus tendinis m. flex. digiti I (Hallicus) longi) and convex from proximal to distal. Distal to the sustentaculum was a large lateral projection. An irregularly shaped coracoid process (Processus coracoideus) projected dorsally from this eminence. The free dorsal border of the coracoid process (Facies articularis malleolaris) was smooth, concavoconvex and articulated with the lateral malleolus. Distal to the coracoid process and on its medeal side, was a wide, shallow, roughened calcaneal groove (Sulcus calcanei). This groove, together with the roughened excavation on the lateral surface of the tibial tarsal bone created the tarsal sinus (Sinus tarsi).

The fibular tarsal bone articulated with the tibial tarsal bone at three separate articular faces (Facies articulares talares). The largest was located at the dorsal surface of the sustentaculum tali and was concave from proximal to distal and convex from medial to lateral. The intermediate articular face was located distal to the calcaneal groove on the medial side of the distal end of the bone. It was oblong and flat except for a plantar concavity which articulated with the plantar surface of the tibial tarsal bone. The smallest articular surface was irregular in shape and located on the medial surface of the coracoid process. The remaining articular surface of the bone was an elongated, concave, twisting, surface located at the palmar distal region of the bone. It articulated with the fused central and fourth tarsal components.

The fused central and fourth tarsal was an irregularly shaped bone with two proximal articular facets and four distal facets. The medial was the larger of the proximal facets and was the site of articulation with the tibial tarsal bone. This facet consisted of two parallel smooth surfaced grooves separated partially by a slight ridge. The grooves were oriented in a dorsoplantar direction and were convex in this dimension as well as from medial to lateral. The intervening ridge was present between the dorsal portion of the grooves and absent on the plantar side. Lateral to the large proximal facet was a smaller elongated twisting facet where this bone articulated with the fibular tarsal bone. This facet was obliquely oriented and was nearly flat from medial to lateral and convex from dorsal to plantar.

The four distal articular facets were of unequal size and irregular in shape. The two dorsal facets were the largest and located at different levels. The medial one was an indented shelf which articulated with the fused second and third tarsal bones. A concave, oval, medial facet was the larger of the plantar articular areas. It articulated with the first tarsal bone. The smallest plantar facet was elongated and transversely oriented at the plantar aspect of the distal surface. It articulated with the large metatarsal bone. Several nutrient foramina pitted the distal surface near its center. The remainder of the surface of the bone was rough and irregular.

The second and third tarsal bones were fused to form an elongated, oval shaped bone which was flattened on its proximal and distal surfaces. The proximal surface was a smooth articular facet which was almost flat from medial to lateral and slightly concave from dorsal to plantar. This surface articulated with the fused central and fourth tarsal bones. The distal surface was also smooth, rather flat from side to side, and concave from dorsal to plantar. The lateral medial and plantar sides were rough and irregular.

The first tarsal bone was the smallest of the bones of the tarsus. It resembled a short cylinder with flat articular facets at the proximal and distal ends. The proximal surface articulated with the fused central and fourth tarsal bones and the distal surface articulated with the large metatarsal bone.

Metatarsus (Figures 95-97)

The metatarsal (Metatarsus) region consisted of a single bone which represented the fusion of two primitive metatarsal units. Metatarsals three and four were united along their axial surfaces except at their distal ends. The resulting large metatarsal bone closely resembled the large metacarpal bone in shape and conformation. Several differences were observed when comparing the large bones of the metatarsal and metacarpal regions. The large metatarsal bone was one inch or longer than the large metacarpal bone. The dorsal longitudinal groove (Sulcus longitudinalis dorsalis) of the dorsal face (Facies dorsalis) was deep and wide in the metatarsal bone while it was difficult to recognize in the large metacarpal bone.

The proximal articular surface of the large metatarsal bone (Facies articularis tarsea) was situated atop the slightly expanded base (Basis). It was more circular than the corresponding face of the large metacarpal bone. It had four separate articular facets which articulated with the bones of the distal row of the tarsus. The central area of this surface was pitted by several foramina, some of which joined to form the proximal metatarsal canal (Canalis metatarsi proximalis). This canal exited the bone in the plantar longitudinal groove (Sulcus longitudinalis plantaris) on the plantar face (Facies plantaris) close to the proximal end. The body (Corpus) of the bone was slightly compressed from medial to lateral in its proximal one half and compressed from dorsal to plantar in its distal one quarter. The medial and lateral faces (Facies medialis et lateralis) were smooth and flat proximally. They were rounded distally.

Lateral and parallel to the proximal end of the dorsal longitudinal groove was a smooth surfaced groove which extended approximately one quarter of the way distally on the shaft. The dorsal longitudinal groove continued distally along the dorsal surface and terminated as the proximal opening of the distal metatarsal canal (Canalis metatarsi distalis). The distal metatarsal canal continued from this point distally into the deep groove between the symmetrical trochlea of the head (Caput). The trochlear region of the head was similar to that of the large metacarpal bones; however, the axial portion of the lateral trochlea was of slightly greater diameter than the axial portion of the medial trochlea. Small metatarsal bones (II and V) were not present.

Digits (Figures 72, 74, 76)

The digital bones of the pes (Ossa digitorum pedis) closely resembled those of the manus. With a few exceptions they varied only in size. The phalanges of the third and fourth digits were slightly larger than those of the manus. The larger size of the components of the weight bearing digits was also true of the sesamoid bones.

The opposite situation was found on the phalanges of the second and fifth digits. Each phalanx of the minor digits was smaller than the corresponding digits of the manus. The first phalanx of the second and fifth digits were reduced in size and were approximately one half the length of the corresponding first phalanx of the manus. It had an expanded distal extremity with a small articular facet.

Heterotopic Skeleton

Os Cordis (Figure 98)

The os cordis (Os cordis) was overlooked on the first five specimens and not found on the sixth. A single small flat bone was found in the fibrous base of the aorta of the last four specimens. It was situated to the right of the right caudal cusp of the aortic semilunar valve. The bone was about two centimeters long and about one-half centimeter wide. A shallow concave arc was present on the cranial two-thirds of the lift side of the bone. Immediately caudal to this arc was a small pointed eminence.

V. DISCUSSION

The osseous structures of the white-tailed deer resemble those of the sheep, goat and ox in their presence and form. However, when the deer skeleton (Figure 1) is compared to other species, the long slender nature of the distal bones of the appendages seem to reflect the grace and speed of the animal.

Slight variations among specimens were encountered when the features of the skeleton were assessed. These variations included size and appearance. Most of the differences observed were attributed to the differences in age and sex of the specimens. Incompletely fused ossification centers and the fusion of separate bones were responsible for some variance. The antlers differed more than any other feature. The variation of symphyseal shape and the presence of antler pedicles was related to the animal's sex. A reason for the differing condition of the shaft of the fibula was not apparent in this study.

The scant accounts of previous investigators were generally in agreement with the present investigation. In Flerov's[12] description of the skull of the family Cervidae, two lacrimal fossae were mentioned as being present in each lacrimal bone. This author found a single lacrimal fossa present in each lacrimal bone. Flerov also called attention to an angular process being present on the mandible. No evidence of its occurrence was found in the present study. Hildebrand[20] observed that a distinguishing characteristic feature of the Odocoileus sp. sacrum was the pars lateralis which extended cranial to the body of the sacrum. The present investigator confirmed this characteristic. The number of coccygeal vertebrae of the family Cervidae was reported by Schmid[47] to be eleven, however, thirteen to fifteen vertebrae were found in this study to be present in the coccygeal region of the white-tailed deer.

Blankenship et al.[4] identified a subscapular ridge and groove as present on the medial side of the scapula of the white-tailed deer and the presence of these features was confirmed by the present author. The account of Blankenship et al.[4] mistakenly indicated that six bones were present in the carpus. They failed to report the presence of the first carpal bone which is described by the present author. In their report, they characterized the lateral bone of the distal row of carpal bones as being the fourth carpal bone. This characterization was disputed by Flower[13] and Young[66] who considered it to be the fused fourth and fifth carpal units. Blankenship et al.[4] also failed to locate a distal sesamoid bone in either the pes or manus. This bone was observed to be present in both the pes and manus in the present study.

The suspensory tuberosities which Taber[53] considered characteristic of the male pelvis of Odocoileus sp. cannot be confirmed as a definite eminence in the present study. These tuberosities were not found on any interischial bones. The caudal ends of the interischial bone may be the tuberosities described by Taber. Lawrence[24] characterized the trochlear ridges of the femur to be slightly oblique in Odocoileus sp. however, the observations of the present investigator and the report of Hildebrand[20] indicate that they are oriented almost straight with the long axis of the bone. Lawrence[24] also reported that the proximal end of the fibula was vestigial or absent and Schmid[47] completely excluded the shaft of the fibula from her account. The proximal end of the fibula was consistantly observed to be fused to the tibia in this study, but evidence of a fibular shaft was frequently found. The deep dorsal longitudinal groove terminating at the distal metatarsal canal was reported by Hildebrand[20] to be characteristic of the metatarsal bone of the Odocoileus sp. and its presence was confirmed in the present study.

The illustrations of deer bones presented by Schmid[47] and Hildebrand[20] were found to be accurate. Frink and Merrick[15] reported that sheep had an occasional second os cordis in the left side of the aortic base, however no evidence of a second bone was found in the white-tailed deer in the present study.

After combining the information presented by these and other authors, the formulated description was grossly incomplete. The description by Mystkowska[36] was a notable exception. Mystkowska's description of the skull of the red deer Cervus elaphus was detailed and presented in precise anatomical nomenclature. The skull of the white-tailed deer as described in this investigation differed slightly from the description of the skull of red deer by Mystkowska. The jugular processes of the white-tailed deer were ventrally directed, whereas those of the red deer were reported to curve rostrally. The numerous foramina in the lacrimal fossa of the red deer were not observed on the white-tailed deer. The single os cordis and distal sesamoid bones described in this study have not been included in previous investigations. The presence of these bones and the occasional absence of an ossified fibular shaft are now added through the present study to the knowledge of the osteology of the white-tailed deer.

Some difficulty was encountered when assessing reports of the bones of the carpus and tarsus. This difficulty arose when interpreting the many different names applied to the component bones. Synonyms for the bones of the carpus included: Radial carpal[39] (Os scaphoideum[39], Scaphoid[13], Naviculare[13]), Intermediate carpal[39] (Os lunatum[39], Lunar[13], Semilunare[13]), Ulnar carpal[39] (Os triquetrum[39], Cuneiform[13]), Acessory carpal[39] (Os pisiforme[39], Pisiform[13]), First carpal[39] (Os trapezium[39], Trapezium[13]), Second carpal[39] (Os trapezoideum[39], Trapezoideum[13]), Third carpal[39] (Os capitatum[39], Magnum[13]), Second and Third carpal[39] (Os trapezoideocapitatum[39]), Fourth carpal[39] (Os hamatum[39]), and Fourth and Fifth carpal (Hamatum[13], Uncinatum[13]).

Synonyms for the bones of the tarsus included: Fibular tarsal (Calcaneus[13,39]), Tibial tarsal (Talus[39], Astralgus[13]), First tarsal (Os cuneiform mediale[39], Internal cuneform[13]), Second and third tarsal (Os cuneiforme intermediolaterale[39], Middle and external cuneiforms[13]), Central tarsal (Os naviculare[39], Navicular[13]) and fourth tarsal (Os cuboideum[39], Cuboid[13]).

Several features of the deer skeleton were not described in Nomina Anatomica Veterinaria[39]. The structures included the facial vacuity described by Flower[13], and Matthew[31], the interischial bone observed by Taber[53], the supra-acetabular fossa reported by Flower[13], Lawrence[24] and Reynolds.[43], the subscapular ridge and groove reported by Blankenship et al.[4], the hamate as described by Flower[13] and Young[66], the supramastoid foramen reported by Mystkowska[36] and the features of the antlers presented by Cornwall[8], Flerov[12], Goss[16], Jones[22], Modell[35], Reynolds[43] and Wislocke[61]. Each of the aforementioned features were found in the white-tailed deer skeleton during the course of this investigation. The nomenclature of previous authors accurately described these features and was incorporated in this paper.

A description of the internal morphology of the skull should be described in a future investigation. The observations by Hillman et al.[21] and Meister[33] of cyclic osteoporosis in the long bones of deer would seem to offer possibilities for identifying bones of male deer. This information would benefit archeologists and law enforcement officials and deserves investigation.

VI. SUMMARY

The skeletons of five male and five female white-tailed deer (Odocoileus virginianus) were examined and the composite external morphology of the bones described. The written description utilizes the nomenclature presented in Nomina Anatomica Veterinaria[39]. Ninety-eight illustrations of the morphological features accompany the written portion.

The skull was described as viewed from several aspects. Typical vertebrae were described in the cervical, thoracic, lumbar, sacral, or coccygeal regions. Atypical vertebrae were described individually. Bones of the appendicular and heterotopic skeletons were described individually.

This thesis should provide assistance to comparative anatomists, archeologists, wildlife investigators, and law enforcement officials. It will form a basis for future myological and craniometric investigations.

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APPENDIX A

TABLE 1

TAXONOMY OF THE WHITE-TAILED DEER [8,60]

KINGDOM	Animalia
SUBKINGDOM	Metazoa
PHYLUM	Chordata
SUBPHYLUM	Vertebrata
CLASS	Mammalia
SUBCLASS	Theria
INFRACLASS	Eutheria
COHORT	Ferungulata
SUPERORDER	Paraxonia
ORDER	Artiodactyla
SUBORDER	Ruminantia
INFRAORDER	Pecora
SUPERFAMILY	Cervoidea
FAMILY	Cervidae
SUBFAMILY	Odocoileinae
TRIBE	Odocoileini
GENUS	Odocoileus
SUBGENUS	Odocoileus (Rafinesque)
SPECIES	virginianus (Zimmerman)

APPENDIX B

Figure 1-Skeleton of the White-Tailed Deer

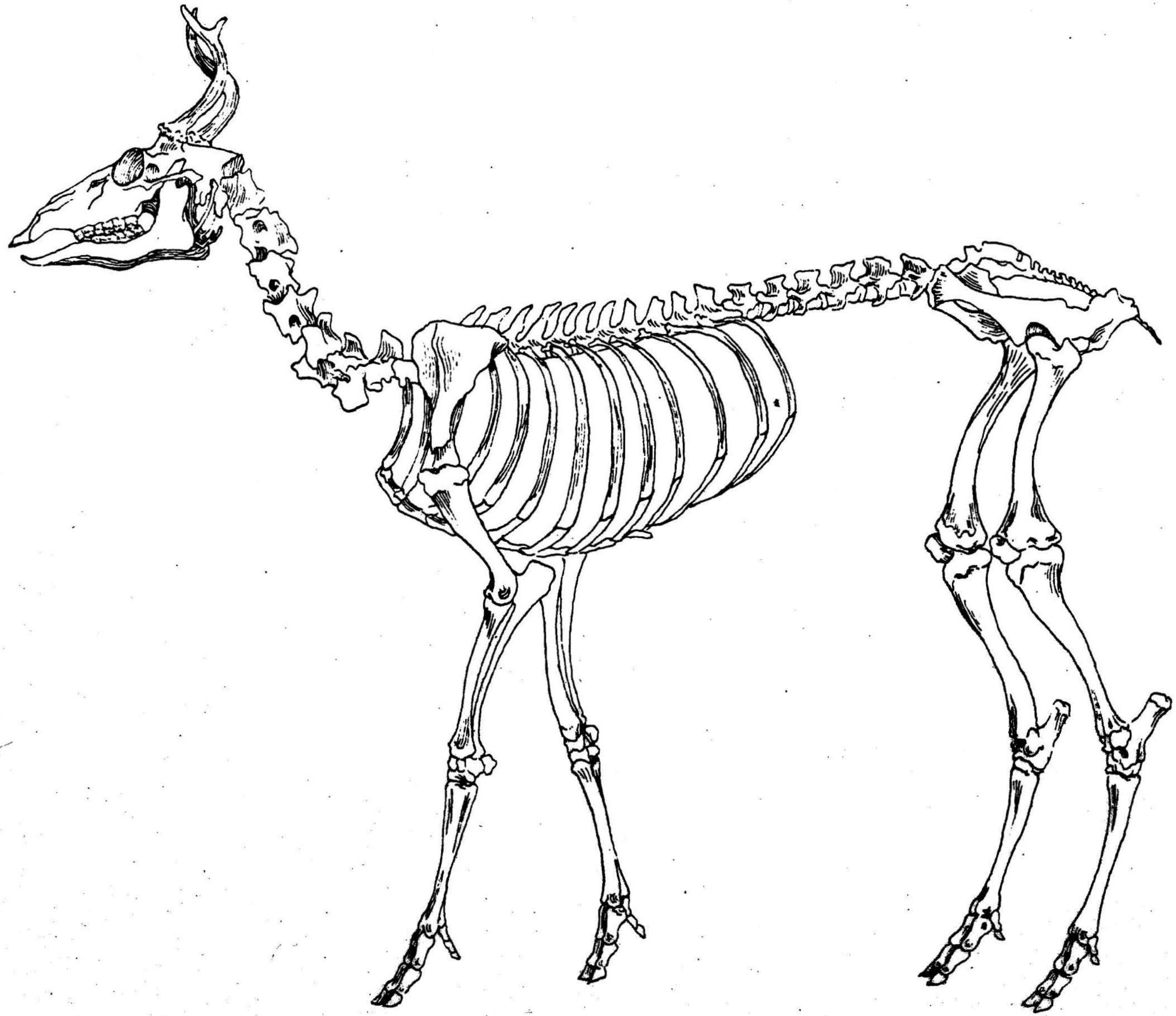

Figure 2-Bones of the Skull, Dorsal Aspect

A. Occipital bone
B. Parietal bones (Fused)
C. Frontal bone
D. Lacrimal bone
E. Nasal bone
F. Maxilla
G. Zygomatic bone
H. Temporal bone
I. Incisive bone
J. Vomer

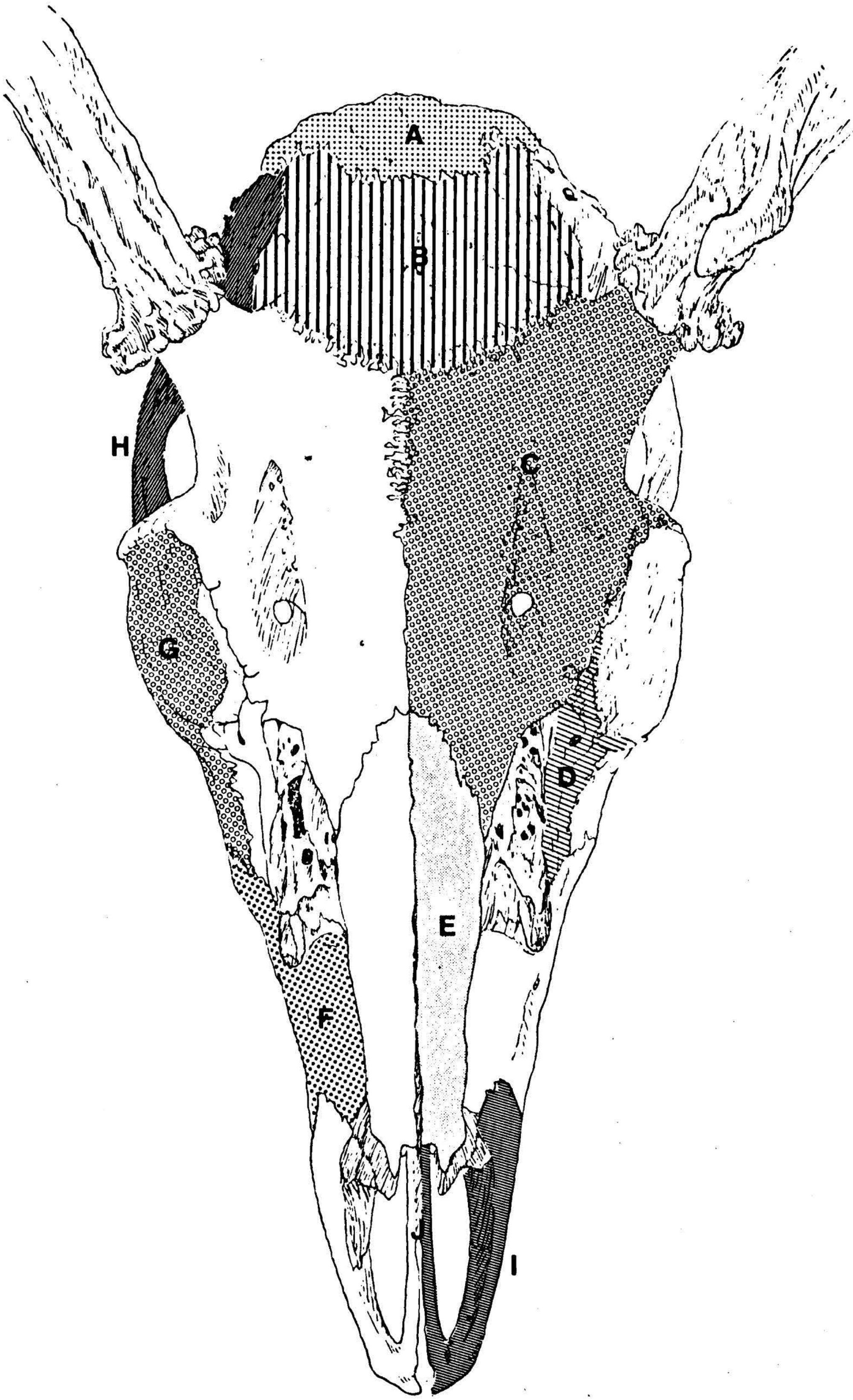
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Figure 3-Features of the Dorsal Surface of the Skull

A. External occipital protuberance
B. Nuchal crest
C. Temporal line
D. Parietal margin
E. Frontal margin
F. Interforntal suture
G. Nasal margin
H. Facial vacuity
I. Supraorbital margin
J. Zygomatic process
K. Saggital margin
L. Supraorbital groove
M. Supraorbital foramen
N. Pedicle
O. Burr
P. Brow tine
Q. External face
R. Internasal suture
S. Nasomaxillary suture

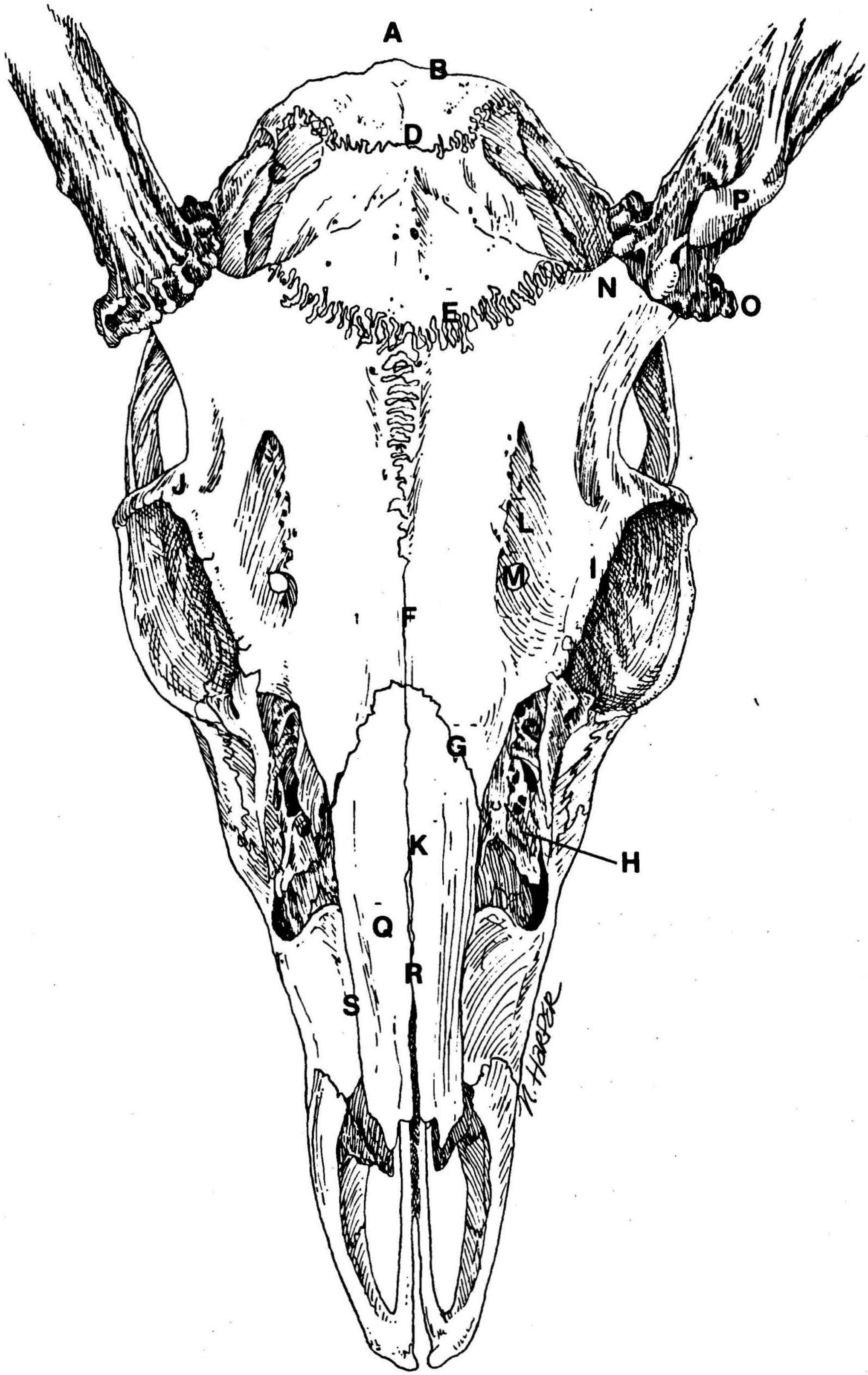
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Figure 4-Male Skull with Fully Developed Antlers

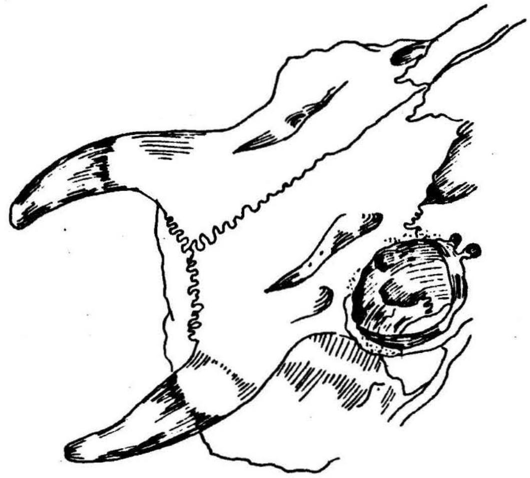
A. Main beam
B. Corona (Burr)
C. Brow tine
D. Bez tine
E. Trez tine

Figure 5-Female Skull


E
D
C
A
B

Figure 6-Male Skull, Pedicles Only

Figure 7-Male Skull, Short Spike Antlers



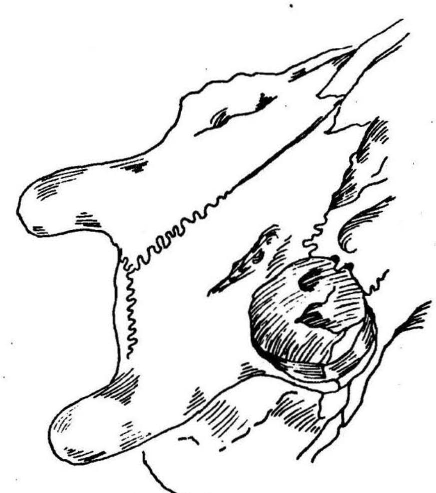
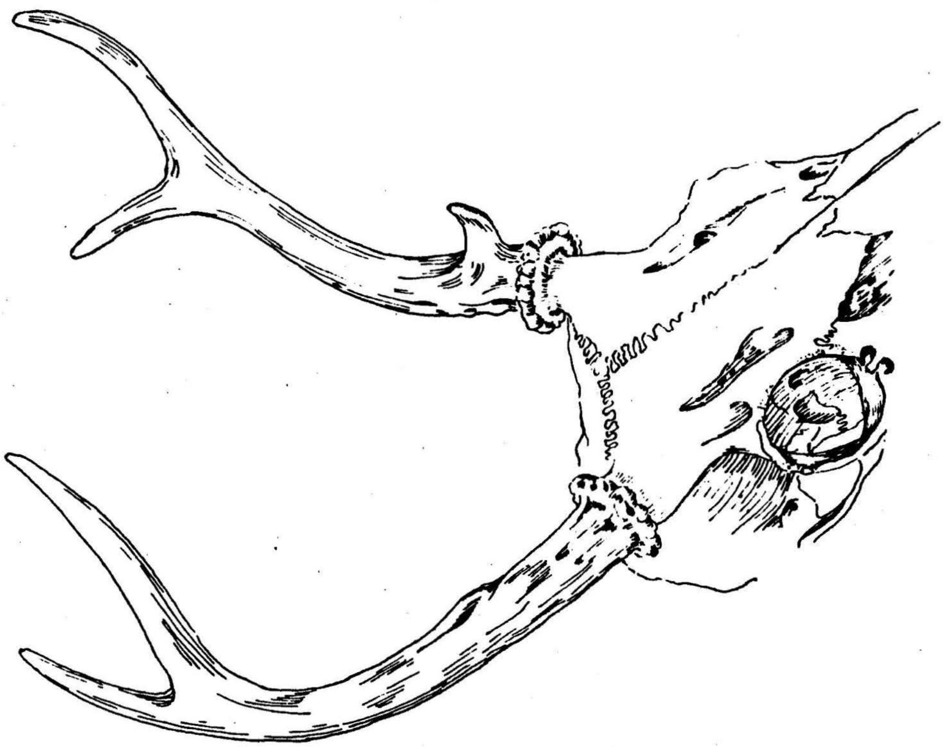


Figure 8-Male Skull, Spike Antlers

Figure 9-Male Skull, Five Point Antlers



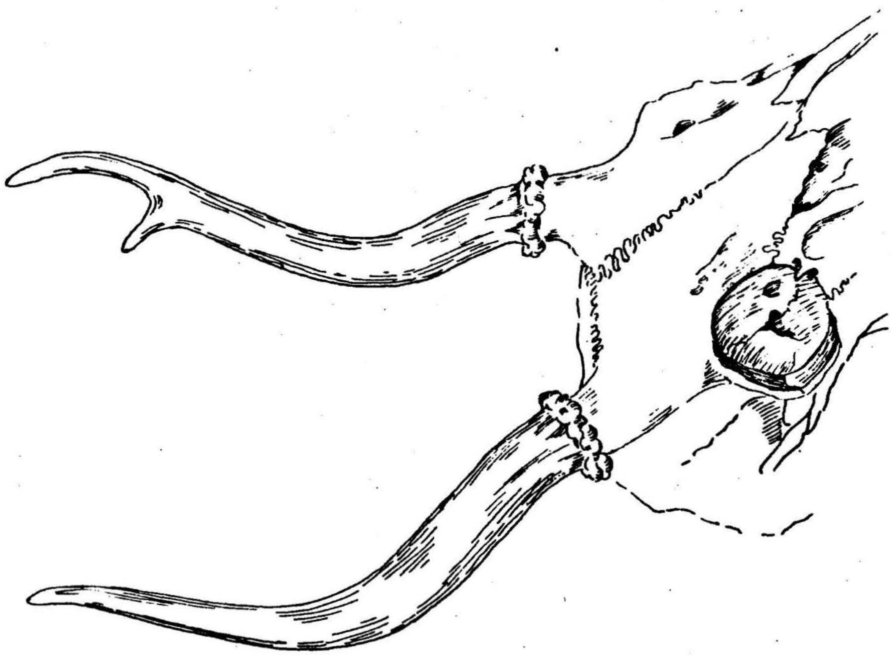


Figure 10-Bones of the Skull, Lateral Aspect

A. Occipital bone
B. Parietal bone
C. Frontal bone
D. Temporal bone
   D1. Pars petrosa
   D2. Pars squamosa
   D3. Pars tympanica
E. Zygomatic bone
F. Lacrimal bone
G. Nasal bone
H. Maxilla
I. Incisive bone
J. Palatine bone
K. Pterygoid bone
L. Vomer
M. Sphenoid
   M1. Basisphenoid
   M2. Presphenoid

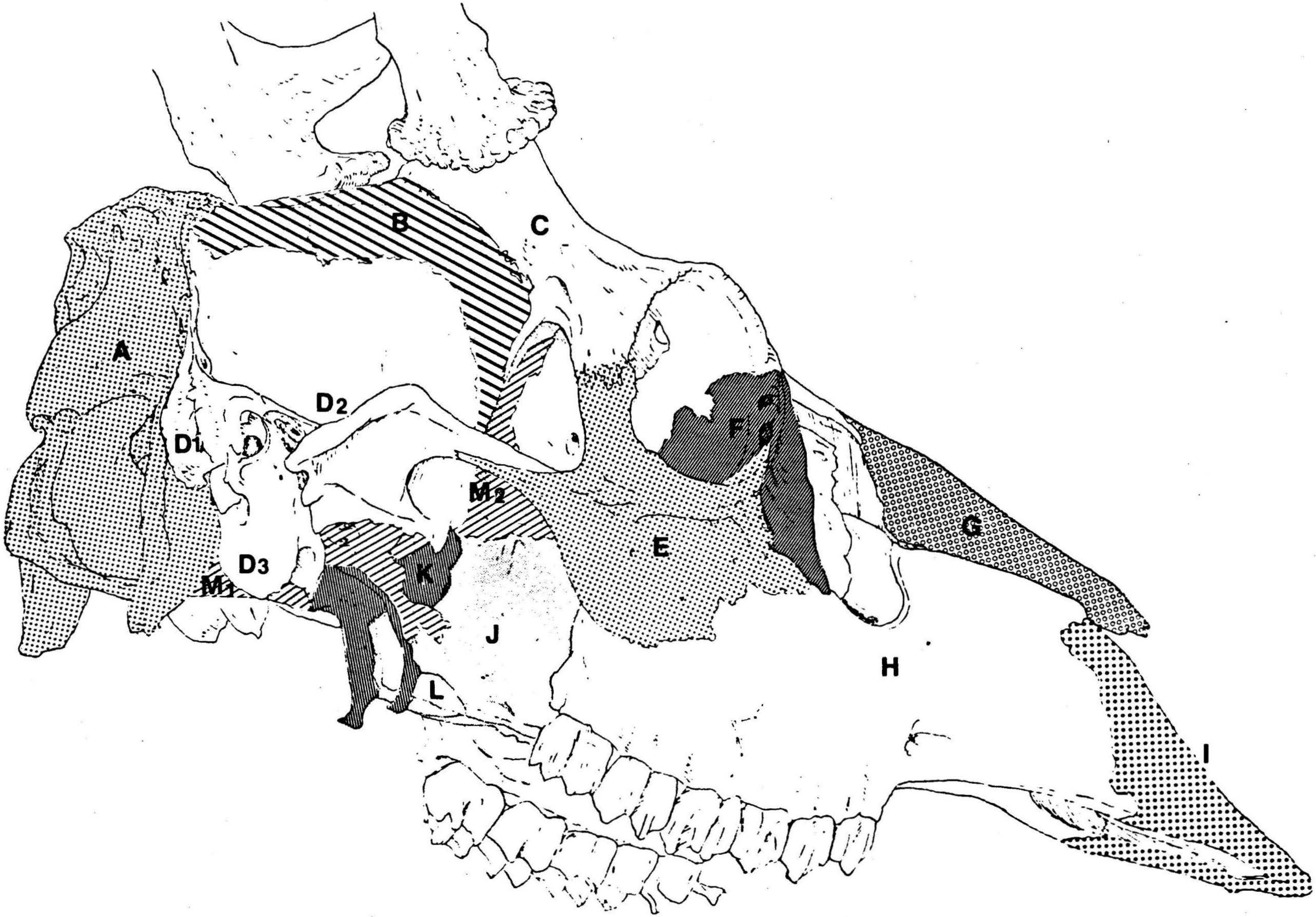

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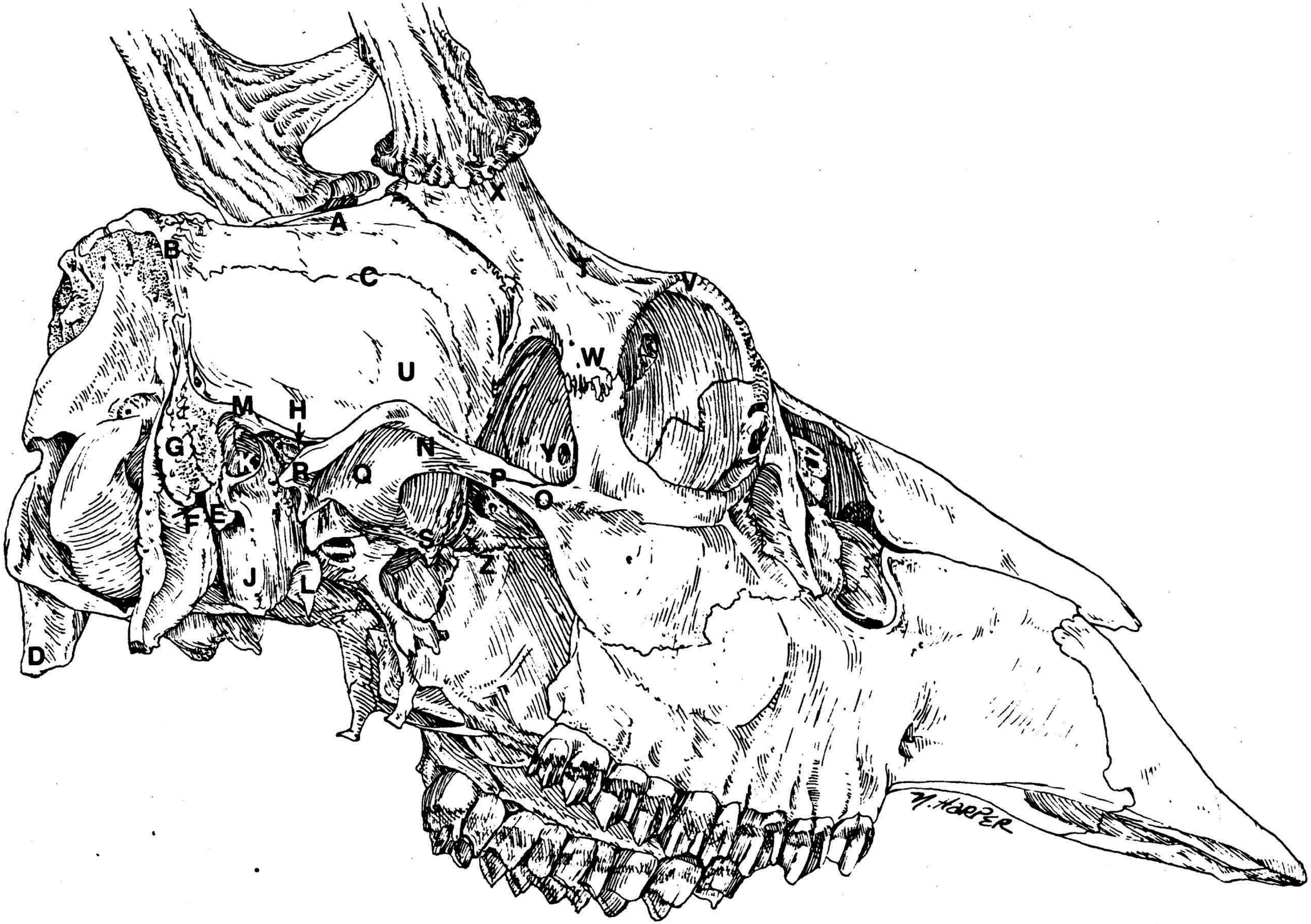
Figure 11-Features of the Lateral Surface of the Skull

A. Temporal line
B. Nuchal line
C. Occipitosquamous suture
D. Jugular process
E. Styloid process
F. Stylomastoid foramen
G. Mastoid process
H. Retroarticular foramen
J. Tympanic bulla
K. External acoustic meatus
L. Muscular process
M. Temporal crest
N. Zygomatic process (Temporal bone)
O. Temporal process
P. Zygomatic arch
Q. Mandibular fossa
R. Retroarticular process
S. Pterygoid crest
T. Frontal margin
U. Temporal fossa
V. Supraorbital margin
W. Zygomatic process (Frontal bone)
X. Pedicle
Y. Ethmoid foramen
Z. Foramen orbitorotundum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M. HARPER

Figure 12-Features of the Lateral Surface of the Skull

1. Oval foramen
2. Pterygoid process
3. Hamulus
4. Wings of presphenoid
5. Optic canal
6. Facial tuberosity
7. Pterygopalatine fossa
8. Perpendicular plate of palatine bone
9. Infraorbital foramen
10. Frontal process
11. Infraorbital margin
12. Orbital rim
13. Facial crest
14. Orbital face
15. Lacrimal foramena
16. External lacrimal fossa
17. Facial vacuity
18. Facial surface (Maxilla)
19. Maxillary tuberosity
20. Supramastoid foramen

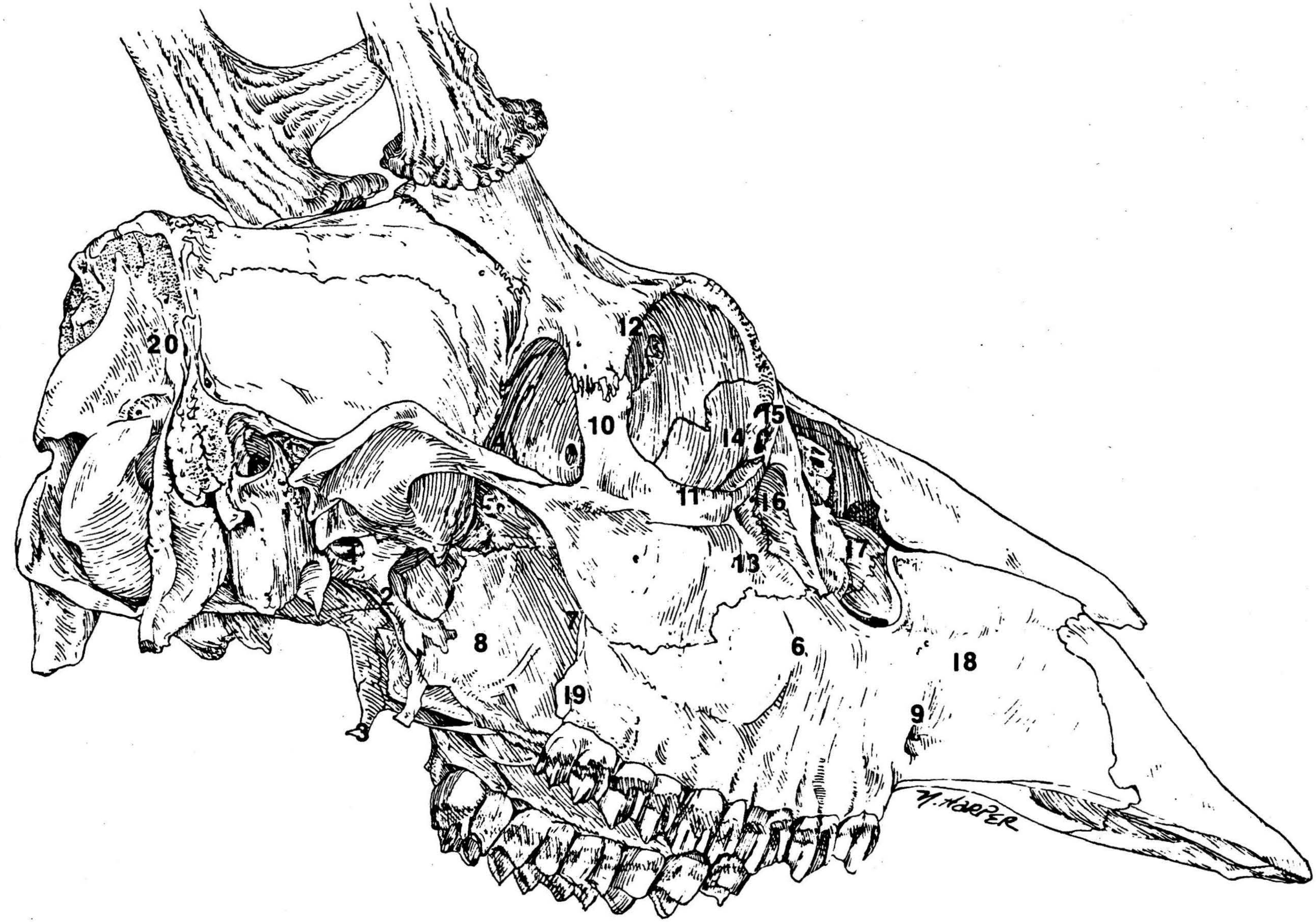
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Figure 13-Bones of the Skull, Ventral Aspect

A. Occipital bone
B. Temporal bone
C. Zygomatic bone
D. Frontal bone
E. Palatine bone
F. Vomer
G. Incisive bone
H. Pterygoid bone
I. Basisphenoid bone
J. Presphenoid bone
K. Maxilla

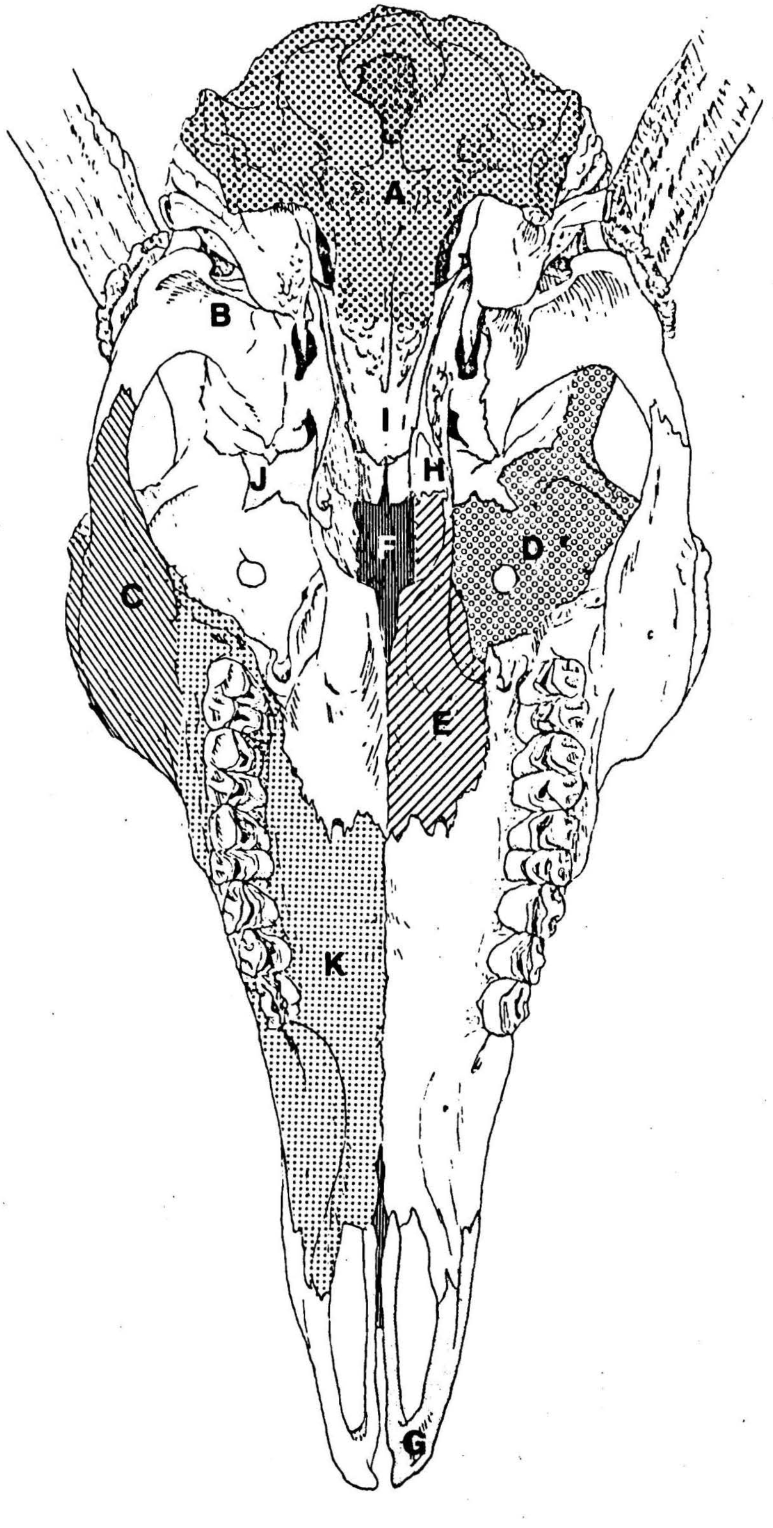
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Figure 14-Features of the Ventral Surface of the Skull

A. Foramen magnum
B. Occipital condyle
C. Nuchal tubercle
D. Ventral condylar fossa
E. Jugular process
F. Basilar part of occipital bone
G. Muscular tubercle
H. Foramen lacerum
I. Petrooccipital fissure
J. Jugular foramen
K. Tympanooccipital fissure
L. Muscular process
M. Musculotuberal canal
O. Oval foramen
P. Hamulus
Q. Choana
R. Crest of vomer
S. Wings of vomer
T. Foramen orbitorotundum
U. Pterygoid process
V. Horizontal lamina of palatine bone
W. Major palatine foramen
X. Alveolar process
Y. Interdental border
Z. Pterygopalatine fossa

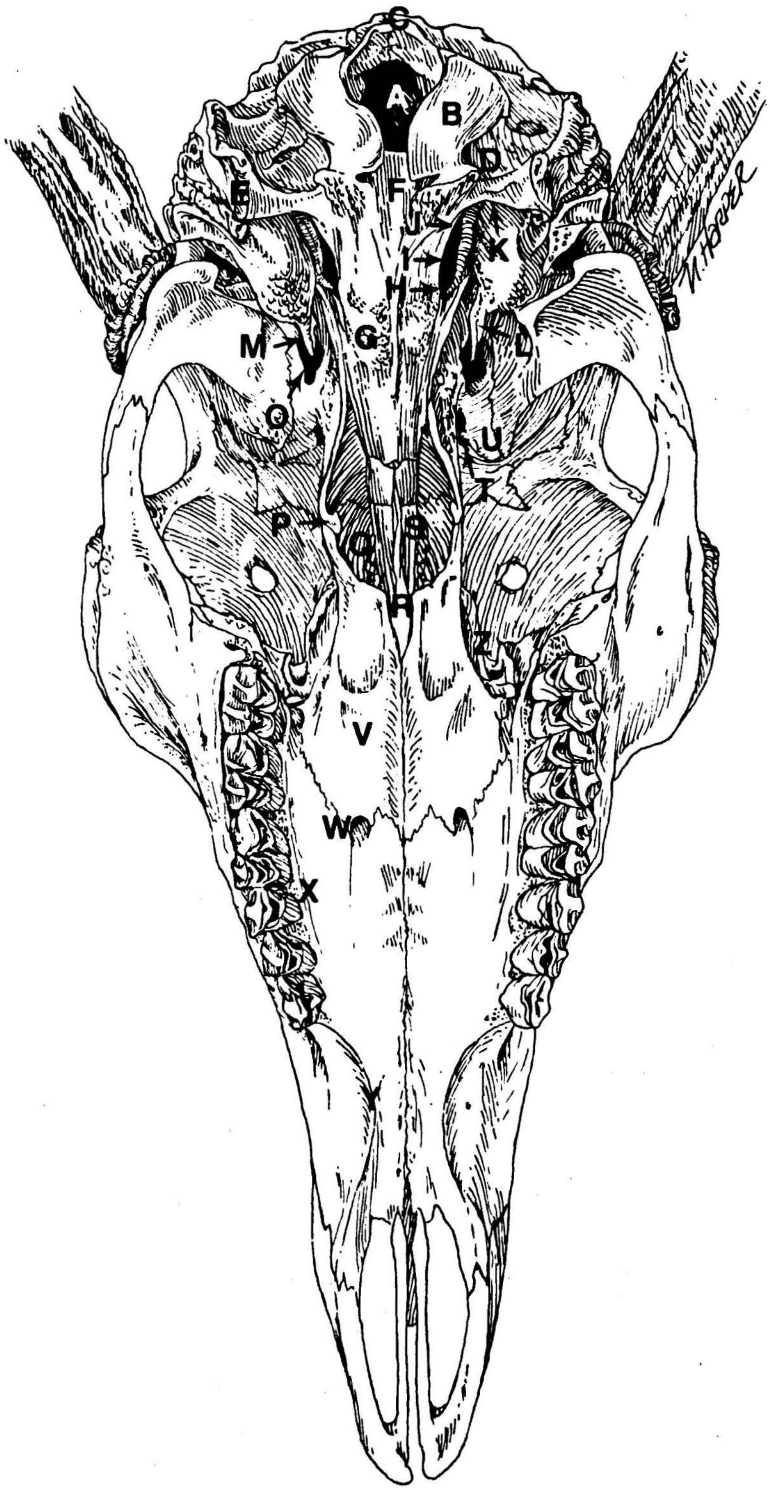
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Figure 15-Features of the Ventral Surface of the Skull

1. Maxillary tuberosity
2. Palatine fissure
3. Palatine face of incisive bone
4. Body of incisive bone
5. Nasal process
6. Palatine process
7. Interincisive fissure

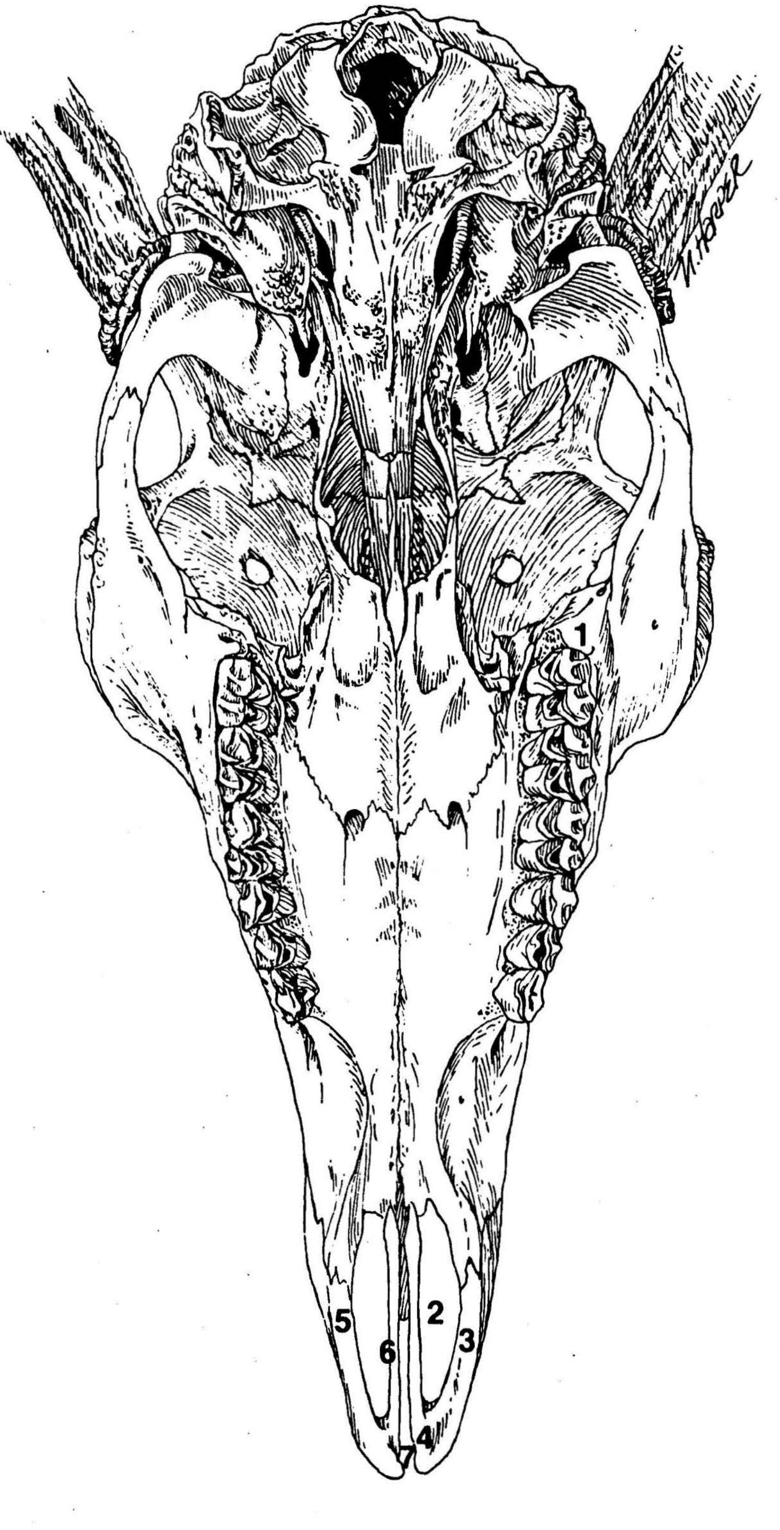
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Figure 16-Alveoli of the Upper Postcanine Teeth

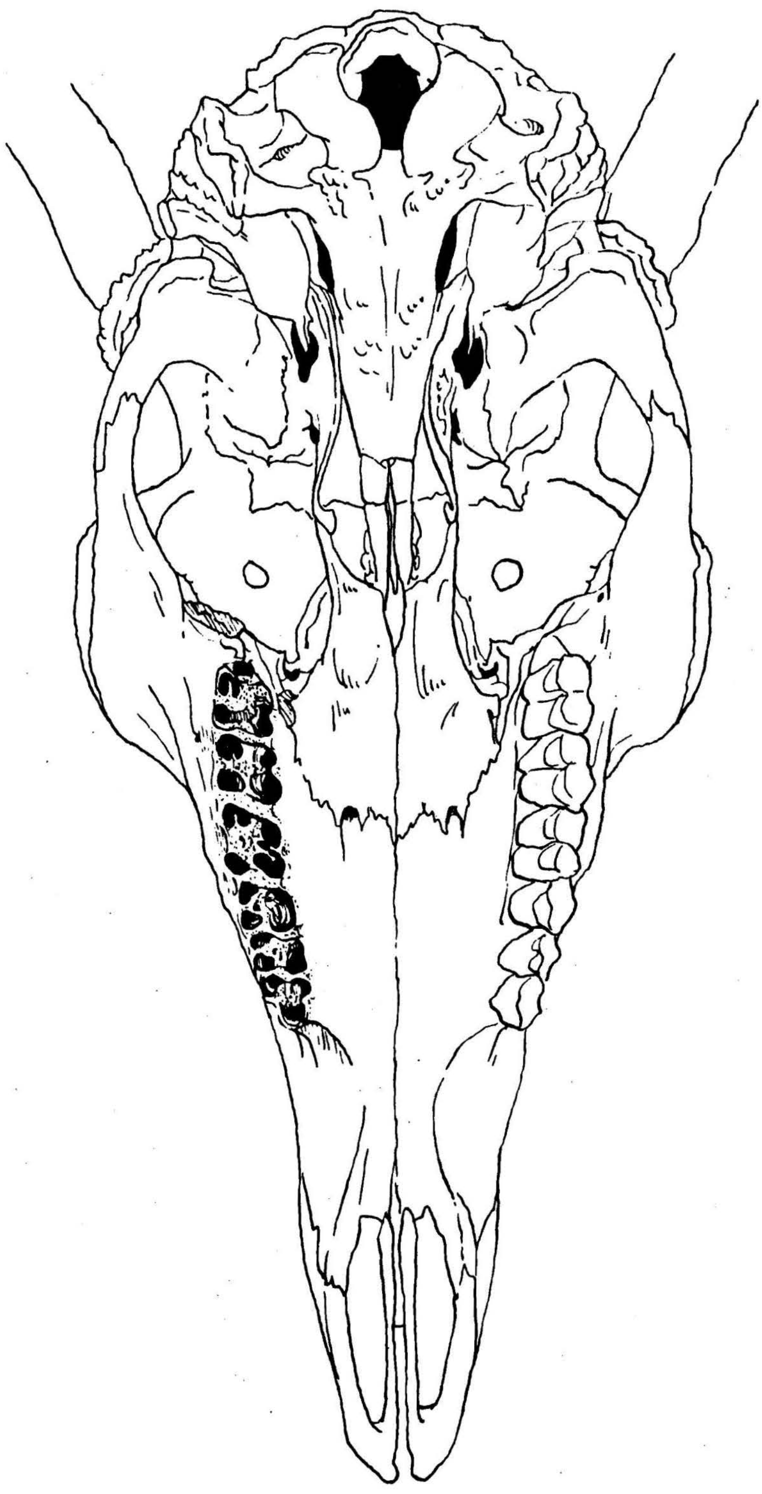

Figure 17-Bones of the Skull, Caudal Aspect

A. Occipital bone
B. Temporal bone
C. Parietal bone
D. Frontal bone
E. Vomer
F. Palatine bone
G. Maxilla
H. Zygomatic bone
I. Lacrimal bone
J. Incisive bone
K. Pterygoid bone

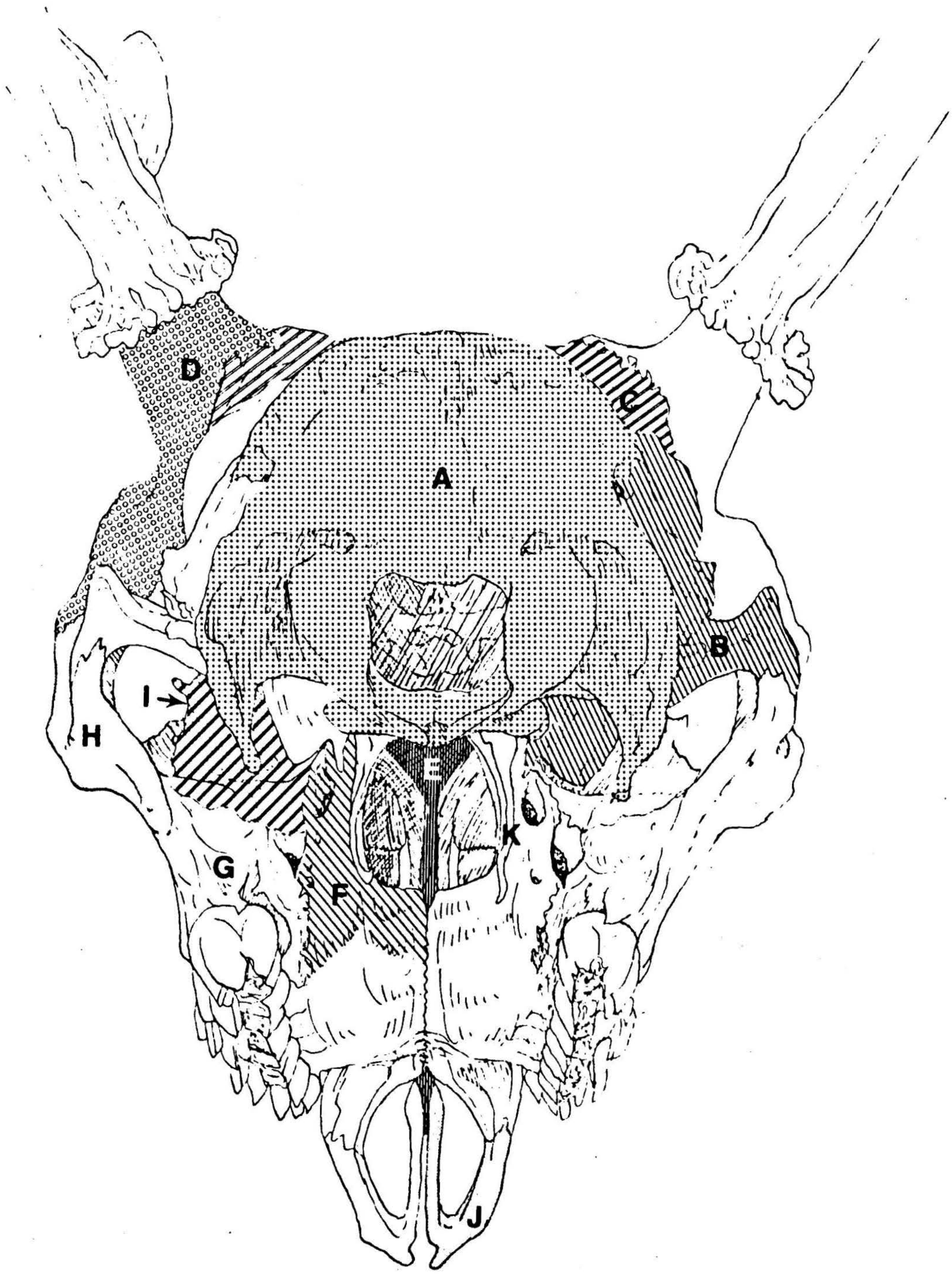
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Figure 18-Features of the Caudal Surface of the Skull

A. Foramen magnum
B. Occipital condyle
C. Dorsal condylar fossa
D. External occipital crest
E. Mastoid process
F. Jugular process
G. Choana
H. Pterygopalatine fossa
I. Caudal palatine foramen
J. Sphenopalatine foramen
K. Maxillary foramen
L. Lacrimal bulla
M. Maxillary tuberosity

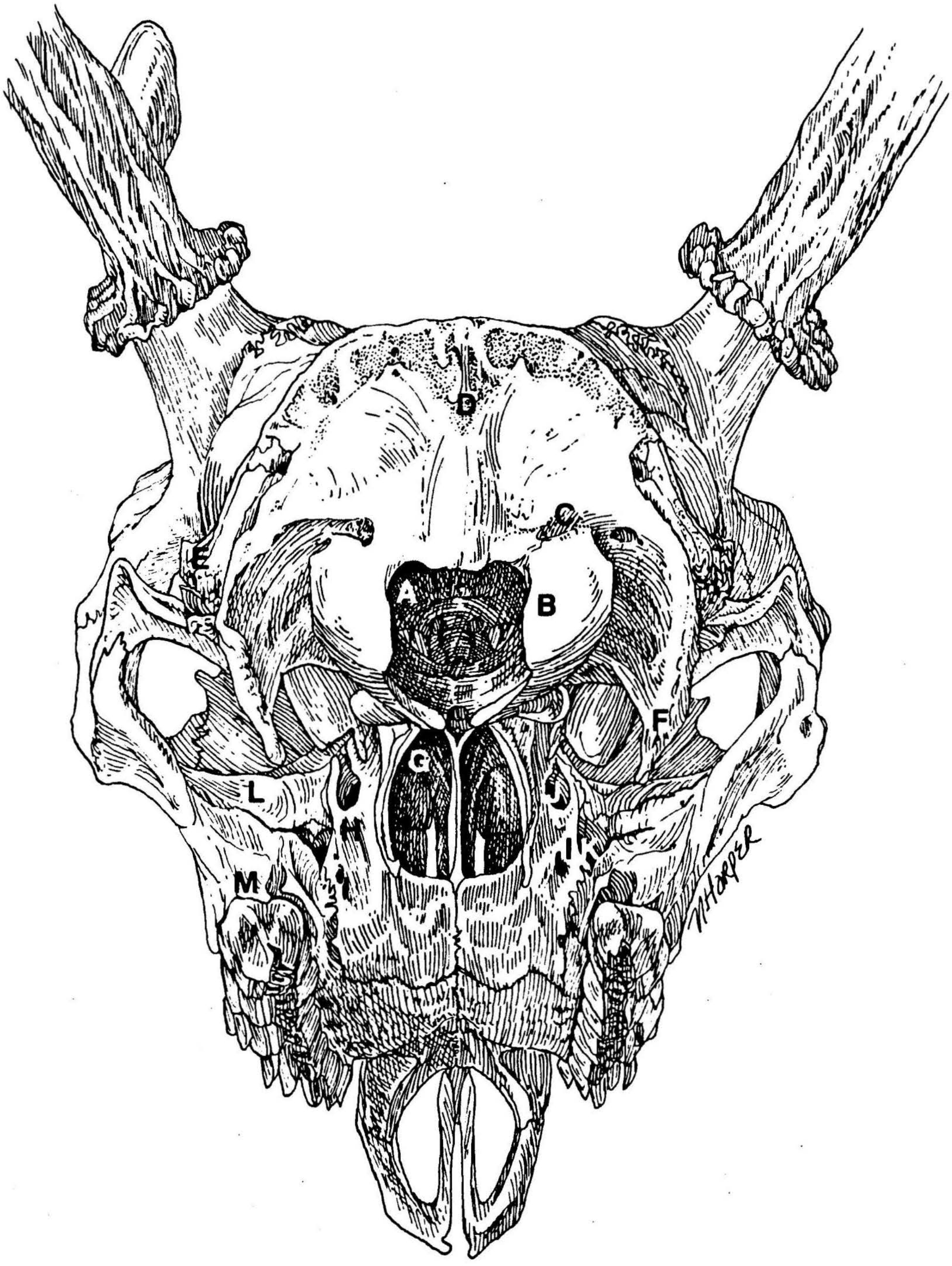

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Figure 19-Hyoid Bones, Anterior View

A. Thyrohyoid bone
B. Basihyoid bone
C. Lingual process
D. Keratohyoid bone
E. Epihyoid bone
F. Stylohyoid bone
G. Stylohyoid angle

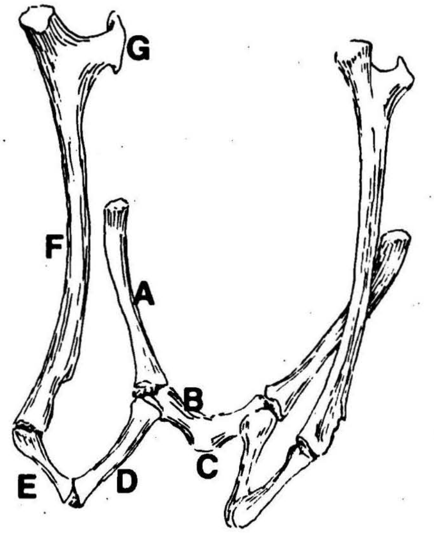
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Figure 20-Right and Left Mandibles, Dorsal Lateral Aspect

A. Body
B. Ramus
C. Incisive part
D. Incisor teeth
E. Canine tooth
F. Molar part
G. Mental foramen
H. Ventral margin
I. Vascular notch
J. Angle
K. Masseteric fossa
L. Mandibular notch
M. Coronoid process
N. Condyloid process
O. Pterygoid fossa
P. Mandibular foramen
Q. Mylohyoid groove
R. Head
S. Neck

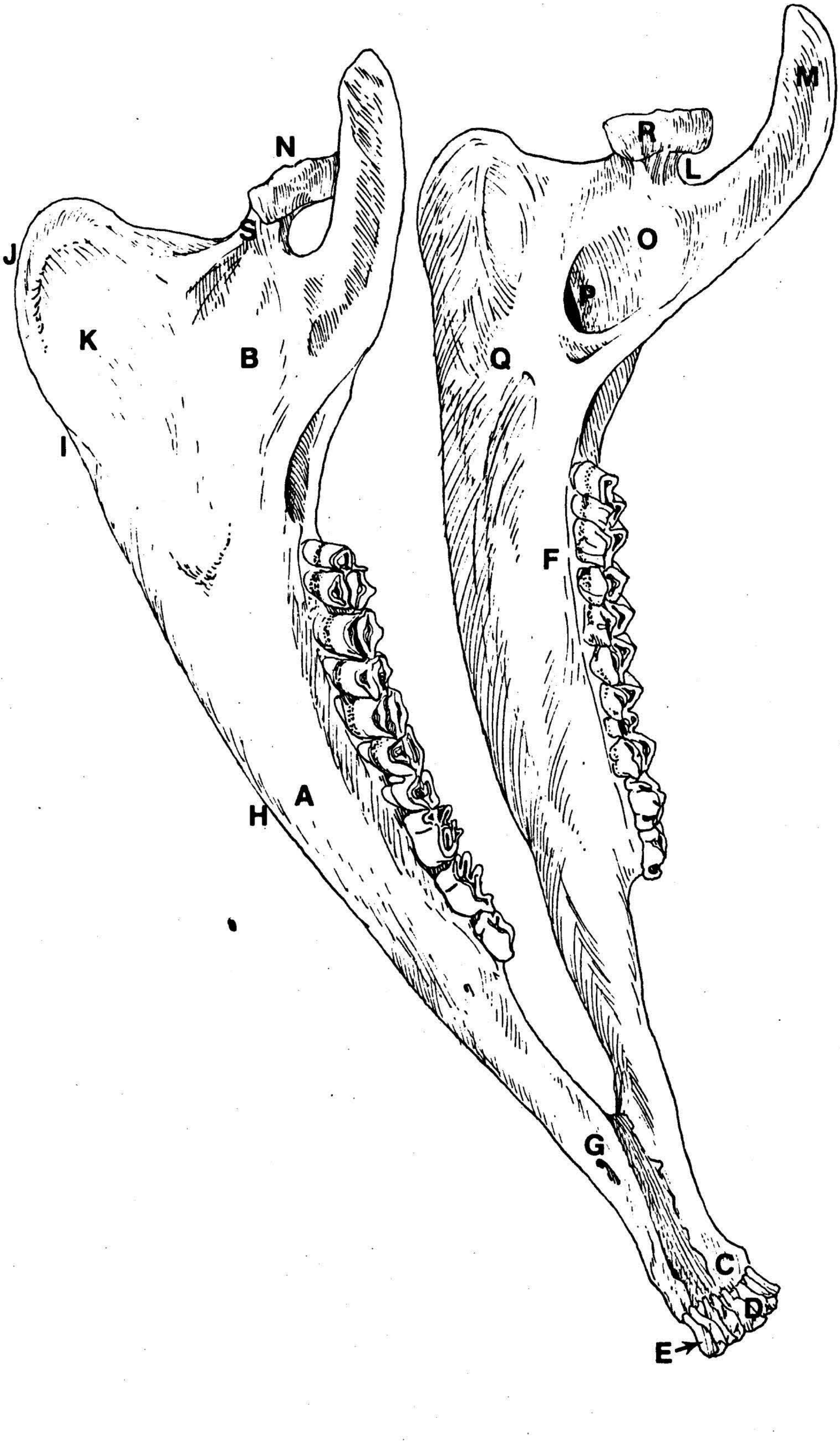
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Figure 21-Cervical Vertebrae, Dorsal Aspect

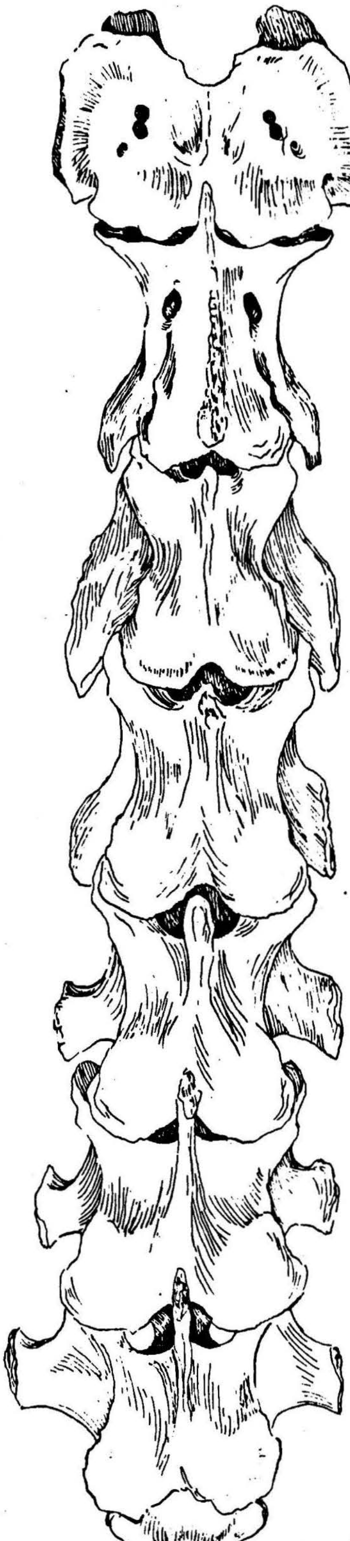

Figure 22-Cervical Vertebrae, Lateral Aspect

A. Atlas
B. Axis
C. Transverse foramen
D. Spinous process
E. Caudal vertebral notch
F. Intervertebral foramen


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B
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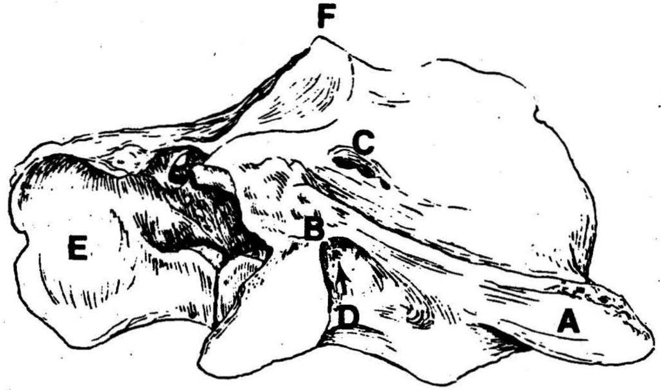
D
E
F

Figure 23-Atlas, Cranial Lateral Aspect

A. Transverse process
B. Lateral mass
C. Alar foramen
D. Atlantal fossa
E. Cranial articular surface
F. Dorsal tubercle

Figure 24-Atlas, Caudal Lateral Aspect

A. Caudal articular surface
B. Fovea dentis
C. Ventral tubercle
D. Dorsal arch
E. Ventral arch
F. Vertebral foramen
G. Lateral foramen
H. Alar foramen
I. Transverse foramen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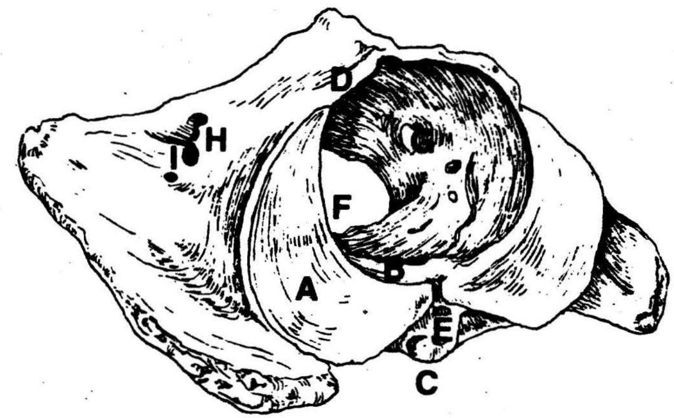
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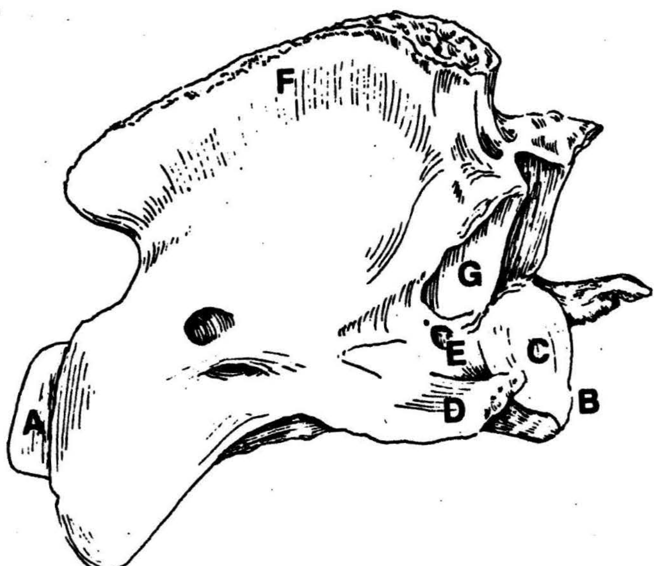
Figure 25-Axis, Caudal Lateral Aspect

A. Dens
B. Caudal extremity
C. Vertebral fossa
D. Transverse process
E. Transverse foramen
F. Spinous process
G. Caudal articular process

Figure 26-Axis, Cranial Lateral Aspect

A. Dens
B. Body
C. Arch
D. Facies articularis ventralis
E. Cranial extremity
F. Ventral crest
G. Lateral foramen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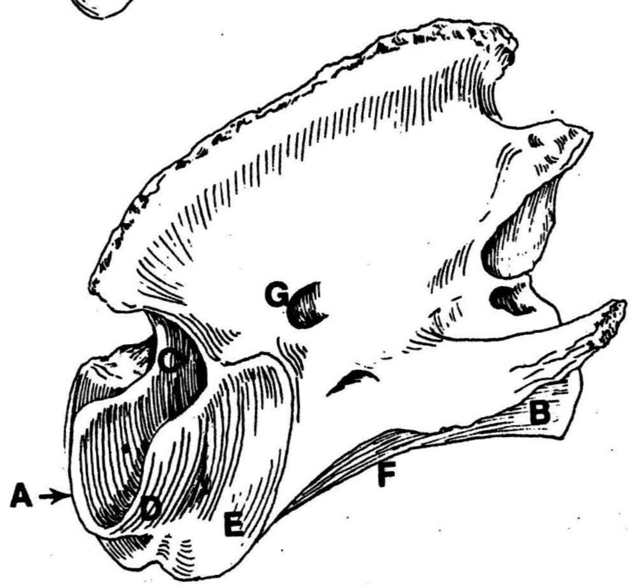
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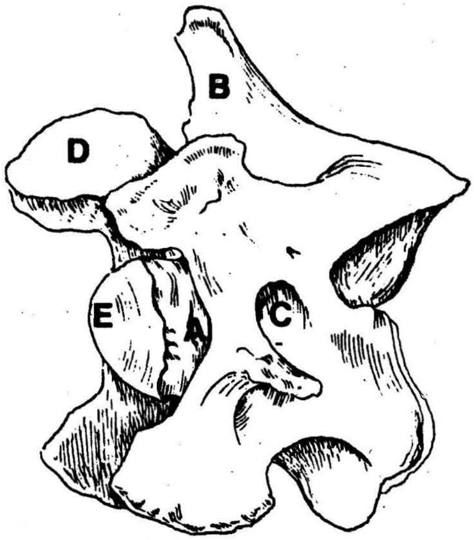
Figure 27-Fifth Cervical Vertebra, Cranial Lateral Aspect

A. Body
B. Spinous process
C. Transverse Foramen
D. Cranial articular process
E. Head

Figure 28-Fifth Cervical Vertebra, Caudal Lateral Aspect

A. Caudal articular process
B. Transverse process
C. Dorsal tubercle
D. Ventral tubercle
E. Lamina
F. Pedicle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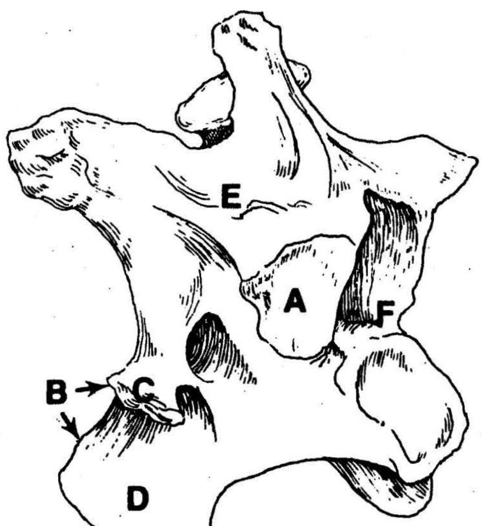
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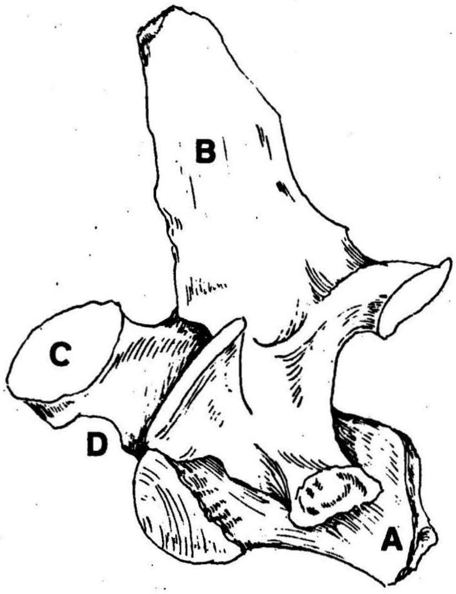
Figure 29-Seventh Cervical Vertebra, Cranial Lateral Aspect

A. Body
B. Spinous process
C. Cranial articular process
D. Cranial vertebral notch

Figure 30-Seventh Cervical Vertebra, Caudal Lateral Aspect

A. Caudal costal fovea
B. Caudal vertebral notch
C. Caudal articular process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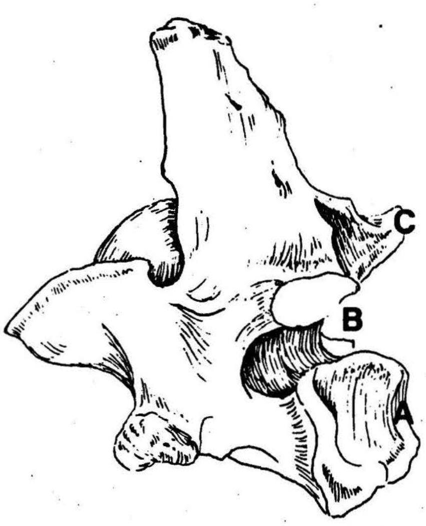
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Figure 31-Thoracic Vertebrae, Lateral Aspect

A. Spinous process
B. Anticlinal vertebra
C. Body
D. Mamillary process
E. Intervertebral foramen

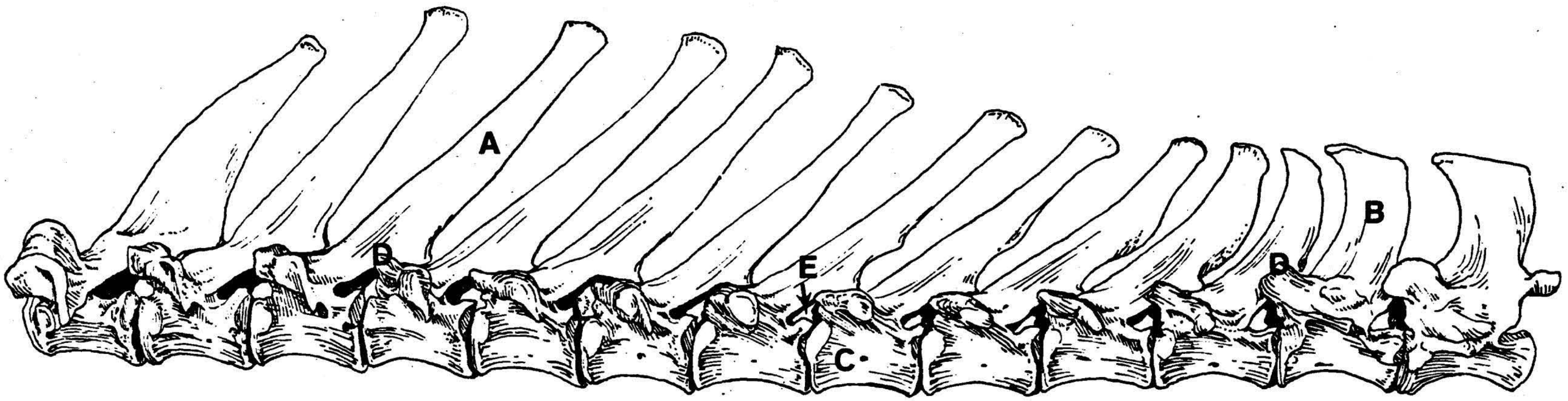
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Figure 32-First Thoracic Vertebra, Cranial Lateral Aspect

A. Spinous process
B. Transverse costal fovea
C. Cranial articular process

Figure 33-Seventh Thoracic Vertebra, Cranial Lateral Aspect

A. Cranial extremity
B. Transverse process
C. Cranial articular process
D. Cranial costal fovea

Figure 34-Twelfth Thoracic Vertebra, Cranial Lateral Aspect

A. Head
B. Cranial costal fovea
C. Mamillary process
D. Cranial articular process

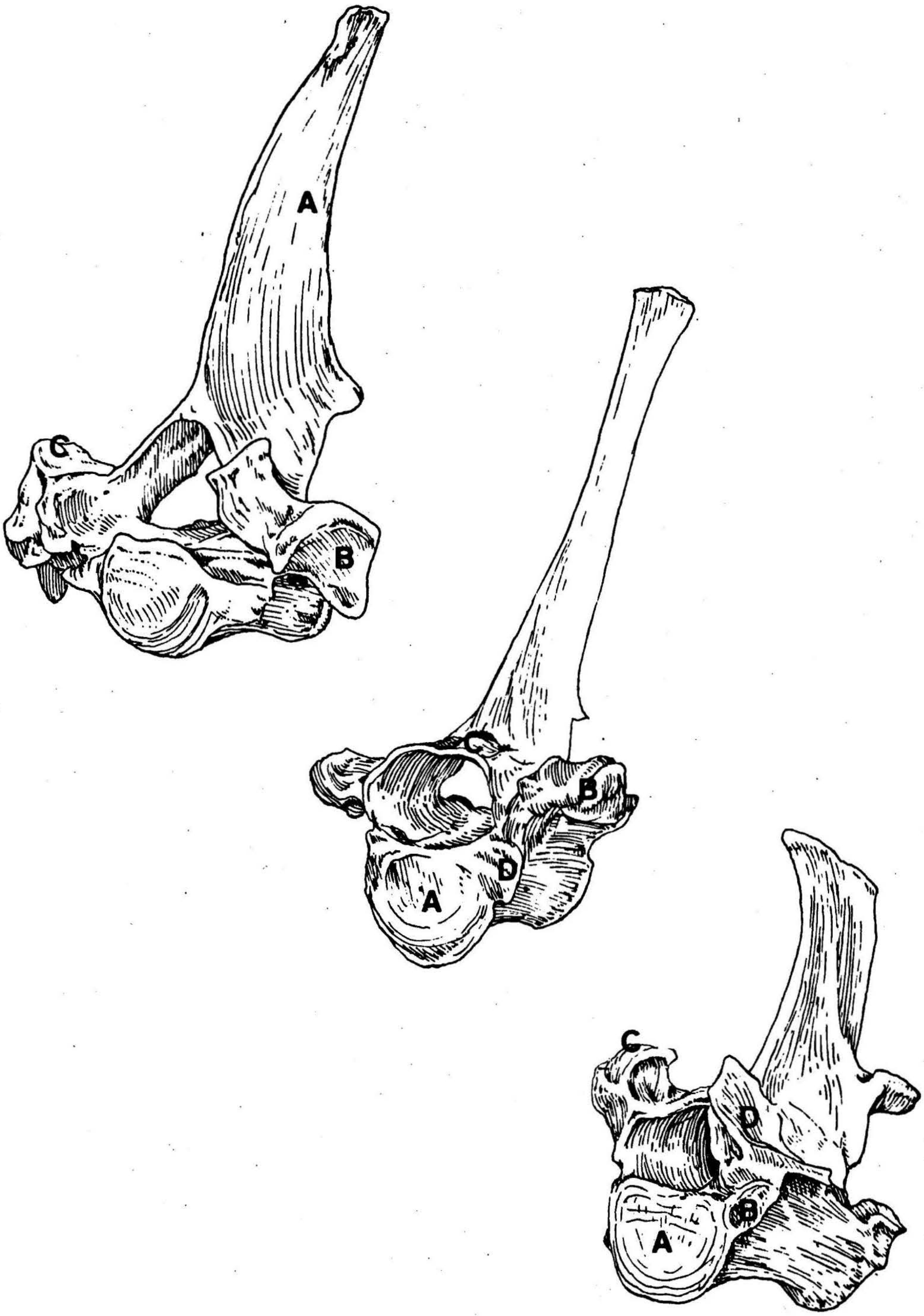
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Figure 35-First Thoracic Vertebra, Caudal Lateral Aspect

A. Spinous process
B. Transverse process
C. Transverse costal fovea
D. Mamillary process
E. Caudal costal fovea

Figure 36-Seventh Thoracic Vertebra, Caudal Lateral Aspect

A. Ventral crest
B. Nutrient foramen
C. Caudal costal fovea
D. Caudal articular process

Figure 37-Twelfth Thoracic Vertebra, Caudal Lateral Aspect

A. Caudal extremity
B. Mamillary process
C. Spinous process
D. Caudal articular process


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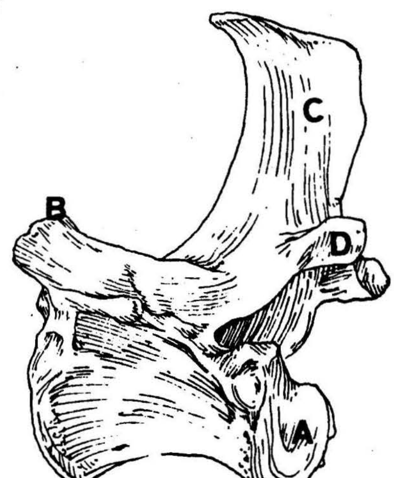
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Figure 38-Lumbar Vertebrae, Dorsal Lateral Aspect

A. Spinous process
B. Transverse process
C. Mamillary process

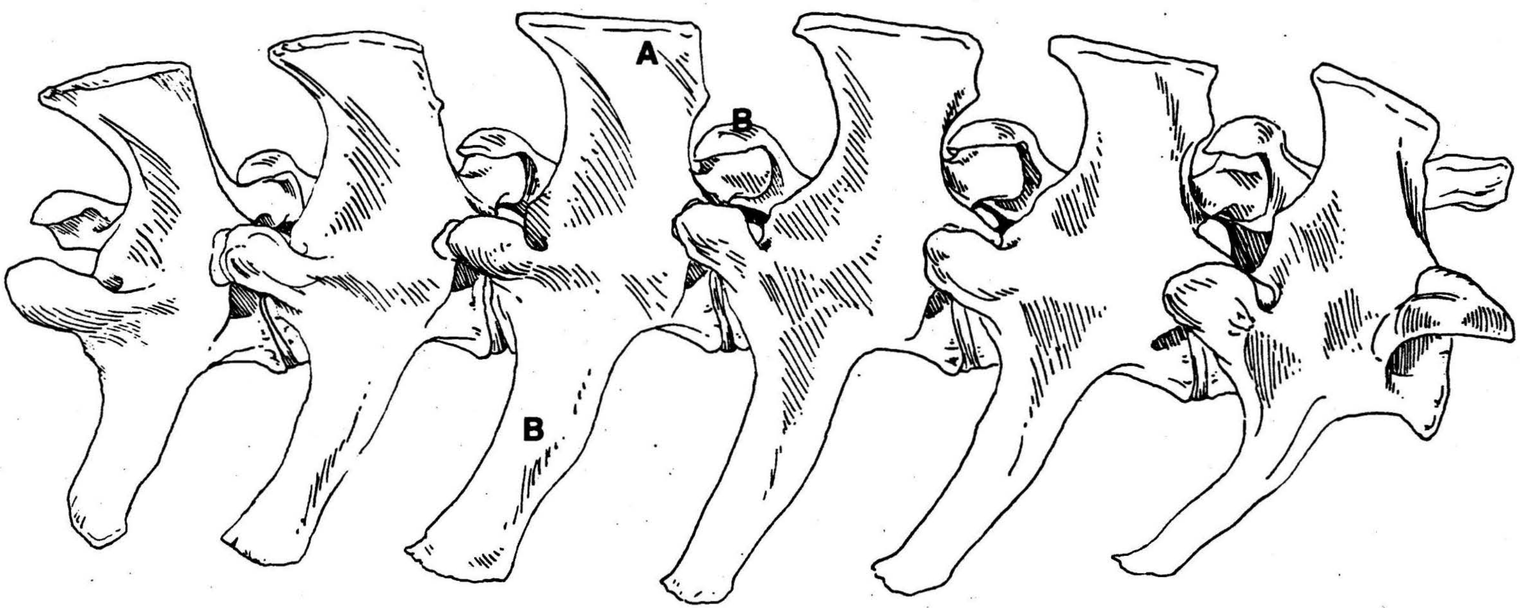
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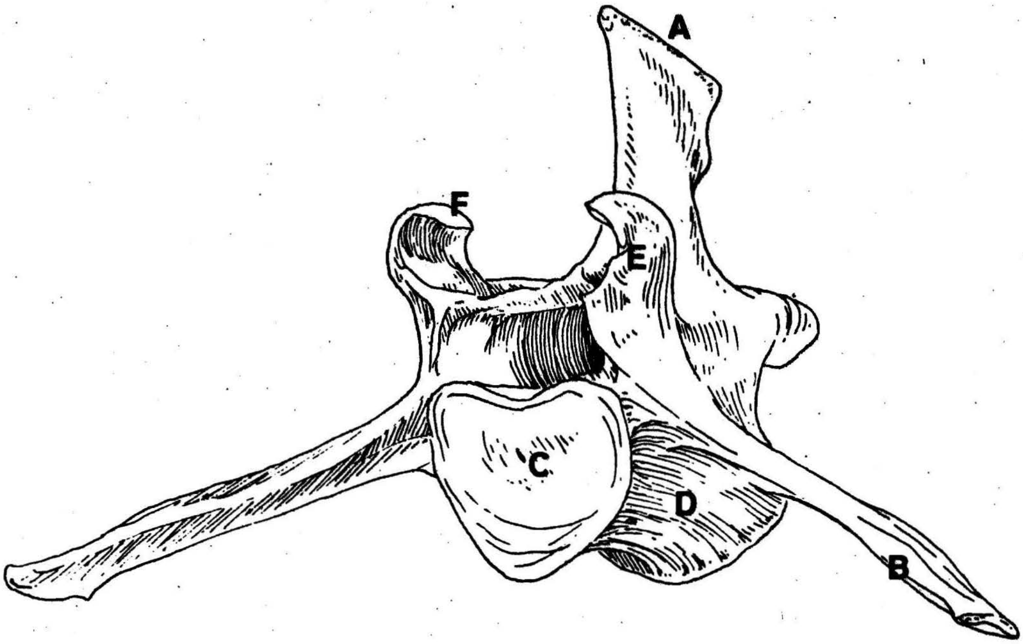
Figure 39-Third Lumbar Vertebra, Cranial Lateral Aspect

A. Spinous process
B. Transverse process
C. Cranial extremity
D. Body
E. Cranial articular process
F. Mamillary process

Figure 40-Third Lumbar Vertebra, Caudal Lateral Aspect

A. Ventral crest
B. Caudal extremity
C. Nutrient foramen
D. Caudal articular process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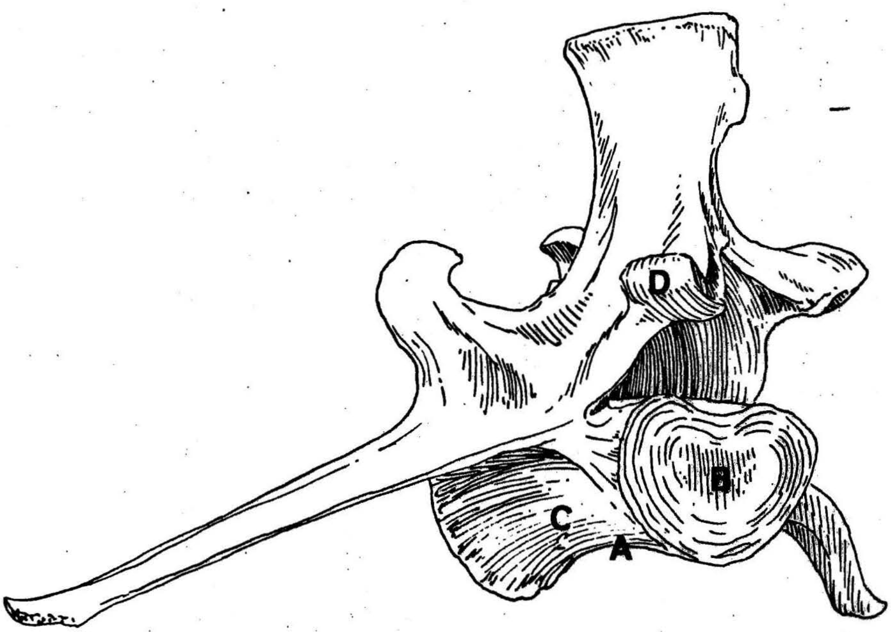
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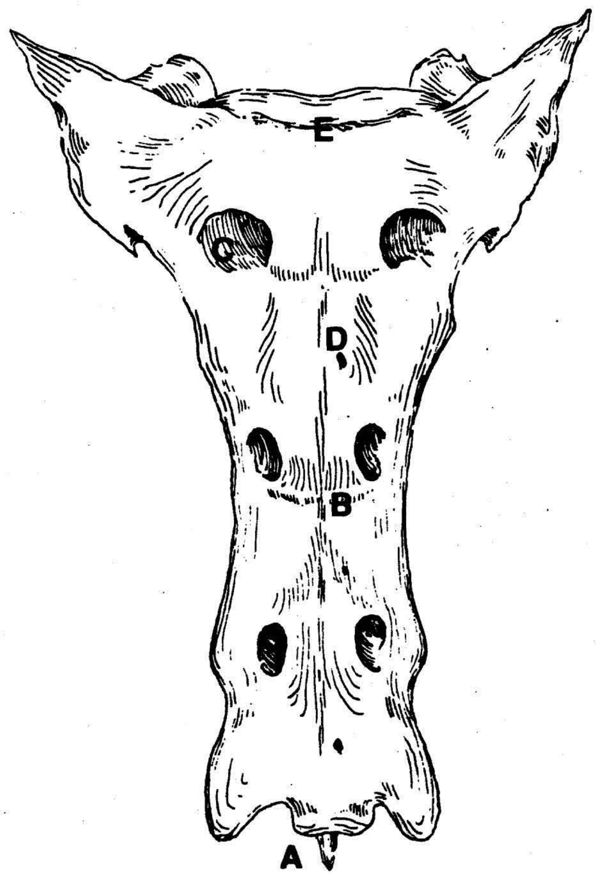
Figure 41-Sacrum, Pelvic Aspect

A. Apex
B. Transverse line
C. Pelvic sacral foramen
D. Nutrient foramen
E. Promontory
F. Caudal extremity

Figure 42-Sacrum, Dorsal Aspect

A. Lateral part
B. Median sacral crest
C. Intermediate sacral crest
D. Dorsal sacral foramen
E. Cranial articular process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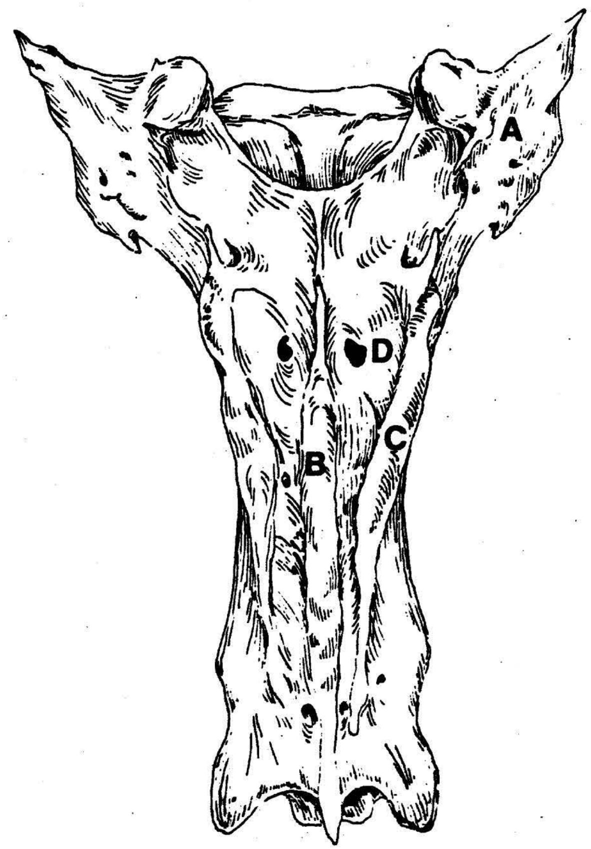
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Figure 43-Sacrum, Cranial Lateral Aspect

A. Base
B. Median sacral crest
C. Intermidiate sacral crest
D. Dorsal sacral foramen
E. Cranial articular process
F. Lateral part
G. Lateral sacral crest
H. Wing
I. Auricular surface
J. Sacral canal

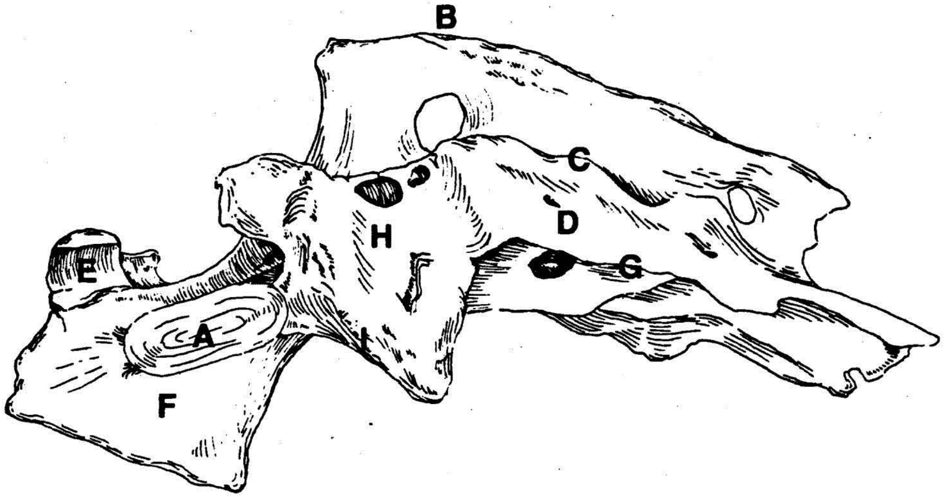
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Figure 44-Coccygeal Vertebrae, Caudal Lateral Aspect of Entire Series

A. Spinous process
B. Transverse process
C. Cranial Articular process
D. Mamillary process

Figure 45-Coccygeal Vertebrae, First, Sixth and Twelfth Enlarged

A. Spinous process
B. Transverse process
C. Caudal extremity
D. Mamilloarticular process

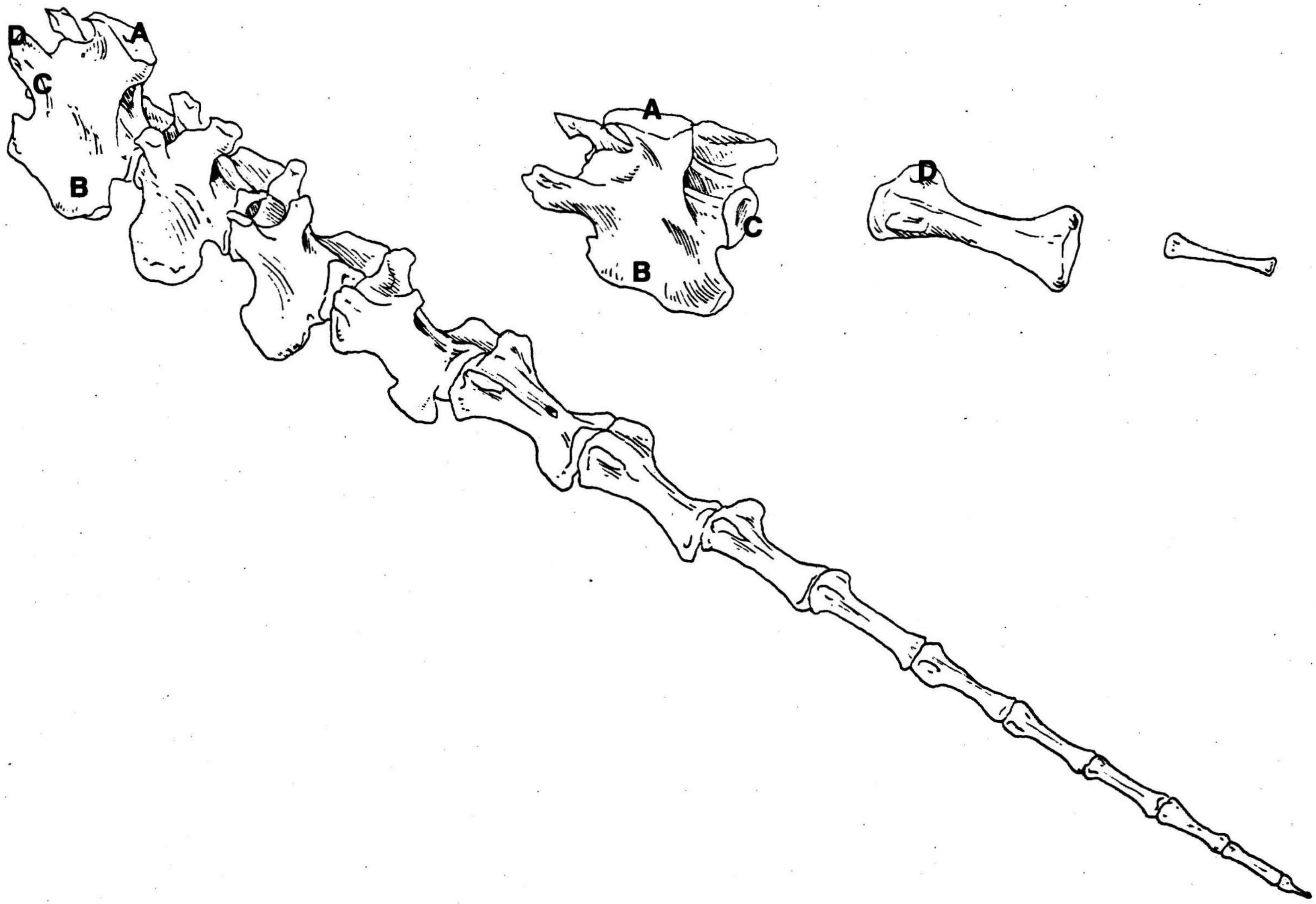
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Figure 46-Bones of the Thorax

A. Ossified portion of rib
B. Costal cartilage
C. Ninth rib
D. Costochondral angle

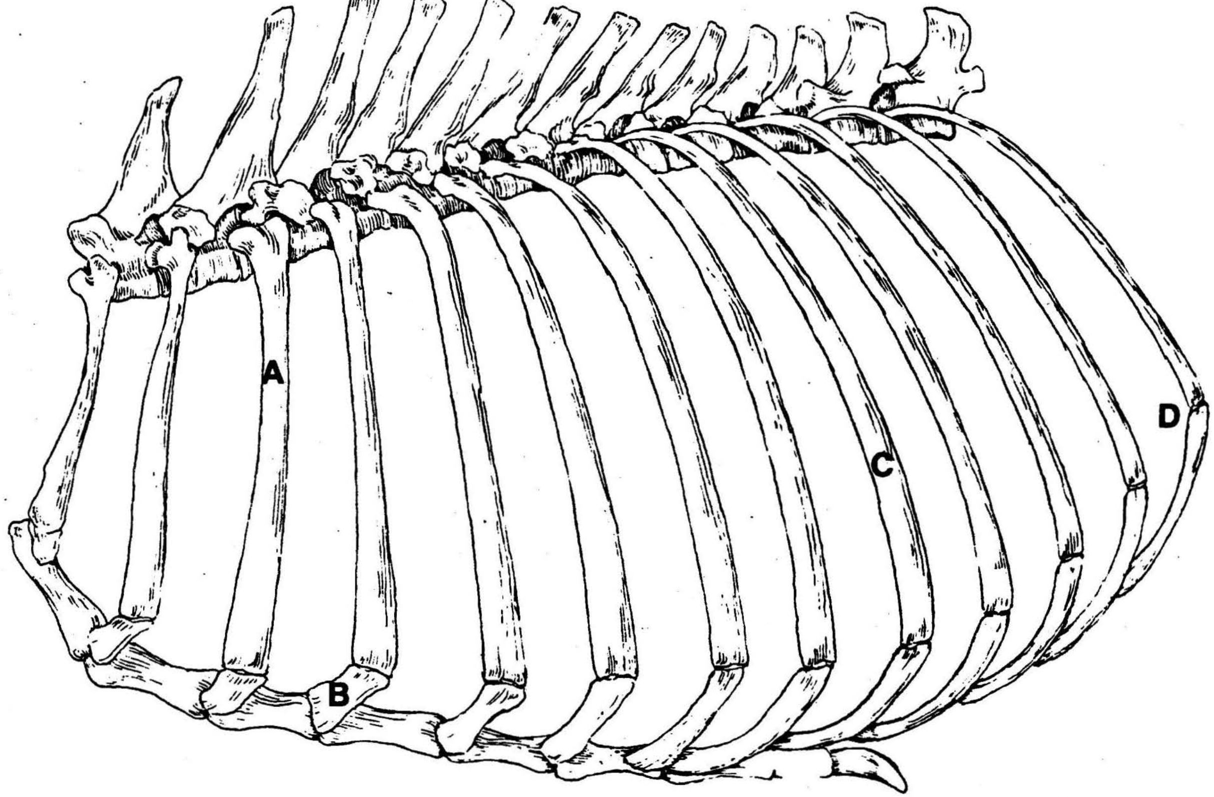
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Figure 47-Left Thirteenth Rib, Medial Aspect

A. Head (Enlarged
B. Neck

Figure 48-Left Seventh Rib, Medial Aspect

A. Costal angle
B. Head
C. Articular surface of head
D. Crest of neck
E. Tubercle
F. Body
G. Costal groove

Figure 49-Left First Rib Medial Aspect

A. Head
B. Articular surface of head
C. Neck
D. Tubercle
E. Body
F. Articular surface of tubercle

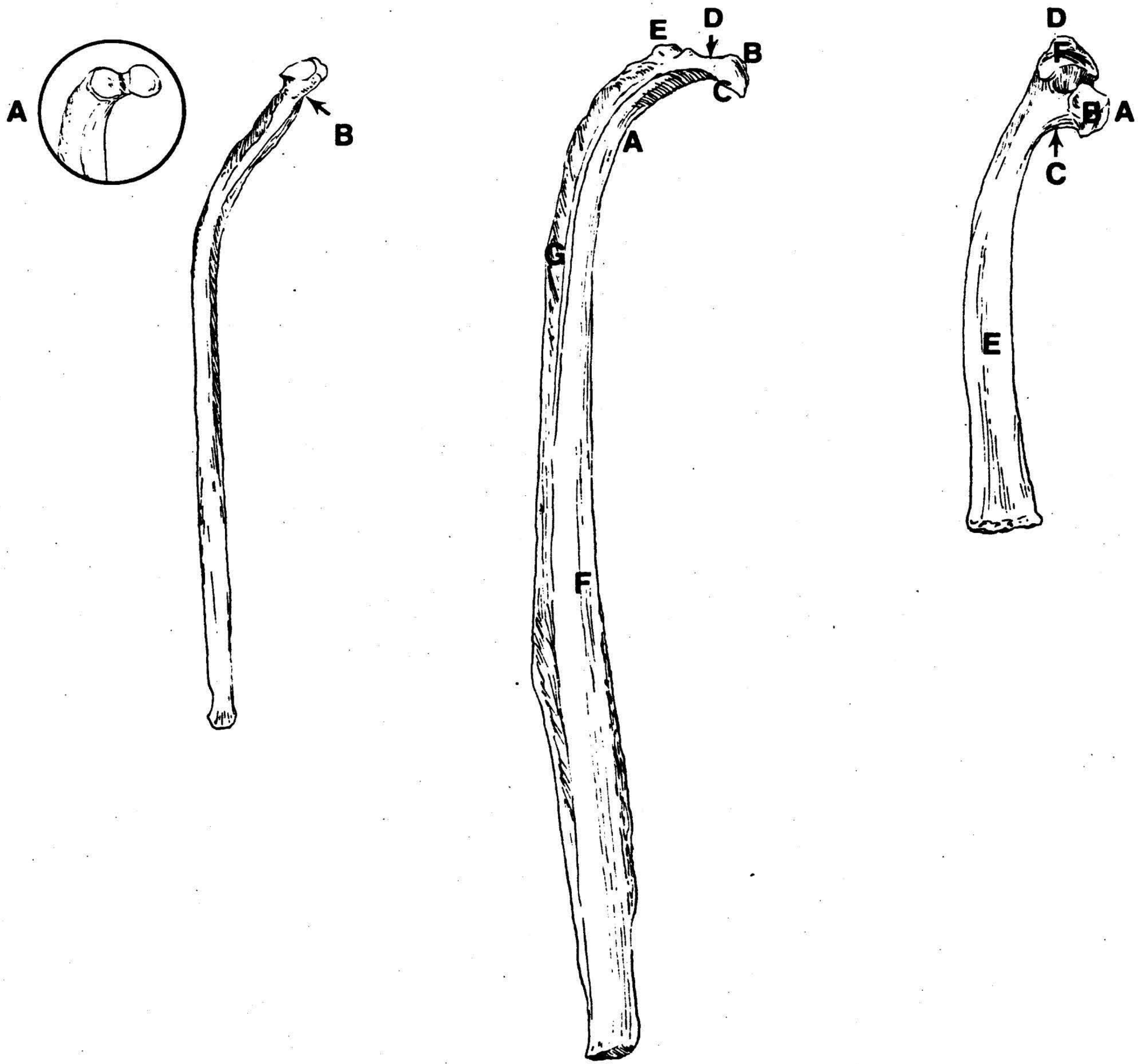
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Figure 50-Sternum, Dorsal Aspect

A. Costal groove
B. Manubrium
C. Xiphoid process
D. Xiphoid cartilage
E. Fifth costal cartilage
F. Sixth costal cartilage
G. Seventh costal cartilage
H. Eighth costal cartilage
I. Ninth costal cartilage

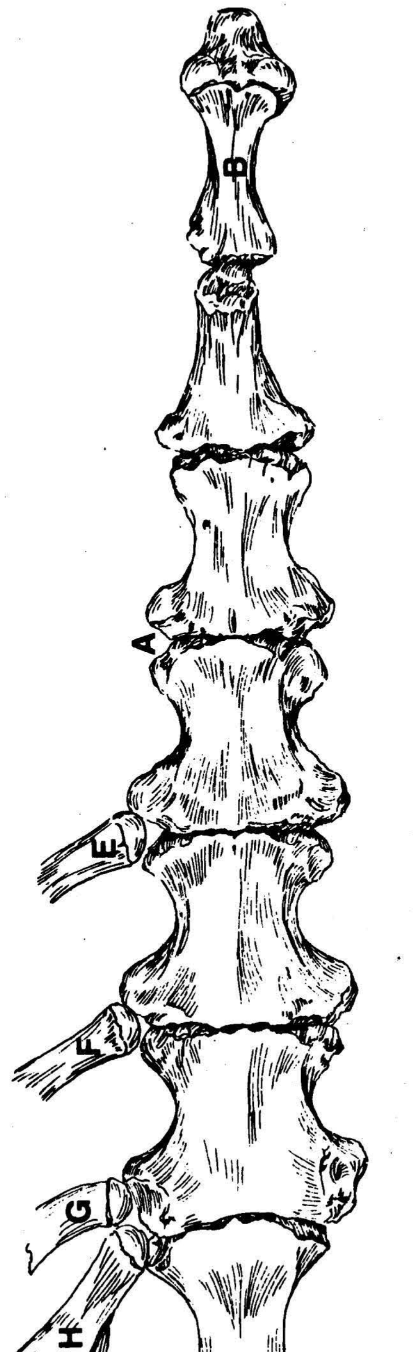
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Figure 51-Left Scapula, Lateral Aspect

A. Spine
B. Nutrient foramen
C. Lateral face
D. Supraspinous fossa
E. Cranial border
F. Infraspinous fossa
G. Dorsal border
H. Neck
I. Tuber spinae
J. Acromion
K. Cranial angle
L. Caudal angle
M. Ventral angle

Figure 52-Left Scapula, Medial Aspect

A. Costal face
B. Serrated face
C. Subscapular fossa
D. Caudal border
E. Subscapular ridge
F. Subscapular groove
G. Glenoid cavity
H. Scapular tuberosity
I. Glenoid notch
J. Coracoid process

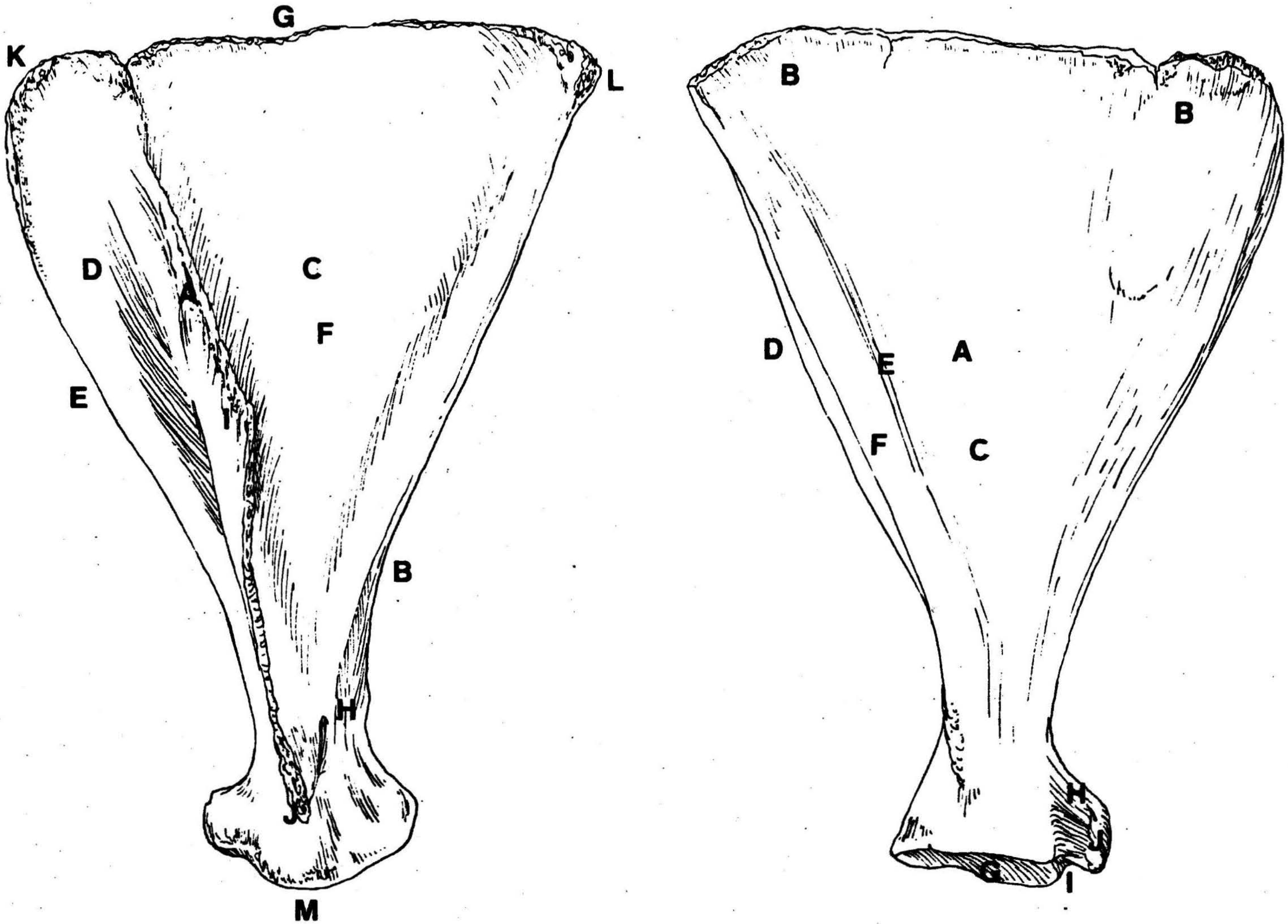
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Figure 53-Right Humerus, Medial Aspect

A. Head
B. Intertuberal groove
C. Crest of minor tubercle
D. Neck
E. Body
F. Minor tubercle
G. Major tubercle
H. Teres tuberosity
I. Medial epicondyle

Figure 54-Right Humerus, Caudal Aspect

A. Head
B. Minor tubercle
C. Major tubercle
D. Pars cranialis
E. Pars caudalis
F. Lateral face
G. Intertuberal groove
H. Musculospiral groove
I. Olecranon fossa
J. Lateral epicondyle
K. Medial epicondyle
L. Lateral epicondyloid crest

Figure 55-Right Humerus, Cranial Aspect

A. Intertuberal groove
B. Crest of major tubercle
C. Lateral face
D. Medial face
E. Deltoid tuberosity
F. Cranial face
G. Humeral crest
H. Condyle
I. Radial fossa
J. Anconeal line

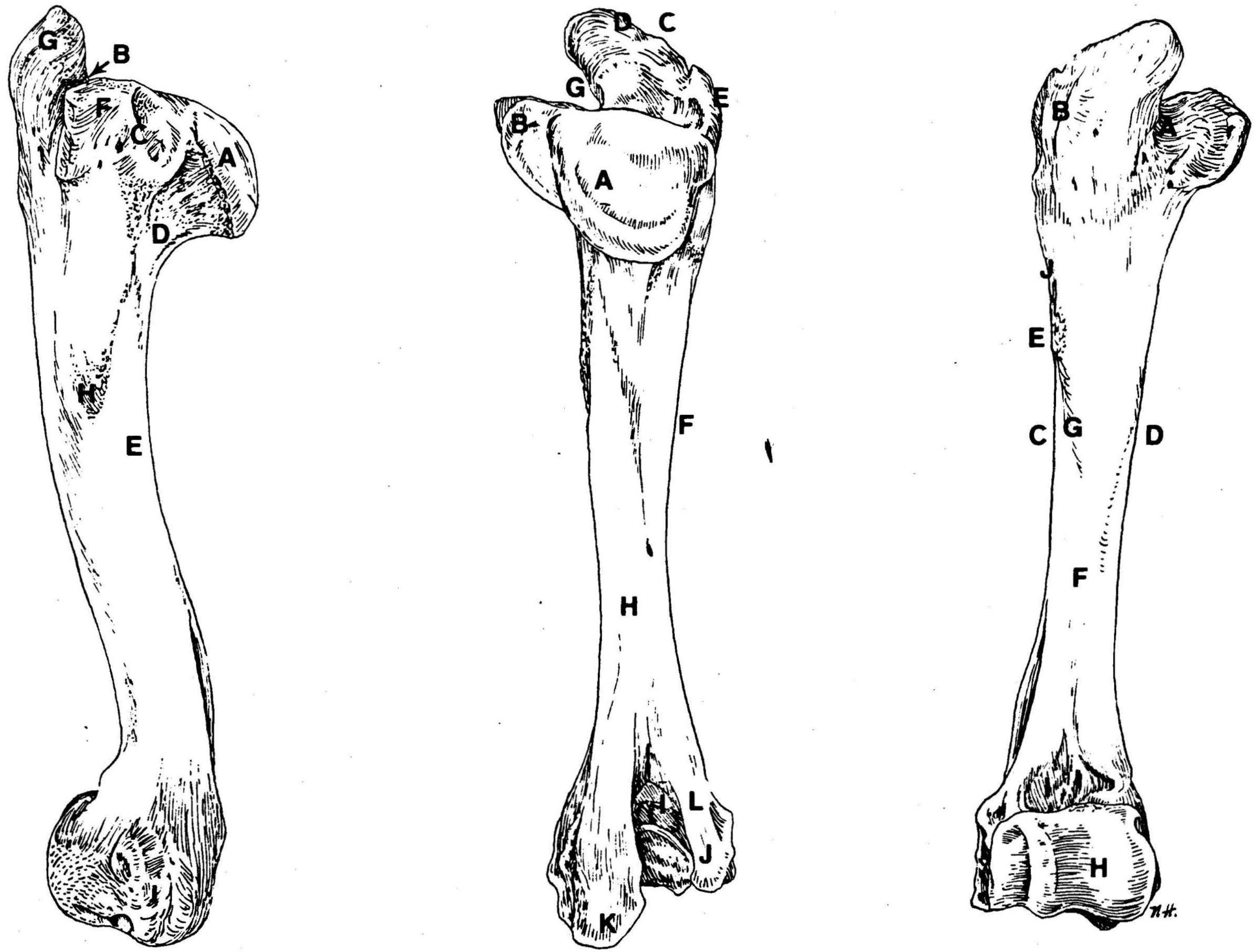

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Figure 56-Right Radius
Cranial Aspect

A. Head
B. Articular surface
C. Medial border
D. Lateral border
E. Radial tuberosity
F. Cranial surface
G. Trochlea
H. Carpal articular surface

Figure 57-Right Radius, Medial Aspect

A. Neck
B. Medial border
C. Body

Figure 58-Right Radius
Caudal Aspect

A. Head
B. Neck
C. Caudal surface
D. Nutrient foramen
E. Transverse crest
F. Medial styloid process

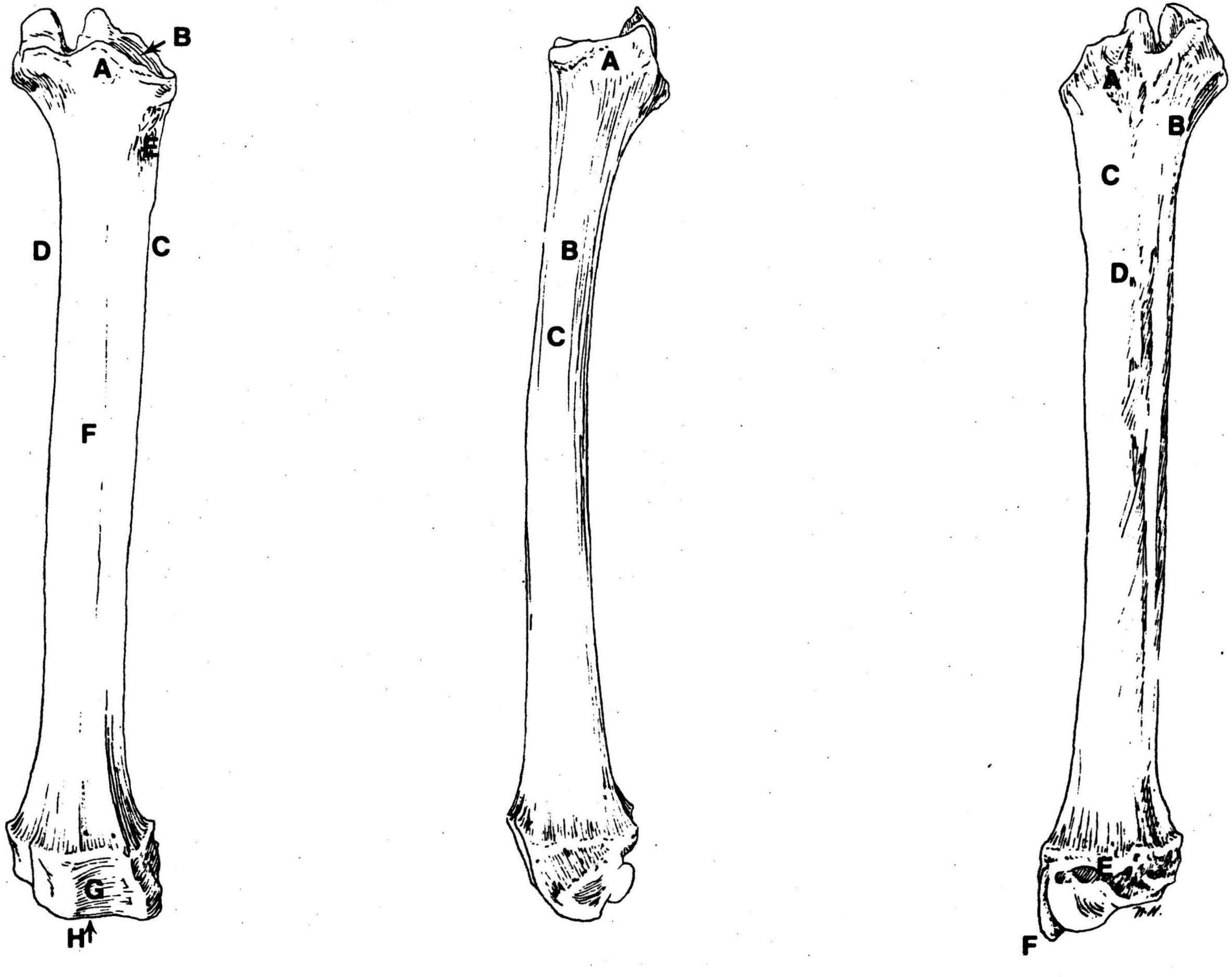
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Figure 59-Right Ulna, Medial Aspect

A. Olecranon
B. Olecranon tuberosity
C. Anconeal process
D. Trochlear notch
E. Caudal border
F. Cranial border
G. Head
H. Styloid process
I. Proximal interosseus space
J. Distal interosseus space

Figure 60-Right Ulna, Cranial Aspect

A. Trochlear notch
B. Medial coronoid process
C. Lateral coronoid process
D. Body
E. Medial face
F. Lateral face
G. Carpal articular face

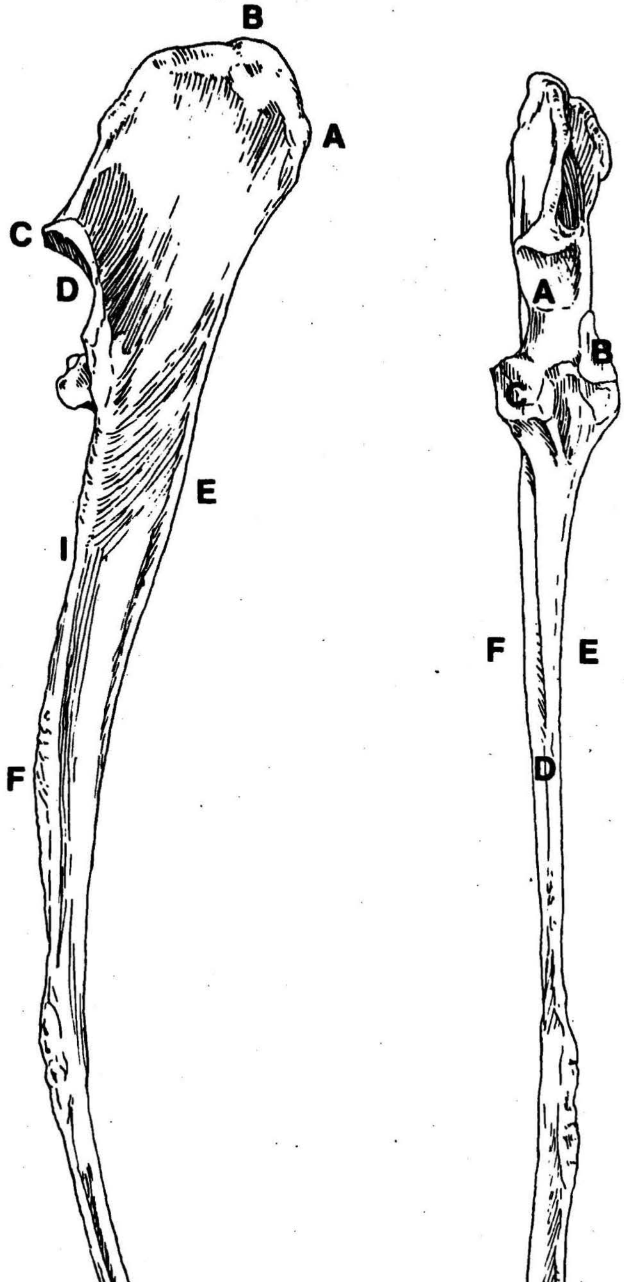
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Figure 61-Right Carpus, Dorsal Medial Aspect

A. Radial carpal bone
B. Intermediate carpal bone
C. Ulnar carpal bone
D. First carpal bone
E. Second and third carpal bones
F. Hamate

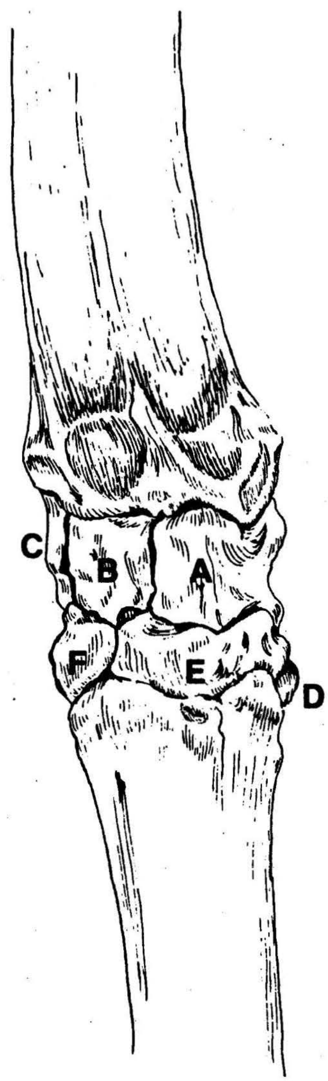
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Figure 62-Right carpus, Palmar Lateral Aspect

A. Accessory carpal bone
B. Radial carpal bone
C. Intermediate carpal bone
D. Ulnar carpal bone
E. First carpal bone
F. Second and third carpal bones
G. Hamate
H. Radius
I. Ulna

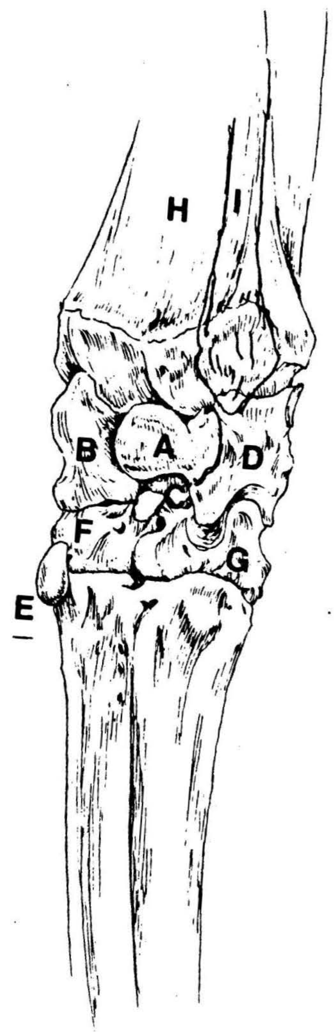
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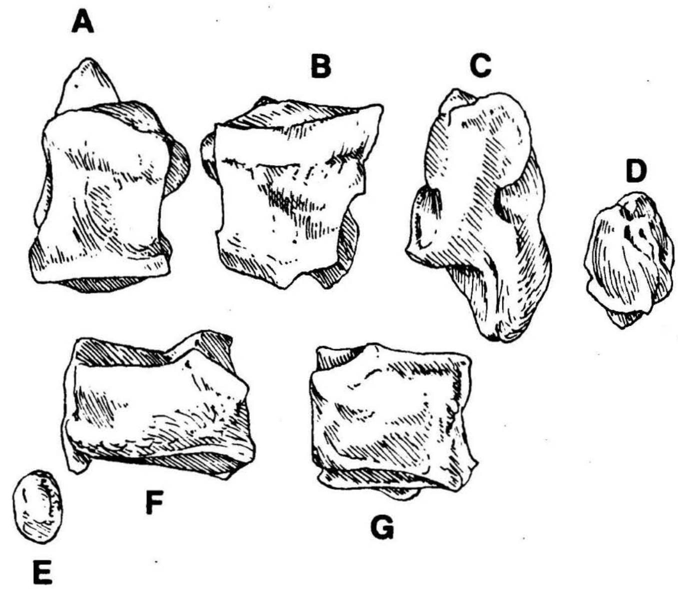
Figure 63-Left Carpus, Dorsal Aspect

A. Radial carpal bone
B. Intermediate carpal bone
C. Ulnar carpal bone
D. Accessory carpal bone
E. First carpal bone
F. Second and third carpal bones
G. Hamate

Figure 64-Left Carpus, Palmar Aspect

A. Radial carpal bone
B. Intermediate carpal bone
C. Ulnar carpal bone
D. Accessory carpal bone
E. First carpal bone
F. Second and third carpal bones
G. Hamate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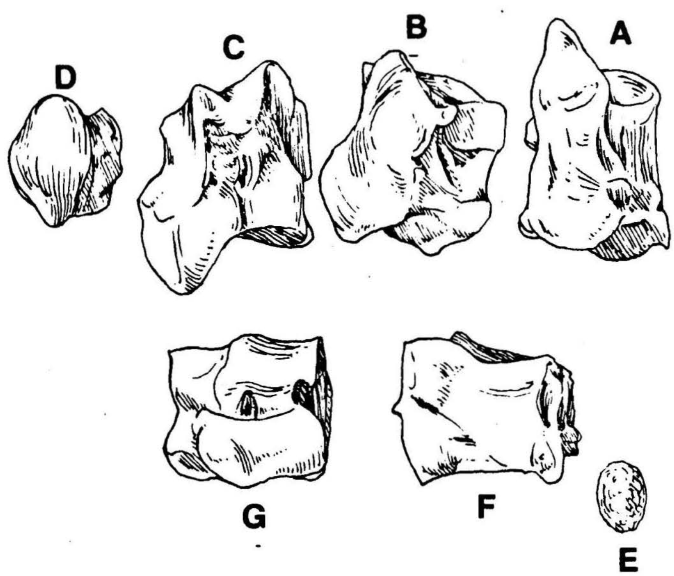
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Figure 65-Right Large Metacarpal Bone, Palmar Aspect

A. Base
B. Articular Surface
C. Proximal vascular canal
D. Palmar surface
E. Head
F. Intertrochlear notch

Figure 66-Right Large Metacarpal Bone, Dorsal Aspect

A. Base
B. Dorsal surface
C. Medial border
D. Lateral border
E. Dorsal longitudial groove
F. Distal vascular canal

Figure 67-Right Large Metacarpal Bone, Lateral Aspect

A. Shaft
B. Dorsal surface

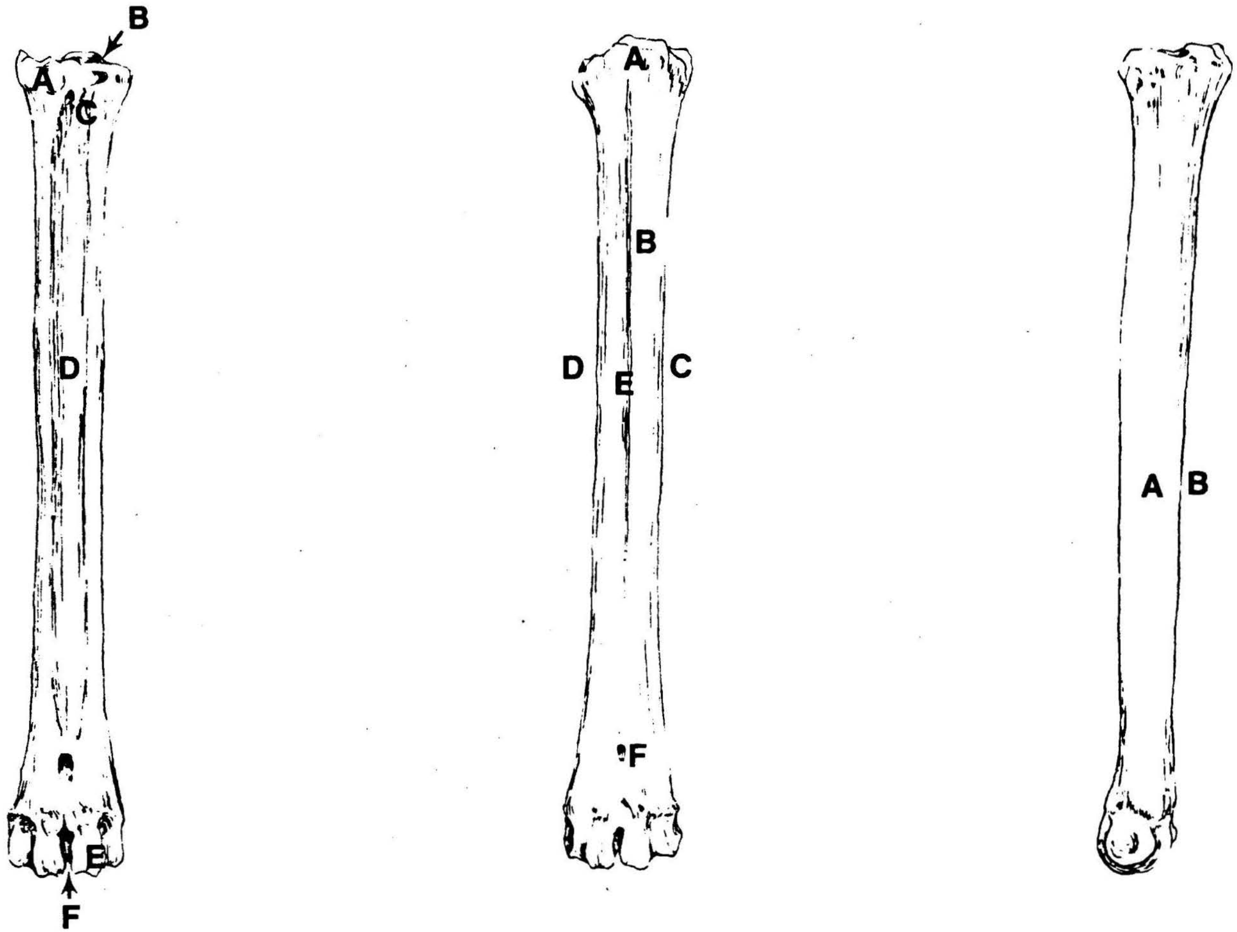
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Figure 68-Right Fourth Digit, Dorsal Aspect

A. Proximal phalanx
B. Middle phalanx
C. Distal phalanx
D. Base
E. Body
F. Trochlea
G. Proximal surface
H. Axial surface
I. Dorsal margin
J. Parietal surface

Figure 69-Right Fourth Digit, Lateral Aspect

A. Base
B. Trochlea
C. Body
D. Proximal articular surface
E. Extensor process
F. Flexor tubercle
G. Extensor process

Figure 70-Right Fourth Digit, Palmar Aspect

A. Sesamoid articular face
B. Apex
C. Solar border
D. Articular surface
E. Sole surface

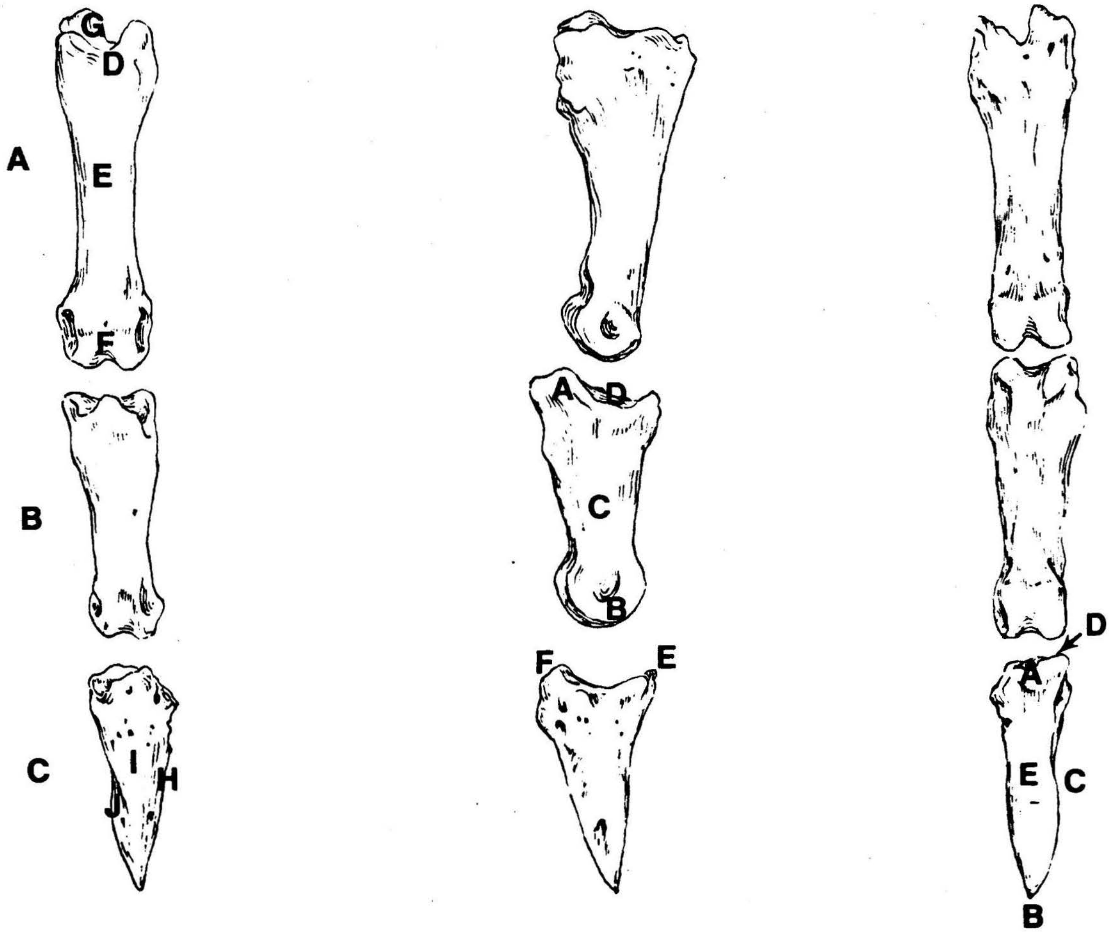

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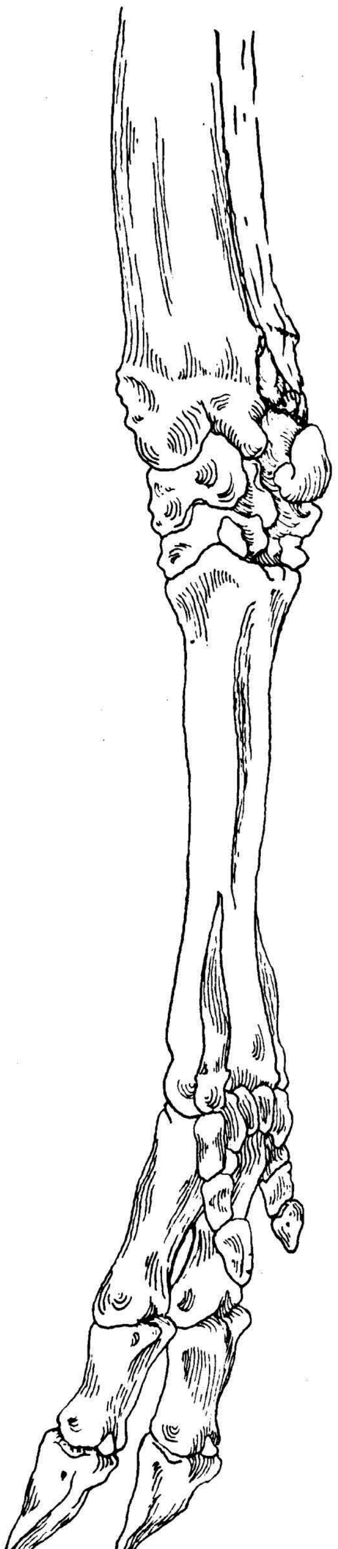
Figure 71-Right Manus, Palmar Medial Aspect

Figure 72-Left Pes, Palmar Lateral Aspect



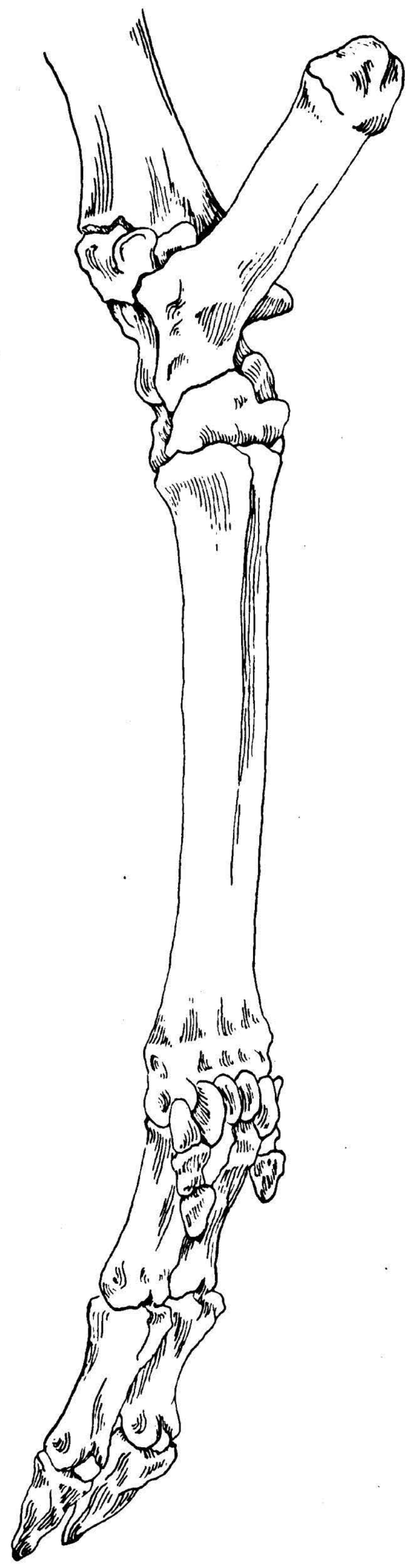
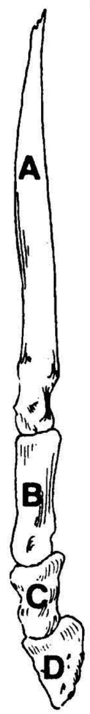


Figure 73-Minor Digit of the Manus

A. Small metacarpal bone
B. Proximal phalanx
C. Middle phalanx
D. Distal phalanx

Figure 74-Minor Digit of the Pes

A. Proximal phalanx
B. Middle phalanx
C. Distal phalanx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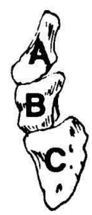
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Figure 75-Sesamord Bones of the Manus
Proximal Sesamoid Bones

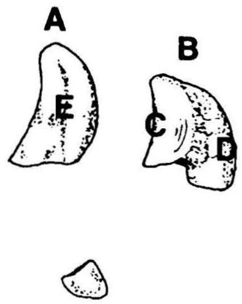
A. Axial sesamoid bone
B. Abaxial sesamoid bone
C. Articular surface
D. Flexor face
E. Interosseous muscle face

Distal Sesamoid Bone, Flexor Surface

Figure 76-Sesamoid Bones of the Pes
Proximal Sesamoid Bones

A. Axial sesamoid bone
B. Abaxial sesamoid bone
C. Articular surface
D. Flexor face
E. Interosseous muscal face

Distal Sesamoid Bone, Flexor Surface
(Enlarged view shows articular face)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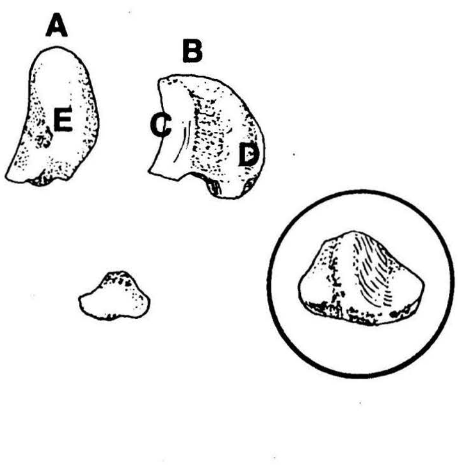
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Figure 77-Ossa Coxarum, Ventral Aspect

A. Ilium
B. Ischium
C. Pubis
D. Acetabulum
E. Lunate surface
F. Body of pubis
G. Caudal branch of pubis
H. Lateral branch of pubis
I. Pectin
J. Iliopectineal eminence
K. Interischial bone
L. Symphyseal crest

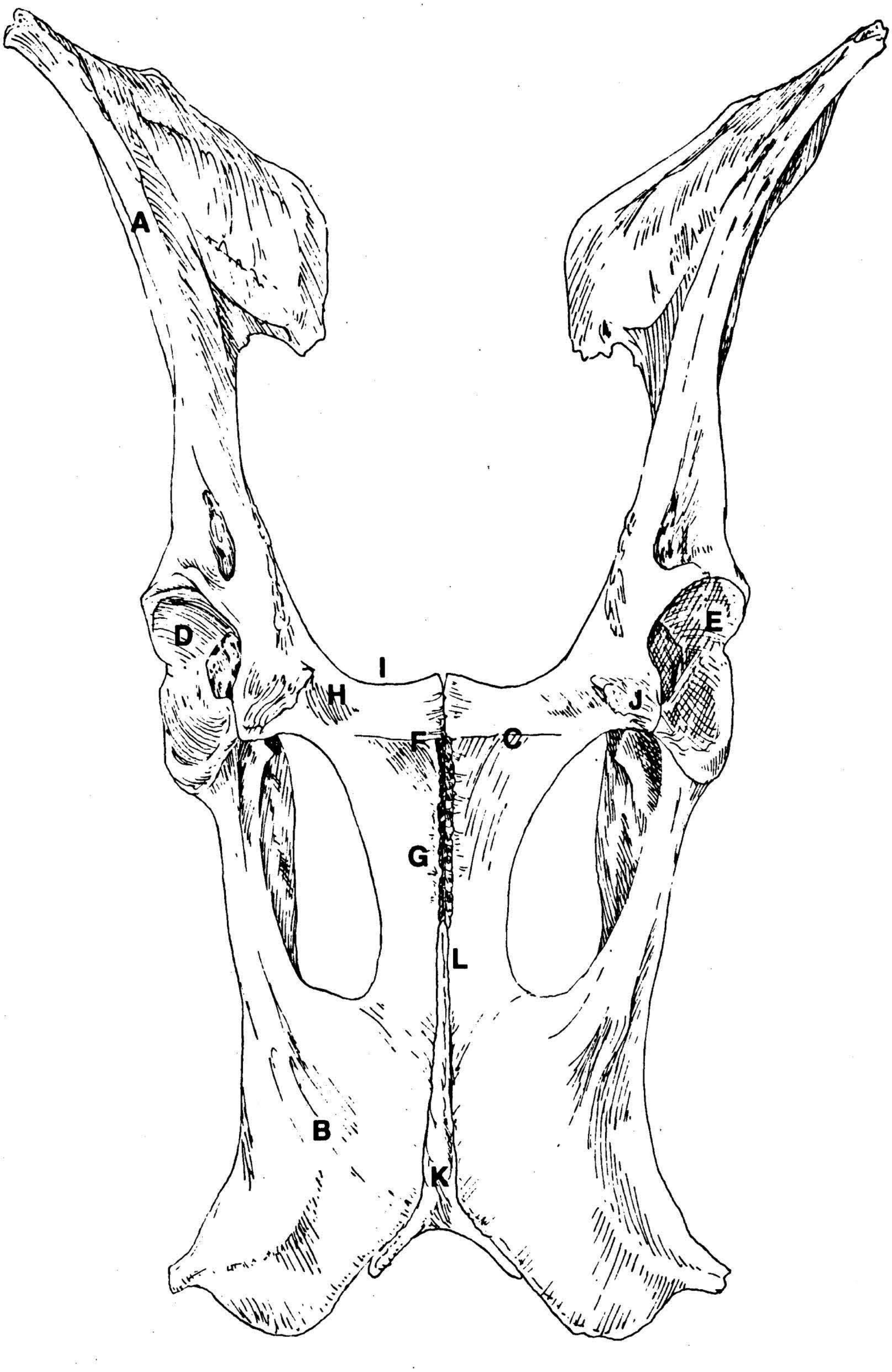
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Figure 78-Ossa Coxarum, Dorsal Aspect

A. Ilium
B. Ischium
C. Pubis
D. Ischiadic symphysis
E. Tuber ischiadicum
F. Body of ischium
G. Ischiadic spine
H. Ischiadic table
I. Ischiadic arch
J. Obturator groove
K. Obturator foramen

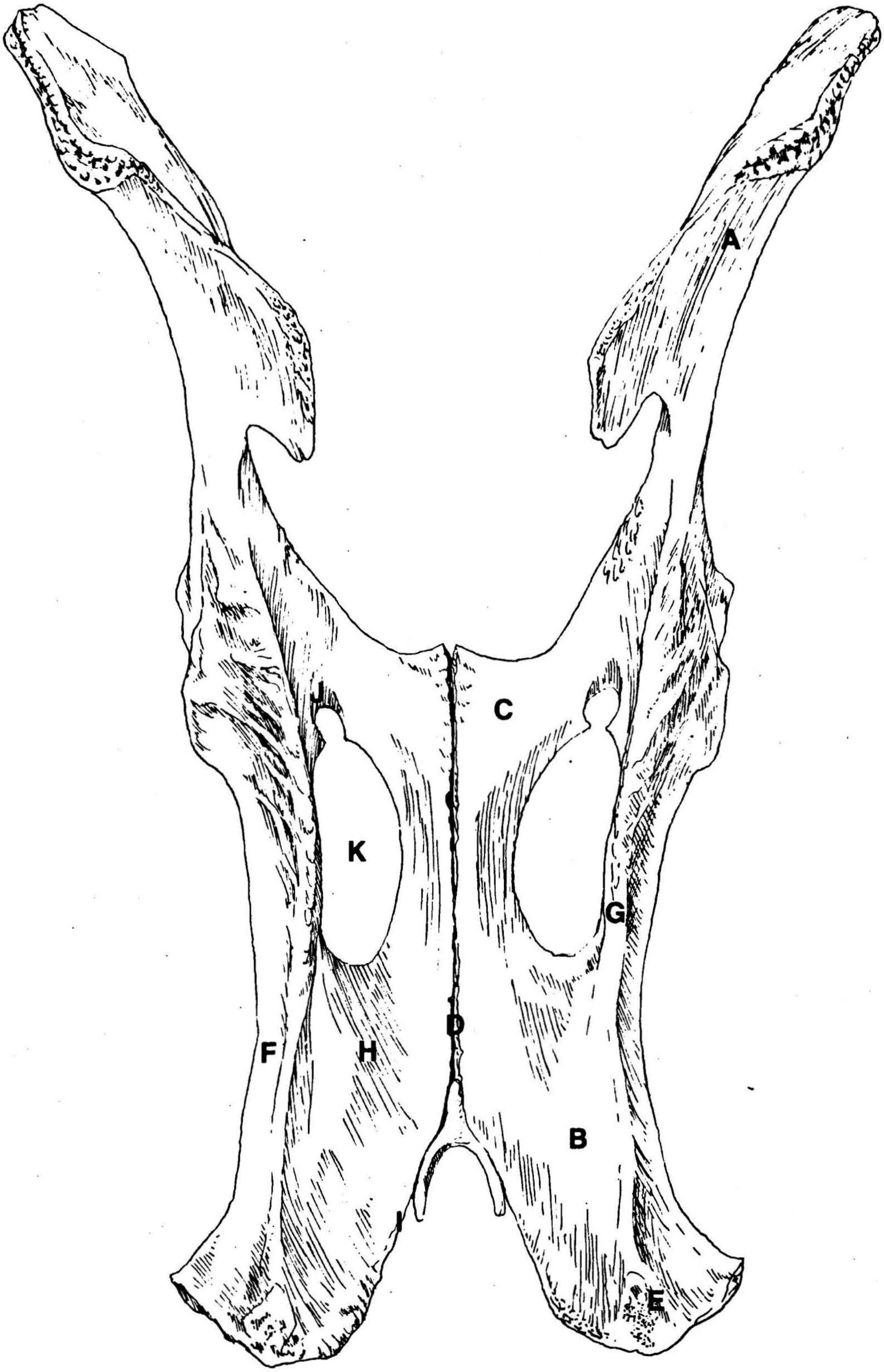
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Figure 79-Ossa Coxarum, Cranial Lateral Aspect

A. Ilium
B. Ischium
C. Pubis
D. Wing of ilium
E. Gluteal surface
F. Sacropelvic surface
G. Gluteal line
H. Tuber coxae
I. Cranial ventral iliac spine
J. Cranial dorsal iliac spine
K. Tuber sacrale
L. Caudal dorsal iliac spine
M. Greater sciatic notch
N. Iliac crest
O. Auricular surface
P. Iliac face
Q. Body of ilium
R. Ischiadic spine
S. Linea arcuata
T. Acetabulum
U. Lunate surface
V. Lesser sciatic notch
W. Acetabular notch
X. Acetabular fossa

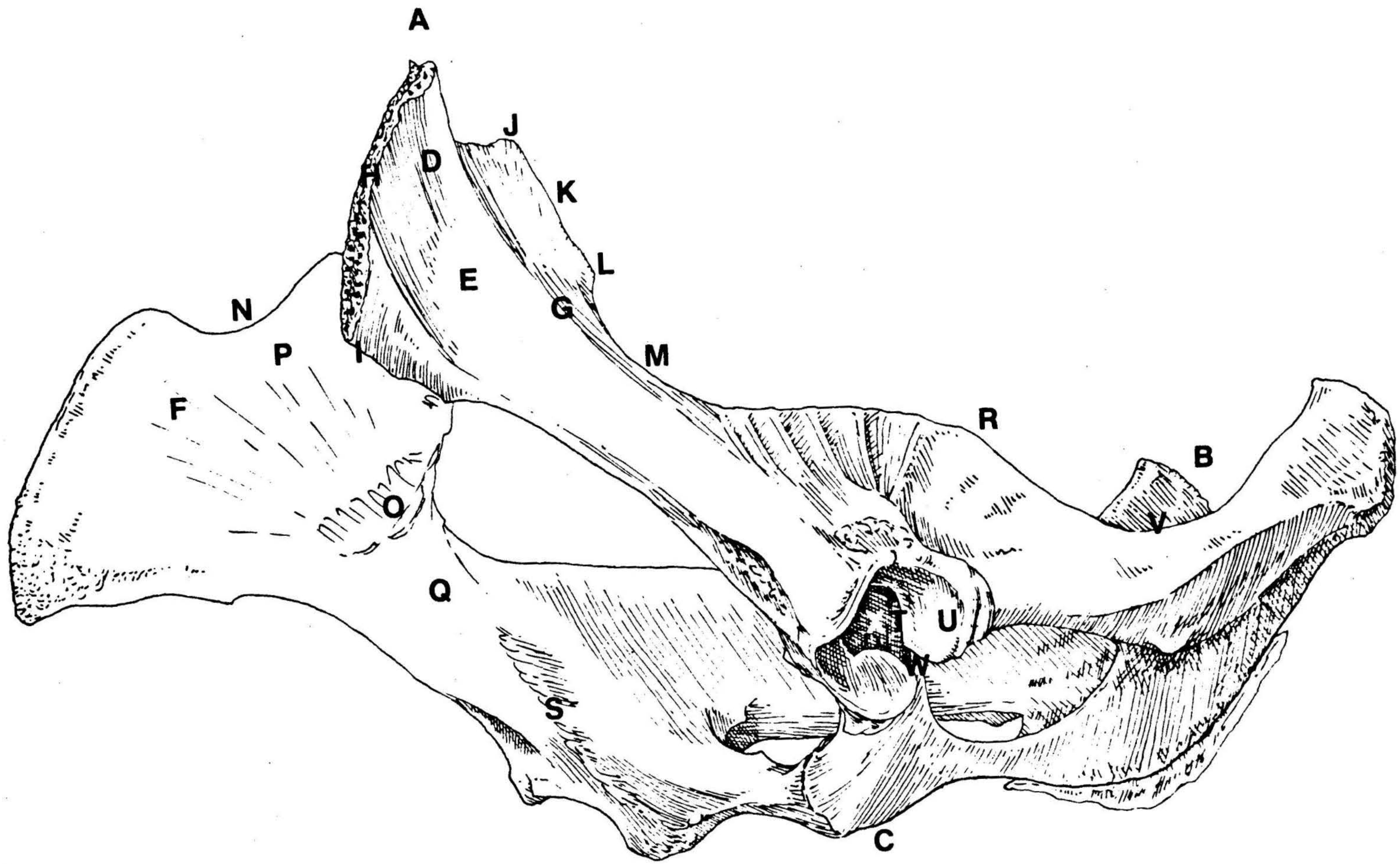
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Figure 80-Symphyseal faces of male and female os coxae

A. Female
B. Male

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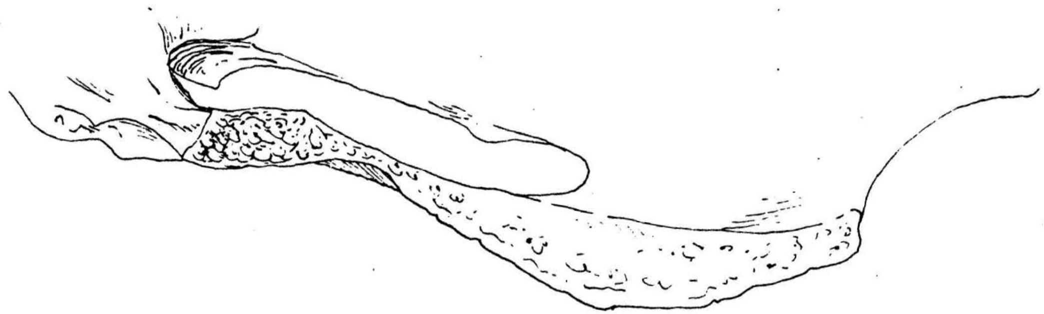

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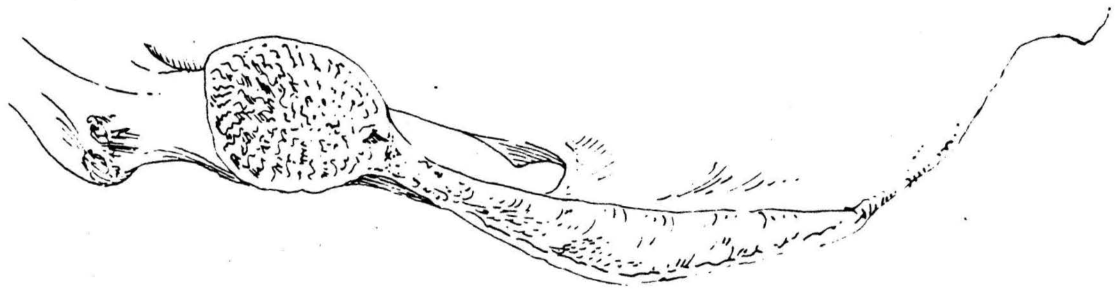


Figure 81-Left Femur
Cranial Aspect

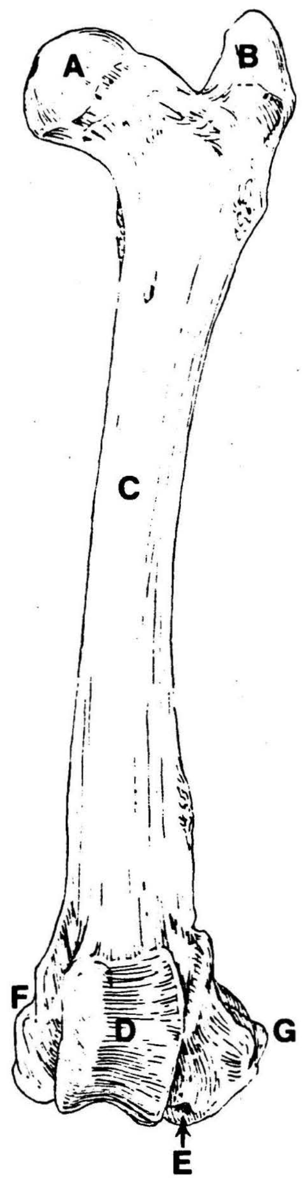
A. Head
B. Trochanter major
C. Body
D. Trochlea
E. Extensor fossa
F. Medial epicondyle
G. Lateral epicondyle

Figure 82-Left Femur, Caudal
Aspect

A. Trochanter major
B. Neck
C. Trochanteric fossa
D. Intertrochanteric crest
E. Trochanter minor
F. Intertrochanteric line
G. Facies aspera
H. Lateral supracondylar tuberosity
I. Lateral lip
J. Medial lip
K. Medial supracondylar tuberosity
L. Supracondylar fossa
M. Popliteal surface
N. Intercondylar line
O. Lateral condyle
P. Medial condyle
Q. Intercondylar fossa

Figure 83-Left Femur,
Medial Aspect

A. Fovea
B. Trochanteric notch
C. Medial epicondyle
D. Intertrochanteric line



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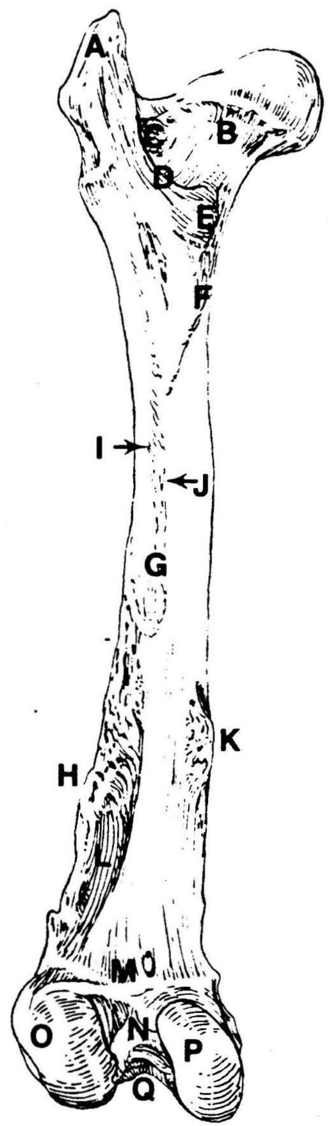

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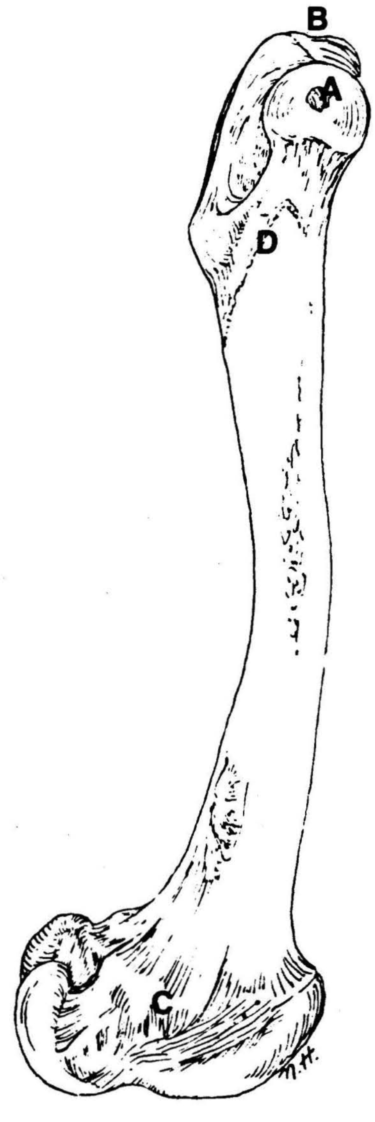

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Figure 84-Right Patella, Cranial Aspect

A. Base
B. Apex
C. Cranial face

Figure 85-Right Patella, Articular Face

A. Base
B. Apex
C. Articular face

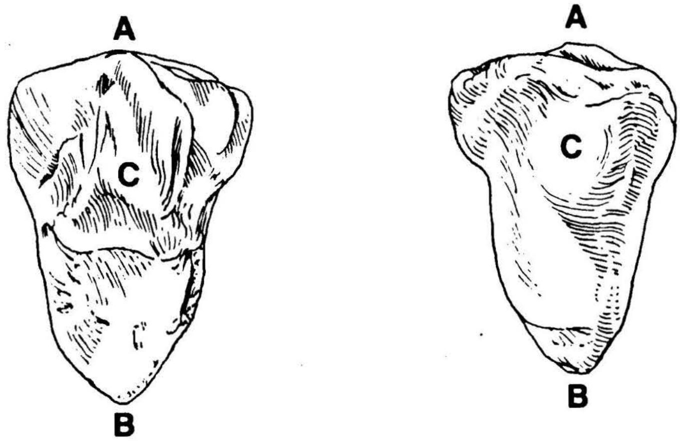
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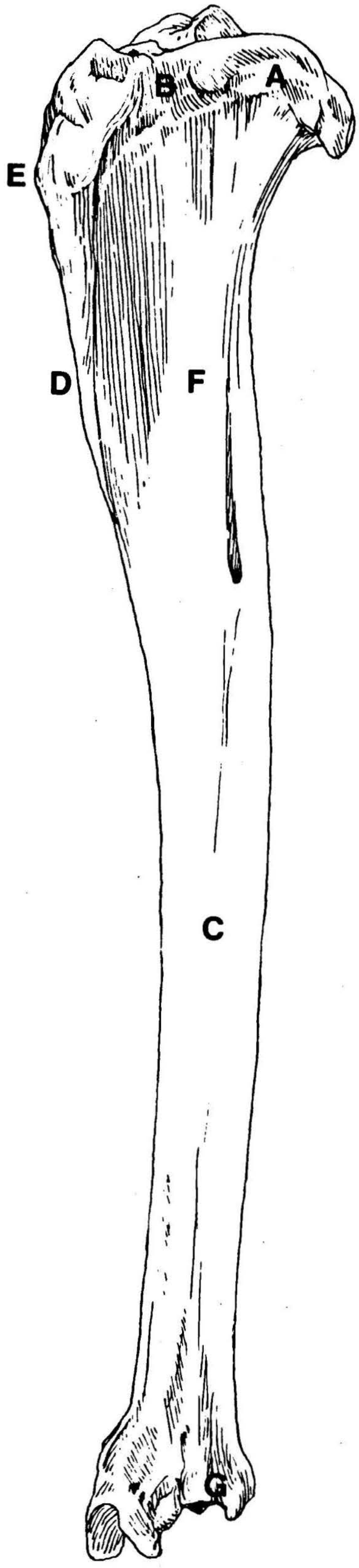
Figure 86-Left Tibia, Lateral Aspect

A. Lateral condyle
B. Extensor groove
C. Body
D. Cranial margin
E. Tibial tuberosity
F. Lateral face
G. Fibular notch

Figure 87-Left Tibia, Cranial Aspect

A. Medial intercondylar tubercle
B. Lateral intercondylar tubercle
C. Medial margin
D. Lateral margin
E. Medial face
F. Medial malleolus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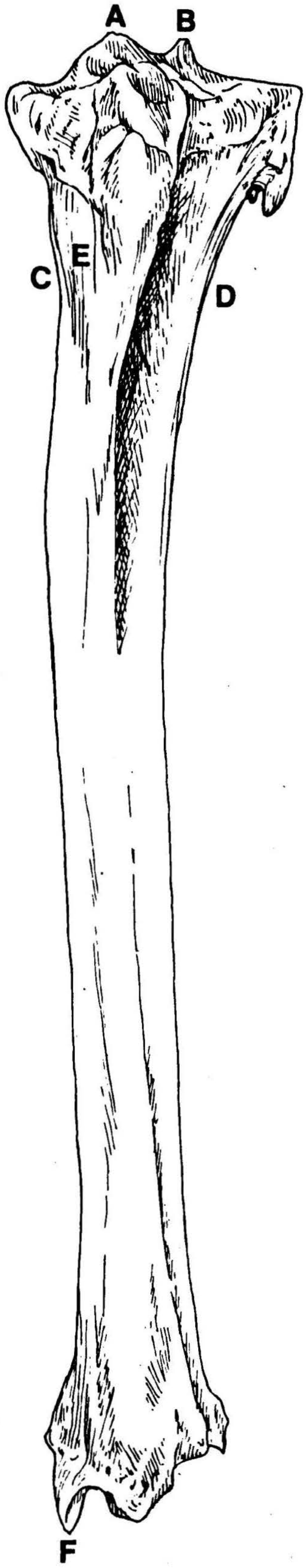
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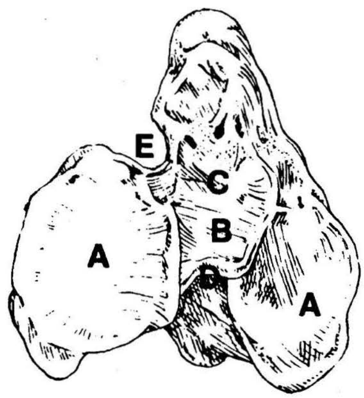
Figure 88-Left Tibia,
Proximal Surface

A. Proximal articular face
B. Central intercondylar area
C. Cranial intercondylar area
D. Caudal intercondylar area
E. Extensor groove

Figure 89-Left Tibia
Caudal Aspect

A. Medial condyle
B. Intercondylar eminence
C. Popliteal notch
D. Caudal face
E. Popliteal line
F. Cochlea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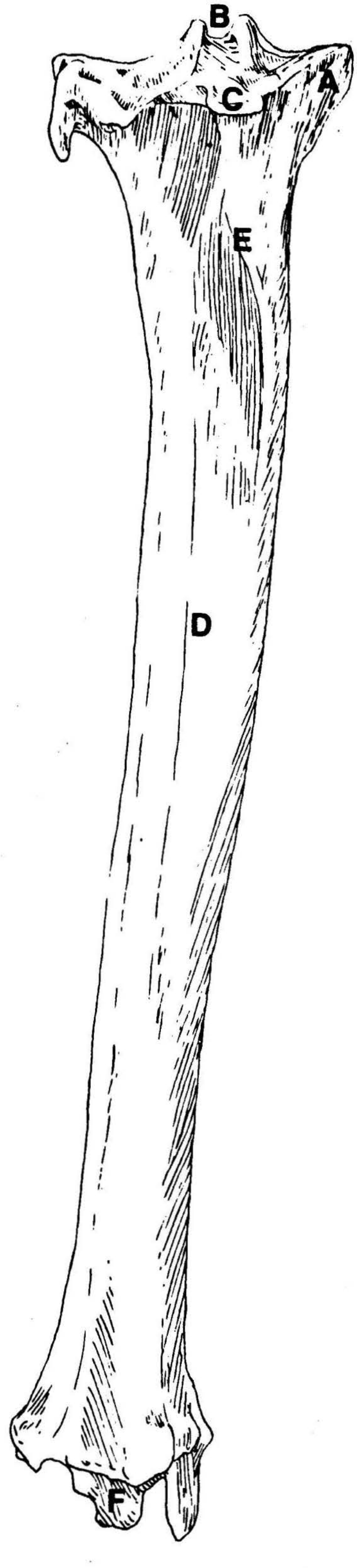
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Figure 90- Left Fibula, Lateral Aspect

A. Head
B. Body
C. Lateral malleolus
D. Malleolar groove

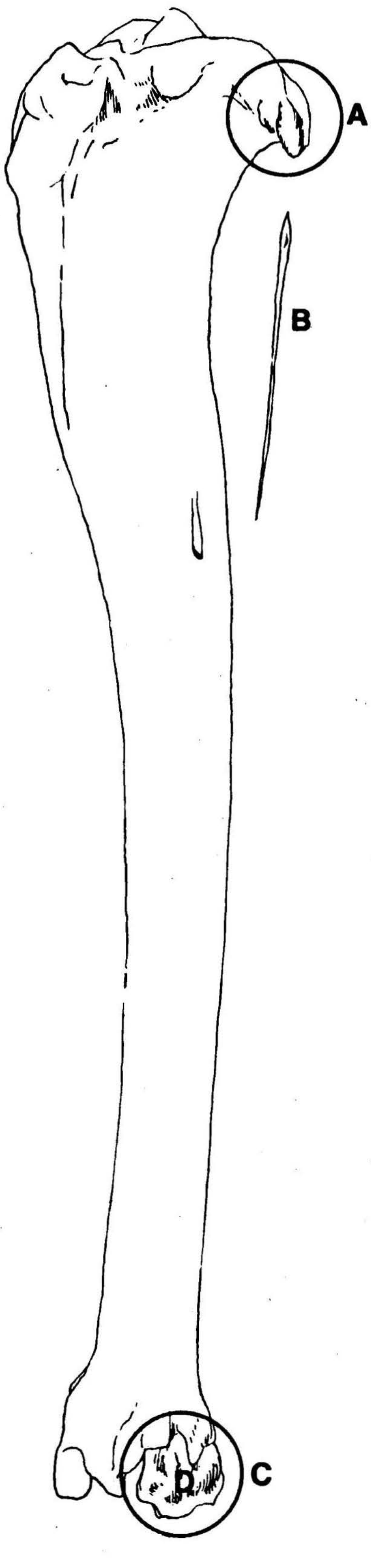
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Figure 91-Left Tarsus, Dorsal lateral Aspect

A. Lateral malleolus
B. Tibial tarsal bone
C. Fibular Tarsal bone
D. Central and fourth tarsal bones
E. Second and third tarsal bones
F. Tarsal sinus

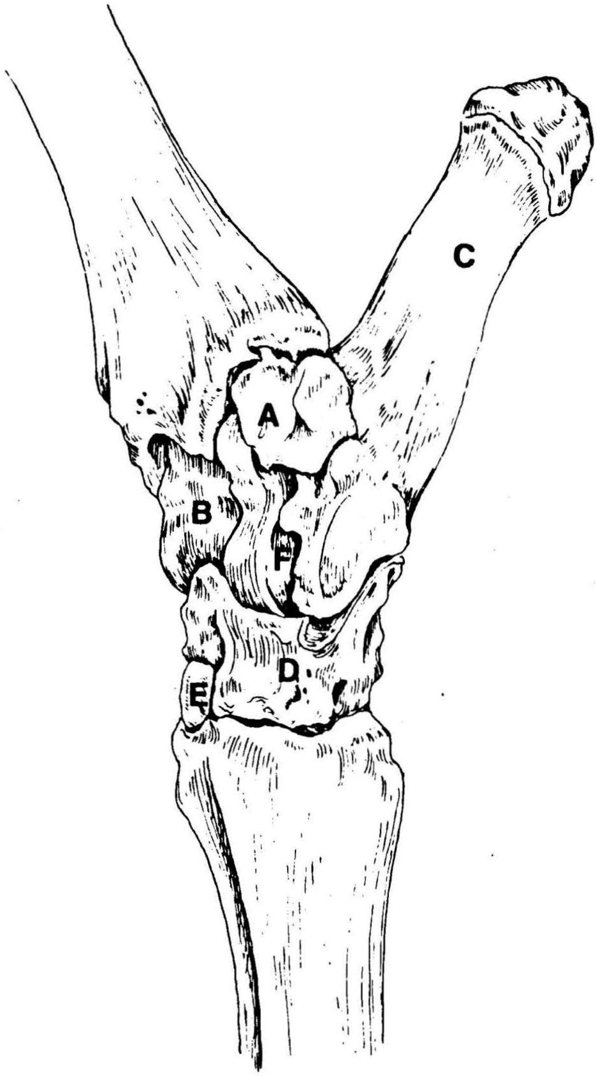
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Figure 92-Left Tarsus, Plantar medial Aspect

A. Medial malleolus
B. Fibular tarsal bone
C. Tibial tarsal bone
D. Central and fourth tarsal bones
E. Second and third tarsal bones
F. First tarsal bone

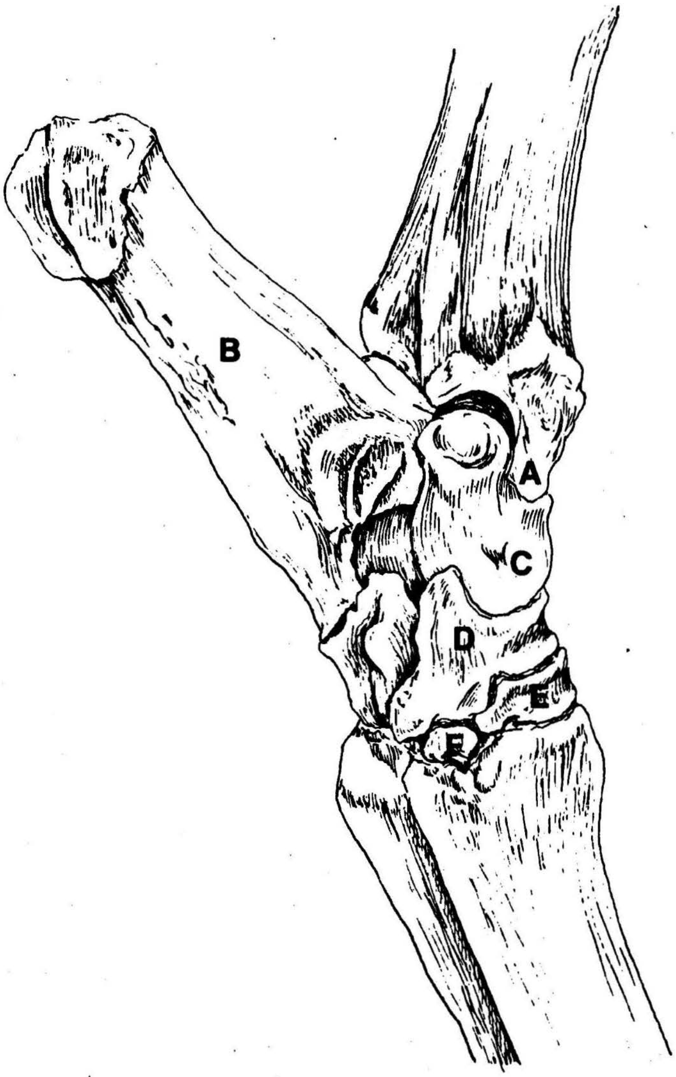
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Figure 93-Right Tarsus, Dorsal Aspect

A. Fibular tarsal bone
B. Tuber calcis
C. Sustentaculum tali
D. Coracoid process
E. Malleolar surface
F. Calcaneal groove
G. Tibial tarsal bone
H. Body
I. Proximal trochlea
J. Neck
K. Head
L. Distal trochlea
M. Central and fourth tarsal bones
N. Second and third tarsal bones
O. First tarsal bone

Figure 94-Right Tarsus, Plantar Aspect

A. Fibular tarsal bone
B. Tuber calcis
C. Groove for flexor hallicus longus m.
D. Tibial tarsal bone
E. Body
F. Proximal trochlea
G. Calcaneal articular face
H. Sulcus tali
I. Central and fourth tarsal bones
J. Second and third tarsal bones
K. First tarsal bone

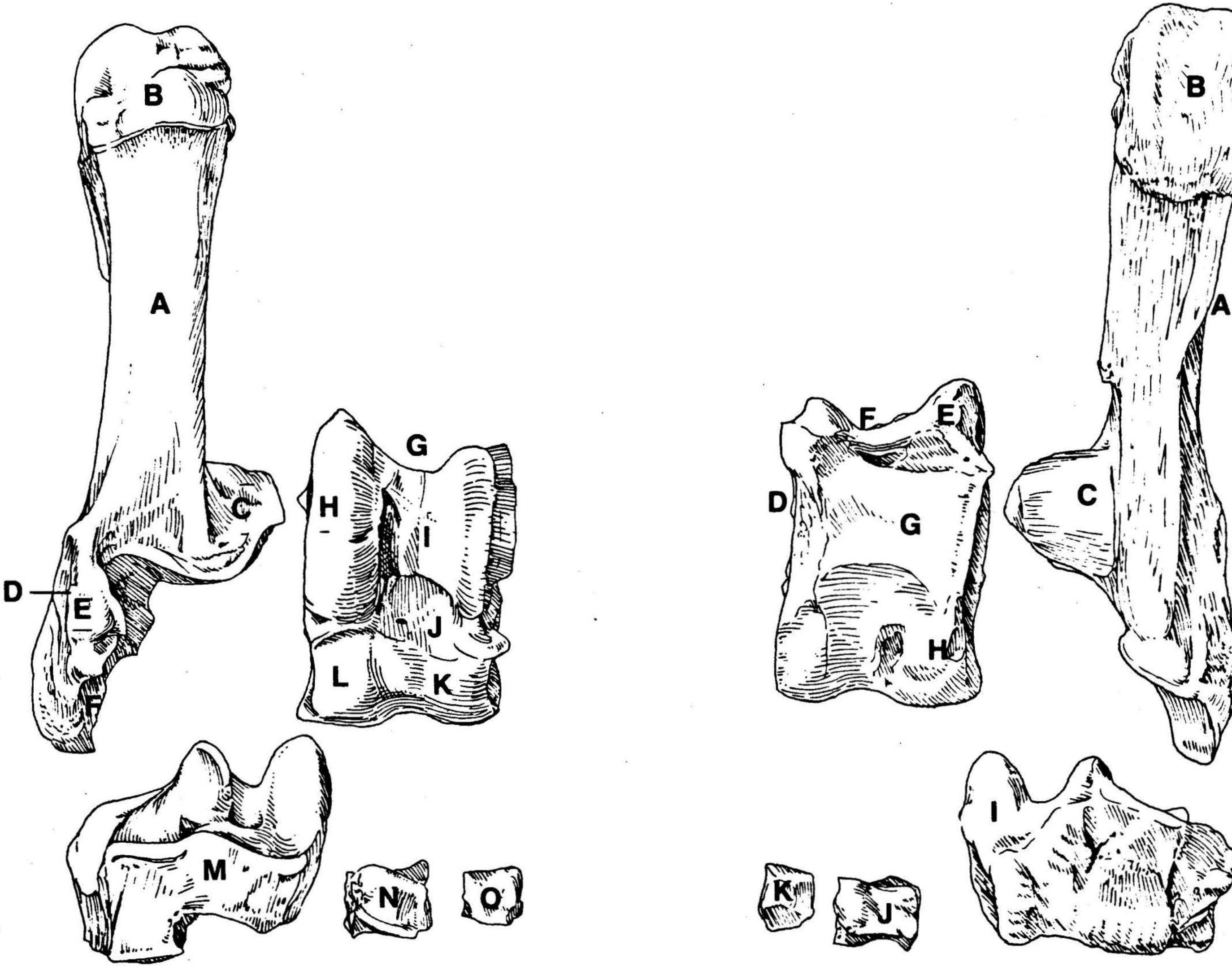
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Figure 95-Right Metatarsal Bone, Dorsal Aspect

A. Dorsal longitudinal groove
B. Dorsal face
C. Medial face
D. Lateral face
E. Distal metatarsal canal
F. Head

Figure 96-Right Metatarsal Bone, Plantar Aspect

A. Base
B. Proximal metatarsal canal
C. Plantar longitudinal groove
D. Plantar face
E. Lateral face
F. Medial face

Figure 97-Right Metatarsal Bone, Lateral Aspect

A. Tarsal articular surface
B. Body
C. Lateral face
D. Head

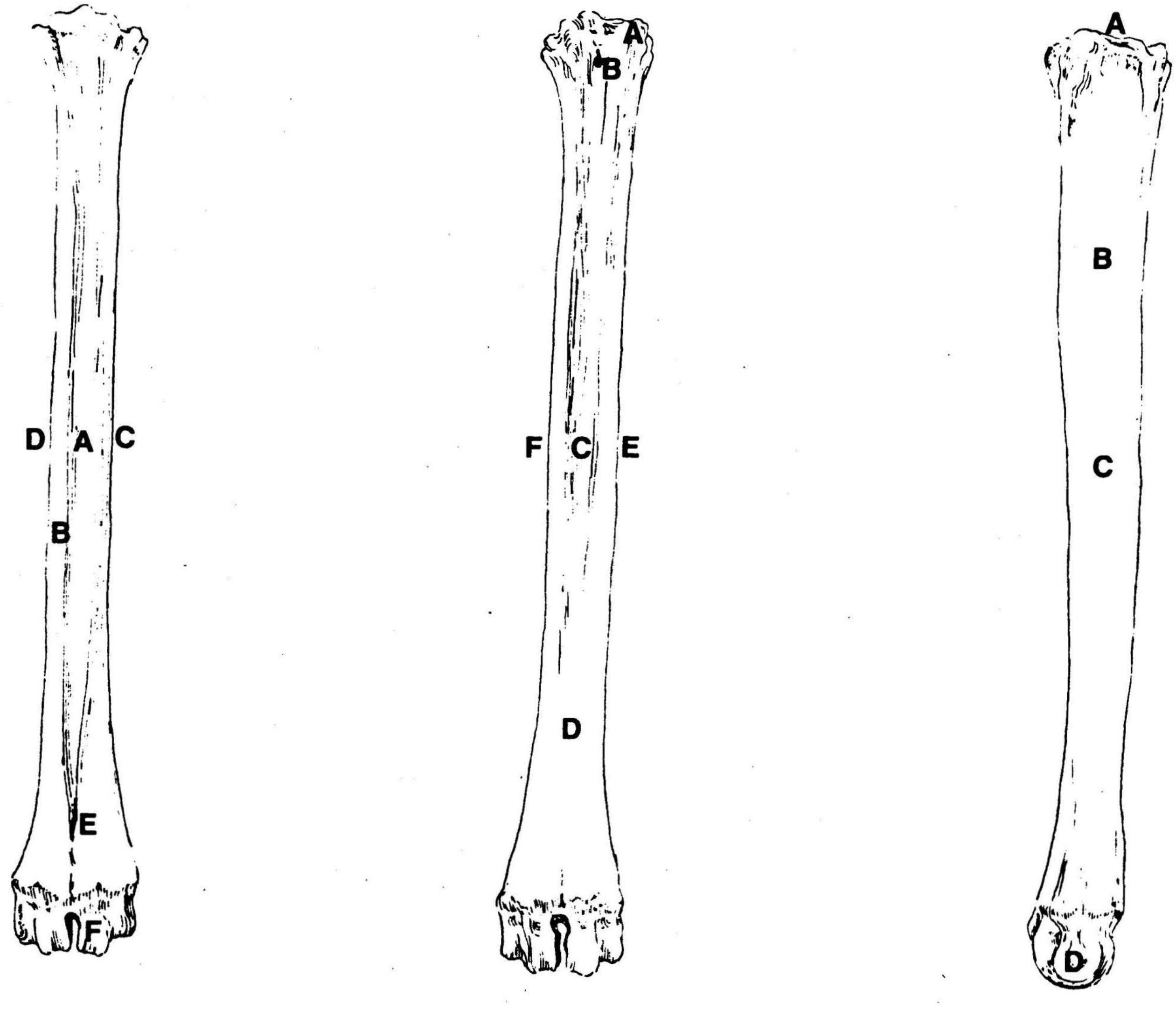
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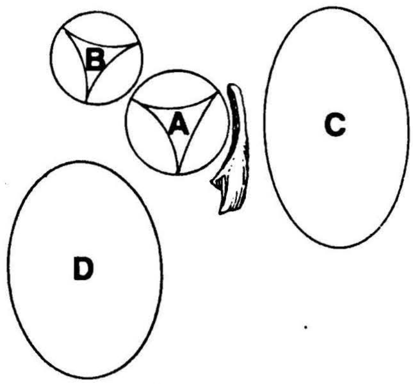
Figure 98-Os Cordis, Dorsal Aspect

A. Aortic semilunar valve
B. Pulmonary semilunar valve
C. Right atrioventricular valve
D. Left atrioventricular valve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