THE OSTEOLOGY OF VULPES MACROTIS

BY

DR. R. W. SHUFELDT.

FROM THE JOURNAL OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA, VOLUME XI, PART 3, AUGUST, 1900.

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By Dr. R. W. Shufeldt.

As long ago as October, 1887, there was collected for me at Fort Mojavé, Arizona, U. S. A., the skeleton of one of the smaller foxes of the southwestern part of the United States. It was from an adult male individual, and was taken by Private Charles Ruby, of Company A, of the 9th U. S. Infantry, who, through Professor S. F. Baird's assistance, had long collected material in the West for the Smithsonian Institution at Washington, D. C. The specimen was sent to me when I was serving at Fort Wingate, New Mexico, as post surgeon. Upon examination the skeleton was found to lack but one patella, a tooth, the clavicles, part of the hyoidean arch, and the os penis. It was labelled *Vulpes velox*.

In April, 1900, this material was still in my private collection, and upon looking into the subject, it seemed to me that the skeleton in none of the smaller western foxes had ever been fully described. On Plate XXXIV, in Baird's *Mammals of North America*, there are three views given of a skull of *Vulpes velox* with two of the mandible. These are quite accurate, as they were carefully compared by me with a good average skull of that species. Mivart gives the dental formula of *V. velox* in his well-known work on the Canidæ, and Professor Huxley had a skull of this fox at hand at the time he wrote his valuable paper *On the Cranial and Dental Characters of the Canidæ*.[1] As this species was known to Say, and to Audubon and Bachman, it is very likely that reference has been made to it many times since their day, but there seems to be no complete account of its skeleton extant or of that of any of its near congeners or allies in the southwest.

Very recently this skeleton was kindly examined for me by Mr. Gerrit S. Miller, Jr., of the Department of Mammals of the United States National Museum, and carefully compared with such material as was necessary representing the osteology of the genus *Vulpes* in the collections of that institution. Mr. Miller quickly made it clear that the skeleton in my possession had belonged to an individual of the species known as *Vulpes macrotis*, a form closely allied to *V. velox*, and not to the latter form, from which it was easily distinguished by a number of very good characters, both osteological and otherwise. This well-known mammalogist was also good enough to loan me an example of the skull and mandible of *V. velox*, belonging to the United States National Museum, for use in the way of comparison in the present account. This skull was from a specimen collected by the late Doctor Elliott Coues on the Souris River, Dakota, and was a male

[1] P. Z. S., April 6, 1880.

animal.[2] At this time the National Museum does not possess a skeleton of either *V. velox* or *V. macrotis*, although there are skeletons of other foxes in the collections.

It is not the object of the present memoir to enter in detail into the subject of the position of the Canidæ in the system, much less to make an exhaustive comparison of the skeletons of the genus *Vulpes*, although that would be an excellent task to accomplish. Unfortunately the material is not at hand at the present writing to carry out either of these projects, so the best that can be done at this writing is to offer as complete an account of the skeleton of *Vulpes macrotis* as possible; then naturalists in the future, better supplied with material, will be able to utilize this contribution in their researches.

Flower, in his *Osteology of the Mammalia*, has truly said that a "perfect arrangement of any group of animals can only be attained simultaneously with a perfect knowledge of their structure and life-history. We are still so far from this that any classification now advanced must be regarded as provisional, and merely representing our present state of knowledge. Moreover, as naturalists will estimate differently the importance to be attached to different structural modifications as indicative of affinity, it must be long before there will be any general agreement upon this subject." It is now about twenty years ago since Professor Flower penned those words, and they are quite as true to-day as the day he wrote them. Several years afterwards, in his masterly contribution to the ninth edition of the *Encyclopædia Britannica*, on the *Mammalia*, he recognizes a Section Cynoidea of the Carnivora, in which the single family Canidæ is placed, to contain all of the "dog-like animals," they holding, as this eminent authority seemed to think, "an intermediate position between the other two sections (Æluroidea and Arctoidea), retaining also many of the more generalized characters of the ancient members of the order. The structure of the auditory bulla and adjacent parts of the bones of the skull is quite intermediate between that of the Æluroid and Arctoid forms. In the number and arrangement of the teeth they more nearly approach the primitive heterodont type than any other existing Carnivora."

Flower divided the family Canidæ into two series, with several genera in each, —thus:

Family.	*Series.*	*Genera.*
CANIDÆ.	A.—Thooid or Lupine Series.	1. Canis.
		2. Cyon.
		3. Lycalopex.
		4. Nyctereutes.
		5. Icticyon.
	B.—Alopecoid or Vulpine Series.	6. Vulpes.
		7. Fennecus.
		8. Lycaon,
		9. Otocyon.

It was Professor Huxley, in his memoir *On the Dental Characters of the*

[2] No. 15,355, Coll. U. S. Nat. Mus.

Canidæ,[3] who first established or distinguished these two series of the Canidæ, and in doing so he admitted that "within each of these series there are considerable modifications, which give rise to corresponding terms in the two series." It appears that the first of these modifications is in the proportion of the sectorial and next following teeth relatively to the basicranial axis, which axis is taken at the value of 100, and is a line, measured mesiad on the base of the skull (bisected) extending from the posterior border of the basioccipital bone to the articulation between the presphenoid and the ethmoid. It is evident, as Professor Huxley adds, that the "measurements of the other parts of the skull can then be expressed in terms of 100, and their development, irrespectively of the absolute size of the animal, becomes apparent."

The second modification noticed refers to the extent of the areas for the insertion of the temporal muscle upon either side of the skull. Huxley observed that "in all young canine animals, the upper edges of the attachment of the temporal muscles are separated by a wide interspace of a lyrate form, with its apex directed posteriorly, which may be called the *sagittal area*. The boundaries of this area are but little raised; and, as age advances, it becomes gradually diminished by the approximation of the temporal muscles. This approximation takes place more rapidly behind than in front, and results in the narrowing, and in most cases coalescence, of the temporal ridges throughout the greater part of the length of the sagittal suture, while in front they diverge to the supra-orbital processes and inclose the glabellar area." This very distinctive feature is well seen in the skulls I have at hand, for in *Vulpes velox* and *V. macrotis*, the sagittal area, though unlike in form in both, is large and distinctly defined, while in all the skulls of a series of *Canis latrans*, collected by me in New Mexico and Arizona, this area is reduced to a median ridge of narrow width, and extending as far forward as the coronal or fronto-parietal suture. This ridge is longitudinally marked in the median line by the sagittal suture for the anterior two-thirds of its length.

In speaking of a third modification, Huxley remarked that "In most of the Alopecoids, the contour of the inferior margin of the angular process continues the direction of that of the inferior margin of the ramus in front of it; and this slopes gradually upward and backward. In *C. littoralis* and *C. cinero-argentatus*, however, the inferior contour of the ramus in the region of the attachment of the digastric muscle, in front of the angular process, is inclined almost at right angles to the latter, and forms a sort of rounded 'subangular lobe' beneath the angular process. De Blainville long since figured and called attention to this feature of the mandible in *C. cinero-argentatus*." The angular processes, as well as the subangular lobes, are characteristically the same in *Vulpes velox*, *V. macrotis* and in *C. latrans*. They quite closely agree with what Professor Huxley found in *C. fulvipes*. Further on in the present paper reference will again be made to some of the data set forth in this excellent memoir.

[3] P. Z. S., 1880, p. 248.

The Skull.

Both the skull (Plate XXII, figs. 1–7) of *Vulpes macrotis* as well as that of *V. velox* before me, belonged to individuals that had not fully reached maturity. This is clearly proven by the fact that both the cranial and the facial sutures are still very evident and easily traced. This is also the case with one of my skulls of *Canis latrans*, while in another skull of the same species the sutures are all nearly obliterated, while other evidences of advanced age are present. These changes are well known to students of mammalian osteology, and are sometimes very remarkably exemplified: the skulls in extremely old individuals varying widely in their external appearances from those of subadult specimens of the same species, and to an extent to sometimes almost lead to the belief that the animals to which they severally belonged were not of the same species. This is a fact that palæontologists bear well in mind, and there are instances upon record where mistakes, due to the non-appreciation of these changes, have occurred.[4] The manner in which they effect the appearance or morphology of the temporal fossæ and sagittal crest in the Canidæ has already been noticed above, and it remains but to say that during their progress there is no appreciable change either in form or appearance of the brain-case within. These changes occur in many mammals, and are particularly noticeable in the elephant.

Viewed upon its *superior surface* it will be seen that the cranium of *Vulpes velox* has a subglobular form with the temporal areas slightly roughened, and the extensive shield-shaped sagittal area quite smooth. The apex of the latter is towards the interparietal bone, and the sagittal crest is barely perceptible, even posteriorily, where in *Canis latrans* it is very conspicuous. In both *Vulpes macrotis* and *V. velox* the coronal suture and the posterior two thirds of the sagittal exhibit interlocking serrations of the apposed margins, a condition that likewise obtains in the frontal suture of the skull of *V. velox*.

All the other sutures upon this aspect of the skull in these two foxes, as well as in the coyote, have smooth margins, especially the nasal and inter-nasal ones. Either post-orbital process is well developed, being a triangular ledge of bone, with its apex directed backward and outward, and its superior surface showing a decided depression, better marked in *macrotis* than in *velox*, while in *Canis latrans* it is not present at all, that surface being rounded, and the process, bluntly pyramidal in form, extending directly outward. Proportionately, the skull in *V. macrotis* is longer and narrower than it is in *V. velox*, and this is well seen in its facial portion on the surface we are now considering, where in the first-named fox this feature is markedly the case.

[4] In this connection Flower has said that these changes or modifications "depend mainly on the fact that the brain, and consequently the cavity which contains it, and also the sense capsules, increase in size in a much smaller ratio than the external parts of the head, especially the jaws and prominences for the attachment of muscles. The disproportionate growth and alteration of form of these parts, concomitant with little or no change in the brain-case, is effected partly by increase in thickness of the bones, but mainly by the expansion of their walls and the development of cells within, which greatly extend the outer surface without adding to the weight of the bone."—*Osteology of the Mammalia*, 3d Ed., p. 148.

The *zygomatic arches* are prominently developed in these animals, and possess the same general characteristics in both species. Their extremities, composed of the usual bones, face directly upward, or, in other words, they have a superior and an inferior surface, the zygomatic or squamosal end being triangular and small, while the malar-maxillary extremity is also triangular, but broad and extensive. The middle third of the arch possesses an internal and external surface, the superior and inferior margins being somewhat sharp and curved,—the upper one convex and the lower concave, Plate XXII, fig. 1.

In *Vulpes macrotis* the fangs or roots of the last molar tooth (m^2) upon either side perforate anteriorly the zygomatic arch. These perforations occur just within the postero-mesial borders of the expanded portion, there formed by the maxillary bone, Plate XXII, fig. 7. Similarly perforations also occur in *Vulpes velox* and in *C. latrans*. Viewing the skull directly from above, the post-orbital processes shut these *molar foramina* out of sight in the majority of skulls, but they are sometimes seen upon this aspect in *macrotis*, because it has such a narrow skull and flaring zygomatic arches.

As in the Canidæ generally, either *nasal* is a long, narrow bone, which, with the fellow of the opposite side, extends from a point opposite the anterior margin of the orbit to the supero-mesial boundary of the anterior nares. Here the border of either bone is notched and free, the two together completing about a fourth of the narial aperature. In *Canis latrans* their anterior extremities are truncated from their antero-external angles backward obliquely to their postero-mesial angles. Their hinder ends in *Vulpes macrotis* articulate with the frontals and are likewise truncated, the two bones together forming a wedge, entering between the frontals, its apex being situated posteriorly. The external border of a nasal articulates with the corresponding borders of the frontal, maxillary and premaxillary of the same side. In this situation the *nasal process of the frontal* tends to extend forward to have its anterior apex meet the apex of the *nasal process of the premaxillary*.

Between these two species, however, a greater or less interval occurs, greater in *velox* than in *macrotis*, while in some of the Canidæ (as figured by Huxley) they seem actually to meet. It is certainly the case in *Canis littoralis*, and may occur in *Canis vulpes*. Foxes and other forms in the family with shorter faces may have the apices of these processes well apart. There is a very considerable interval, for example, in *Octocyon lalandii*. Upon the posterior aspect of the skull of *Vulpes macrotis* it is to be observed that in the median line above is the well-developed *inter-parietal bone*, with its contracted anterior angulation extending forward between the parietals, with its similar and lateral projections lying, on either hand, between the corresponding parietal and supraoccipital. Its mid-longitudinal line is co-extensive with the comparatively feebly developed sagittal crest; the low but well-defined *occipital crest* traverses from side to side its lateral projections. The parietal sutures of the interparietal long remain visible or even ununited, while the bone seems to early ankylose with the supraoccipital. This is also the case in other Canidæ and in many domesticated dogs. As in all true foxes the *supraoccipital*

is comparatively large and broad, with its internal and external surfaces quite smooth. For the most part it lies in the vertical plane, being perpendicular to the basi-cranial plane.

Vulpes macrotis possesses a very large *foramen magnum*, a trifle larger in proportion than it is in *V. velox*, and very distinctly so in comparison with that foramen in *C. latrans*. For example, the transverse or major axis of the subelliptical foramen magnum in *V. macrotis* measures 1.3 centimeters, its minor vertical axis 1.1 cm. and the mid-longitudinal axis of the skull, from the border of the foramen magnum to the most anterior point between the premaxillaries, measures 10.2 cms. In *C. latrans* the corresponding measurements are 1.8 x 1.4 cms., and 18.5 cms. The *occipital condyles* have their narrow and mesial moieties in the horizontal plane where they are but barely separated in the middle line. Their broader and more rounded halves curl upward, one upon either hand, and their anterior borders are markedly concaved, being correspondingly convex behind.

As in the Canidæ generally the *paroccipital processes* are conspicuously developed. Either one, as a strong projection, descends and completely molds itself upon the superior and posterior aspect of the corresponding *auditory bulla*, lending to it considerable support. Between either par-occipital process and the occipital condyle of the same side, there is a narrow though deep valley, while to the outer side of the process, upon this aspect of the skull, may distinctly be seen the mastoid portion of the periotic bone. It is bounded in front by the low, thin, sharp line of the *lambdoid* or *occipital crest*.

Turning to the lateral aspect of the skull in *V. macrotis*, Plate XXII, fig. 1, the long, narrow face that this fox possesses at once becomes apparent. The lengthy and acute backward projecting naso-maxillary process of the premaxillary is distinctly seen, as is the sutural line between the maxillary and frontal and malar bones. It is tangent to the periphery of the orbit in front, and passes beneath it, below. Forward of this, and above the diastema existing between the third premolar and sectorial teeth, is the large and vertical slit-like *infraorbital foramen*, for the passage of the second division of the fifth nerve. Within the orbit may be seen the usual foramina and the usual bones forming its smooth, shallow, antero-mesial concavity. The upper half of this is formed by the orbital portion of the *frontal;* anteriorly by the small *lacrymal;* below by the *pterygoid* and *maxillary;* externally by the malar; and postero-mesially by the *palatine*, *orbito-spenoid* and the *alisphenoid*. The various foramina require no special description, as they make no particular departure from those openings as they occur in the skull of the common dog. A description of the *zygomatic arch* has already been given in a previous paragraph.

In *Vulpes macrotis* the *meatus auditorius externus*, is somewhat larger, in comparison, than in *V. velox;* very much more so than in *C. latrans*. Indeed, the opening is so large in the specimen at hand that the interior of the *tympanic cavity* can easily be studied from without. The *ossicula auditus* (*malleus*, *incus* and *stapes*) all appear to be lost, and so cannot at this writing be described.

Firm osseous union has solidly sealed together the various bones bounding the auditory chamber, as the *periotic*, the *squamosal* (above), the *tympanic*, and the *auditory bulla* (beneath), while to the inner side we see the *basi-* and *exoccipital*. The sutures among the *squamosal*, *parietal*, *alisphenoid*, and *frontal bones* upon the lateral aspect of the skull, remain clearly defined for the greater part of the animal's life, and it is only in Canidæ of extreme old age that they become to some degree faintly defined or almost obliterated.

Passing to the consideration of the base of the skull in *Vulpes macrotis* it is interesting in the first place to note the extent of difference existing between it and a skull of *V. velox* seen upon the same view, Pl. XXII, figs. 5 and 6. Upon examination of material in the United States National Museum it would appear that these differences are constant and diagnostic. Principally, there are three of them that are evident upon casual observation:—In *V. macrotis* the osseous palate is transversely much narrower than in *V. velox*. This is especially noticeable in the distance between the carnassial and first molar teeth of the opposite sides. The *malar portion* of the zygomatic arch is deeper in the antero-posterior direction in *macrotis* than in *velox*. The *auditory bullæ* are comparatively larger in the first-named fox than in the last-named. This character is very evident when we come to compare series of skulls of these two well-marked species. In general the entire skull of *V. macrotis* is thinner and more delicately fashioned than in *velox*, and its being narrower throughout is easily appreciated upon comparison, either from a dorsal or ventral aspect, Pl. XXII, figs. 2, 5, 6 and 7.

In the bony roof of the mouth in the specimen of *V. macrotis* at hand, the sutures defining the limits of the *premaxillary*, *maxillary* and *palatine bones* have become almost entirely obliterated. This is not usual in other Canidæ, unless age has very far advanced. We know, however, that in this family the suture between the maxillaries and premaxillaries in this situation is a transverse one, extending from a mid-point upon one canine tooth to pass directly across to the one upon the other side,—the two, long, slit-like *anterior palatine foramina* lying partly upon the maxillary side of the boundary, Pl. XXII, fig. 5. Otherwise, upon either side, the maxillary supports the dental armature of the upper jaw in this, as in other true foxes, namely, the four premolars, and the two true molars, each premaxillary supporting three inciser teeth. Posteriorly, the free margins of the *palatines* are rounded, forming, as they do, the anterior border of the posterior narial aperature. Upon either side, the palatine bones are continued backward by the thin and compressed *pterygoid bones*, which here, as vertical plates, descend directly downward from the alisphenoids, terminating below in free laminæ of bone, each known as the *hamular process* of the pterygoid. Each is represented by a thin triangular plate of bone in a vertical longitudinal plane, separated by an interval of nearly a centimeter in width. The valley thus created is deep and of some length (2 cms.), it being the backward extension of the narial passage, and forms in the Canidæ a conspicuous feature of the mid-basal area of the skull. Above, either *pterygoid* articulates with the under surface of the *presphenoid* and the *basi-sphenoid bones*.

In the middle line of the base of this skull of *V. macrotis*, proceeding from before backwards, we are enabled to see the *vomer*, the *presphenoid* and the *basi-sphenoid*, and the sutures among them are fairly well defined. Still more posteriorly the *basi-occipital* creates the roof of the narrow, but deep passage between the *auditory bullæ*, and its lateral margins are raised that they may better articulate with those remarkable osseous capsules upon either side. Upon examining the aperature of the *Eustachian canal*, the *foramen lacerum medium*, the *foramen ovale*, *foramen rotundum*, the *alisphenoid canal*, the *postglenoid foramen*, the *foramen lacerum posterius*, the *condylar foramen*, the *stylomastoid foramen*, and some few other features in this region of the base of the skull, they are seen to agree with what is already known as to the cranial osteology of this family of mammals.

The glenoid fossæ are narrow and elongated; their long axes being perpendicular to the longitudinal axis of the skull. Behind either one is a conspicuous *post-glenoid process*, curving downward and forward, and serving to retain the condyles of the mandible in their sockets during life. Either *auditory bulla* is hemi-ellipsoidal in form,—thin and hollow. The exposed convex surface is extremely smooth, though in some species of the Canidæ it may be slightly roughened by delicate venations, but these are absent in the genus *Vulpes*. Within the cranial casket a well-defined *sella turcica* is seen, and upon either hand, the internal surfaces of the *orbito-sphenoid bones*. Anteriorly, the posterior margin of the *mesethmoid* is inserted, forming, as usual, the *crista galli*. The *cribriform plate* is extensive, and presents two suboval moieties with the posterior surfaces facing backward and very slightly, upward. Internally, this plate is perfectly smooth, and the foraminal perforations exceedingly numerous.

As is the case in *Canis latrans*, and other Canidæ, the dense inner surface of the vault of the cranium is marked by convolutions, to receive the corresponding convolutions of the brain-mass, while the *tentorium cerebelli* very extensively ossifies. All the fossæ of the brain-case—*cerebellar*, *cerebral*, and *olfactory*—are well marked off, and comparatively capacious. Other features of the interior of the brain-case are present, but being well known require no special description here.

The spongy bones of *V. macrotis* were not studied in section, but they are probably as complicated as in *C. latrans*, of which such a sectional preparation was examined.

That they are so in many of the domesticated dogs has been clearly shown by the late Sir William Henry Flower.[5]

These *turbinal masses* of bone in the olfactory chamber of the skull in mammals are worthy throughout the class of our very closest study. Morphologically they are full of interest, and should never be set aside as was the habit of the late Dr. Elliott Coues, who thought them too complicated to be worthy of description. Such an unscientific opinion was fully controverted by the late keen anatomist, Dr. Harrison Allen, who devoted an entire memoir to the comparative morphology

[5] Osteology of the Mammalia, pp. 129, 130.

of these ossifications in many of the mammalia. They appear to be of certain taxonomic value among the bats.

The *hyoidean apparatus*, in so far as its osseous parts are concerned, is not complete in this skeleton, some of the delicate bones having been lost. There is every indication, however, that it in no way markedly departs from the corresponding structures in other small foxes, and in the main with the Canidæ generally. Professor Flower gives an excellent account of the hyoidean apparatus of the dog in his *Osteology*, and I have studied these visceral arches in both adult and embryonic types among the mammalia. They are more or less uniform for the family, and among the Canidæ, if my information be correct, present hardly any generic differences. The *mandible* has the general form of that bone in the family Canidæ (Pl. XXII, figs. 1, 3 and 4), it being V-shaped in form, and ankylosed quite firmly anteriorly by an extensive symphysis. By active maceration, however, the two elongated rami will separate at this point, as has been the case in jaws of the coyote and kit fox at hand. According to some authorities, in very old animals the union may become complete and firm through coössification. In *V. velox* a ramus of the mandible is shorter, deeper, and thicker through and through than it is in *V. macrotis*, in which latter fox it is evidently more delicately fashioned. Either ramus has an extreme length of about 7.9 cms., its lower margin being thickened and rounded, convex in the antero-posterior direction, and very slightly curved from side to side. Its upper border exhibits the sockets for the implantation of the mandibular teeth, six much smaller ones occurring anteriorly on the united rami for the incisors. The *symphysis* has a length of about 2.3 cms., it being more extensive in front and tapering off behind. Between a canine socket and the coronoidal vertical portion of the jaw, the *alveolar border* is quite straight, while nearly a level surface exists anteriorly and above the symphysis bounded by the sockets of the first premolars, the canines and the incisors. The *condyles* stand out quite prominently, being transversely elongated, narrow and attached by their mid-anterior points at right angles to the plane of either coronoidal portion of the jaw, at points about half way between the apices of the *coronoid processes* and the *angles*, or about in the same plane in which the alveolar borders lie. The *coronoid process* upon either side is flat and smooth on its mesial surface, and concaved throughout upon its external aspect. It is, on the whole, moderately recurved backward, the true apex being pointed in that direction. Its anterior border, externally, is thickened and there forms a narrow though conspicuous rim. At either *angle* there is a prominent *angular process* developed, which is present in the jaws of all of the Canidæ examined by me. Anything approaching a subangular lobe, however, is quite absent,—in which character, strange to say, it agrees with *Icticyon venaticus*, but not with *Otocyon lalandii* (where this lobe is much produced), nor with *Canis azaræ* and *C. littoralis*. On the mesial aspect of either ramus below and between the condyle and the posterior commencement of the alveolar border, we meet with the *inferior dental foramen*, it being of some considerable size, and opens directly backward.

On the external surface of either ramus in front there are to be seen two more foramina,—the anterior one is the *mental foramen*, and is at a point below the diastema between the first and second premolars; the other, behind it, smaller in size, is slightly in front of the corresponding interval between the second and third premolars. In *C. latrans* they are nearly of a size, and the posterior one is immediately below the centre of the third premolar. In all instances these foramina are in the same horizontal plane and midway between the alveolar and lower border of the ramus. Viewing the ascending portion of either ramus from behind, it will be seen that it curves gently outward, which is the case in all of the Canidæ.

Professor Huxley made some interesting comparisons of this aspect of the mandible among groups more or less remotely or nearly allied to the canine group.[6]

The Axial Skeleton.

Vulpes macrotis may be said to have a somewhat delicate frame constituting the skeleton of its trunk. The cervical, dorsal and lumbar vertebræ all possess thin, sharpened and produced processes, thus doing away with all appearance of heaviness in structure or bulkiness in form, as we notice in some small mammals. The caudal vertebræ again are slender and elongated, making the skeleton of the tail appear lash-like and frail. Much lateral compression characterizes the skeleton of the thorax, the ribs being long and not at all stout, while the sternum has a corresponding structure, the segments composing it being small, elongated, and more or less slender. For the size of the animal, the pelvis is rather a stout bone, but at the same time by no means strikingly so. In the *number of vertebræ* possessed by *Vulpes macrotis*, or in the specimen now being examined by me, it agrees exactly with a specimen examined by Sir Wm. Henry Flower of *Canis vulpes;* in other words, it has seven cervicals, thirteen dorsals, seven lumbar, three sacrals, and twenty-one caudal vertebræ. Professor Flower met with a specimen of *Canis lagopus* that had the same number in the various divisions of the vertebral chain, while in another case of *Canis vulpes* the animal had but nineteen caudal vertebræ. All of the ferine forms of the Canidæ, so far as we know, possess seven cervicals and three sacrals. Variation sometimes takes place in the domesticated breeds of dogs in the lumbar and sacral regions, as Flower found a German boarhound with fourteen thoracic or dorsal vertebræ; Newfoundlands and mastiffs with eight lumbar vertebræ; and a greyhound with four sacrals. *Canis procynoides* has fourteen thoracic and but six lumbar vertebræ, and *C. vulpes* has been known to have the same number. *Otocyon megalotis* has the usual number in the series, but has twenty-two vertebræ in the skeleton of its tail. It is this caudal part of the vertebral column that varies most in this particular. Omitting the domesticated breeds of dogs, however, it probably can be said with truth for the Canidæ that the number of caudal vertebræ are never less than fourteen (*Icticyon venaticus*) nor more than twenty-two, which is the case, as has just been noted, in *Otocyon megalotis*.

[6] P. Z. S., 1880, p. 263, fig. 14.

The *atlas* is the broadest bone of the entire column, though the spreading transverse processes of the last lumbar gives it nearly an equal breadth. No vertebra in the entire chain at all resembles the atlas in form. It is about twice as wide as it is long, and its big neural canal is bounded on either side by the narrow cap-like articulations for the condyles of the occiput. Either quadrate, horizontal transverse process is pierced, near its middle, by the vertebrarterial canal, the foramen for the first spinal nerve being anterior to this just within the supero-anterior border close to the condyloid cup. A rudimentary hypapophysis exists, but the neural spine is entirely absent. There is a smooth articular facet present for the articulation of the long, peg-like odontoidal apophysis of the axis. It is situated in the middle line inferiorly within the neural canal. The thin, sharp, lofty neural spine of the *axis* extends the entire length of that bone, and projects conspicuously beyond the centrum in front. The hæmal spine is likewise laterally compressed, but it is feebly developed and principally confined to the hinder part of the centrum of the vertebra. This is likewise the case with the third, fourth and fifth cervicals, this inferior spine being absent upon the sixth and seventh cervicals, as it is completely so from the balance of the vertebral column. Neural spines, however, are found upon the last five cervicals, where they increase in height and sharpness as we pass backward in the direction of the thorax. Large, strong zygapophyses characterize the cervicals, and the transverse processes are thin, sharp and conspicuous. In the second to the sixth inclusive they are bent downward and project beyond the centra both in front and behind. These processes become suddenly contracted in the seventh cervical, where they more closely resemble those in the pre-dorsal series. Upon either side the vertebrarterial canal passes through all of the cervicals, save the seventh or last one.

Metapophysial processes are first seen feebly pronounced on the third cervical, they grow stronger and stronger from before backward to include the sixth. On the seventh they are more or less aborted, as they are upon the first five dorsals, when they again make their appearance upon the sixth dorsal, as a feeble pair of minute spines pointing backward. After this they gradually increase in size to diminish again on the fourth lumbar, being entirely absent in the fifth, sixth and seventh lumbar, and the remaining part of the column.

The *ten* first dorsal vertebræ are more or less like each other, while the last three dorsals, although they support true ribs, resemble the first lumbar. In the ten first dorsals the neural spines are very prominent, being well separated from each other in the articulated skeleton, lofty, laterally compressed, narrow, with nearly parallel anterior and posterior borders. This spine in the leading dorsal or thoracic vertebra has a height of two centimeters, and it is nearly perpendicular to the longitudinal axis of the centrum. In the tenth dorsal the neural spine is but one centimeter high, and the process leans backward. Between these two extremes a gradual change in form and height takes place from the first to the tenth inclusive. Thoracic vertebræ have their zygapophyses much reduced, but the interlocking among them is very firm. Transverse apophyses are also inconspicuous in

this part of the column. Laterally the heads of the ribs upon either side articulate *between* the facets of the centra, except in the last two pair, where they articulate entirely upon the body of the vertebra to which they belong. From the eighth thoracic to the ultimate lumbar inclusive the vertebræ increase in size and conspicuousness. The neural spines, situated upon the fore part of the centra, lean forward, and are thin, narrow and laterally compressed. We find the tallest in the middle of this series, while the zygapophyses are strongly tilted upward in the last three dorsals and leading lumbar, to become slightly less and less so as the pelvis is approached.

The transverse processes, bent downward, forward and outward, are narrow, thin, sharp plates, compressed from above downward, and in the last of the series have somewhat dilated ends. They are hardly to be noticed in the last three thoracics, but after that they gradually commence to lengthen, until those on the last two lumbar vertebræ attain a length of two centimeters each. The neural canal appears to have the least calibre in the post-thoracic region, and the greatest in the pre-cervical and post-lumbar. Throughout the chain at their ordinary sites in the carnivora, the usual foramina exist between the vertebral centra for the exit of the pairs of the spinal nerves.

The three *sacral vertebræ* are all firmly anchylosed together, and present, both dorsally and ventrally, two pairs of neural foramina. Small neural spines are also present, but no hæmal ones. With respect to size, the first sacral is the biggest. It and the second offer strong lateral abutments for the ilia of the pelvis. It is only the fore part of the last sacral that does this,—the postero-lateral processes of this vertebra being free and directed backward and outward. Somewhat similar ones are developed upon the four leading caudal vertebræ, but the rest of the series of those in the tail become more and more rudimentary and elongated as we pass toward its tip, the last few again shortening, to become mere rodlets of bone, with barely any semblance whatever to a true vertebra.

The Sternum.—Agreeing with other small vulpine forms among the Canidæ, this part of the skeleton in *Vulpes macrotis* consists of *eight* pieces,—one being the *presternum*, one *xiphisternum*, and six pieces in the *mesosternum*. These latter decrease in size from before backward, being in any case but small subcylindrical rods of bone with enlarged extremities. They meet each other in subcircular disc-like articulatory facettes, the mesial extremities of the cartilagimous costal ribs articulating between them, one upon either side. The *xiphisternum* is represented merely by a long very slender piece of cartilage, while the *presternum* is longer than any of these sternal segments.

Rather more anteriorly than midway on its shaft dorsad, there is a small pair of facettes, one upon either side, with which articulate the first pair of costal ribs. The apex of this piece of the sternum is bluntly rounded off. The second pair of costal ribs articulate at the junction of the presternum and first piece of the mesosternum, while at the junction of the last piece and the xiphisternum two pairs of costal ribs articulate, and the extremities of a "floating pair" approach this point.

All of this arrangement agrees with what Professor Flower found in a domesticated dog, *Canis familiaris*. The sternal or costal ribs appear to have a feeble ossification of a somewhat granular nature.

Their are thirteen pairs of true *vertebral ribs*, the first pair being the shortest and the ninth pair the longest. From the 8th to the 13th pair inclusive they are very slender, but slightly curved, and decidedly rod-like. The first pair of ribs are short, rather stout, and subcylindrical in form. They are likewise curved. In the first five pair, and especially in the first three pair, the sternal moities are dilated and flattened from side to side. All the leading pairs of these ribs have their vertebral ends completely developed, possessing all the characters known to be present in the ribs of the ordinary mammalia. As we pass posteriorly the features of the vertebral heads become gradually more rudimentary, especially in the matter of the disappearance of the neck, the tubercle and the angle, the capitulum alone remaining for articulation with the vertebra above. The last two or three pairs of the costal ribs do not meet the sternum, but come in contact with the same structures in advance of them. *Vulpes velox* in all probability agrees with *V. macrotis* in all this part of its skeleton; that is, in its vertebral column, sternum and ribs.

The Shoulder Girdle.

Many anatomatists have touched upon this part of the skeleton of the Canidæ in osteological works. For example, Sir Richard Owen, in his second volume of the *Comparative Anatomy and Physiolgy of Vertebrates*, on page 510, said in effect that in the Canidæ the scapulæ, and especially the limb-bones, are longer and more slender relatively than in the Viverridæ, Mustelidæ and in the plantigrade carnivora. The clavicles are reduced to mere styles. Years afterward, Sir Wm. Henry Flower, in his *Osteology of the Mammalia*, stated that in "the carnivora the anterior and posterior fossæ of the scapula are nearly equal in area. [Refers to the scapula of the domestic dog as an example.] The spine and acromion are fairly developed, the latter often with a broad metacromial process. The coracoid is much reduced." According to Parker "a portion of the scapula, near the coracoid border, ossifies from an independent centre. The clavicle is sometimes absent, and when present varies much in its development, but is always rudimentary and suspended in the muscles, never reaching either the acromion or sternum. In the Felidæ it is slender and curved, being longer than in any other members of the order. In the Canidæ it is very short, and rather broad and flat. In most of the Ursidæ it is absent."

The *clavicles* in the skeleton of *V. macrotis* before me are missing, but there is every reason to suppose that they agreed in their general characters with the vulpine carnivora generally; that is, in some respects they were rudimentary and did not reach either the acromion or the sternum; they have been lost in this particular specimen.

The *scapulæ*, however, are thoroughly developed and strong, well-ossified bones.

The one from the left side is here shown in fig. 8 of Plate XXIII, seen upon its dorsal surface. A small double foramen, or twin foramina, are seen in the post-scapula part near the hinder margin, that may or not be present in the scapulæ of other individuals. Sharp and thin, the decidedly convex margin of the *præscapula* has its bounding rim slightly thickened, but not nearly so much so as the straight margin of the glenoid or posterior border, where, too, the edge for its entire length is raised and tilted outward and backward. On the other hand, the supra-scapular border, which is very slightly convex upward, has its edge about as thick as the antero-superior part of the coracoid or anterior border, and is the continuation of it. It meets the thickened glenoid border almost at a right angle, which angle is especially thickened. As to the amount of surface, the *præscapula* and the *post-scapula* areas are about equal, while that of the *mesoscapula* presents an anterior surface about equal to half the præscapular area, and a posterior surface about equal to half the area of the postscapular. The inner or thoracic surface of the scapula is generally smooth, being but slightly ridged and roughened in certain places for the origin and insertion of muscles. There is a sub-vertical shallow groove present, extending from the glenoid cavity to the junction of the anterior and posterior borders that indicates the location of the base of the "spine of the scapula," or meso-scapula of the other side of the bone. An *acromion process* is well developed. If we hold the bone in its normal position as the animal stands up, it is gently curled backward. The coracoid is thick and strong, and it adds considerable strength to the anterior part of the glenoid cavity. This last has a subelliptical outline, is moderately concave, the major axis of the concavity being in the longitudinal direction, or in a plane roughly parallel to one in which the spinal column is situated. A slight constriction or neck joins the glenoidal portion of the scapula with its "blade." This scapula has an extreme height of about six centimeters and a width of about 3.5 cms.

The Arm, Forearm and Manus (Pl. XXIII).—In describing this part of the skeleton, as well as the bones of the posterior extremity, the terms of the relative position employed are those which the bones assume when the animal stands or walks in the ordinary way.

Upon examining the *humerus*, it is found to present all the usual characters found in that bone among the Canidæ generally. This statement also applies to the remaining bones of the pectoral limb, as well as to those of the skeleton of the hinder extremity. As shown in figure 9, the humerus is very slightly shorter than it actually is in life, judging from the specimen at hand. It has an extreme length of 9.2 cms., the ulna having a length of 10.2 cms., and the radius shorter than either measures but 8.7 cms.

At the proximal extremity of the *humerus* we find the smooth, convex head of the bone, with its axis directed upward and backward. There is scarcely any neck between it and the rest of the bone, though the articular portion below curls over the part commonly so considered. To its inner side is the *lesser tuberosity*, it being well developed. To the outer side of this, and distinctly marked off by the rather

shallow bicipital groove, is the *greater tuberosity*, it being broad, flattened from without inward, and having its thick, roughened, convex margin reared well above the general summit of the bone. Distally, at the other end of the humerus, the articular trochleæ are conspicuously developed, being distinctly separated from each other by an intertrochlear groove, which is especially deep posteriorly. The radial condyle is small and pitted upon the outer aspect, while the ulnar or internal condyle is more prominent, has a very sharp and raised inner boundary, and develops a tuberosity instead of a pit upon its outer side. The deep anconeal fossa is perforated by a large intercondylar foramen, and the supinator ridge, extending up the shaft from the external condyle is strongly marked. Another strong muscular ridge passes entirely down the shaft from the greater tuberosity to the internal condyle, it, at the lower end of the bone, being spirally parallel to the aforesaid supinator ridge. Between the two extremities, or the middle third of the shaft of the humerus, is otherwise smooth and subcylindrical in form; the shaft as a whole exhibiting a gentle sigmoid curve from one end to the other. Its deltoid ridge, occurring in the upper third of the shaft in the muscular line described above as passing down from the greater tuberosity, is but feebly pronounced, being not nearly as well marked as it is in some of the other carnivora, as for example in the Ursidæ.

In common with all other mammals the forearm or *anti-brachium* has in its skeleton the two bones *radius* and *ulna*, both articulating with the humerus at their proximal extremities and with the upper row of the carpus, distally. Between the bones themselves the articulation is very close, both at their extremities and by elongated roughened facettes, one on either bone, at the junction of upper and middle thirds. Here a dense ligament helps to hold the bones together. As we have seen, the *radius*, although shorter than its companion, is much the stouter bone of the two, its antero-posteriorly flattened shaft is but very slightly bowed, and nearly of uniform calibre from one end to the other. Its extremities are enlarged for the articulatory purposes, as has already been stated. The facet for the humerus is of an oblong shape, and is co-extensive with the greater sigmoid cavity of the ulna. Distally, the carpal facet of the radius is much larger, also oblong in outline and concave. Here, anteriorly, on either hand occurs a deep, short groove, which in life transmits tendons. Flower says that the radius in the carnivora "differs from that of man, inasmuch as its upper end is broad, flattened and extends further across the front of the humeral articular surface, forming part of the hinge; and although it is never ankylosed with the ulna, scarcely any appreciable amount of movement is allowed between them." [7]

At the distal extremity of the antibrachium, the *ulna* is about equal in length to the radius, its end being considerably enlarged, projecting and mesially concaved in conformity with the radius in such a way as to complete the concavity in which the proximal row of carpal bones articulate. This distal ulnar enlargement is less than one-third of that of the radius at the same extremity. Proximally, the ulna projects over a centimeter and a half beyond the radius, the projection being the

[7] *Loc. cit., p.* 274.

olecranon or *anconeal* process,—the most conspicuous part of this bone of the fore-arm. It is strong, quadrilateral in outline, compressed from side to side. A deep, longitudinal notch is found on the supero-anterior angle of the olecranon. While its postero-internal aspect is somewhat concaved, caused by a prominent raised rim of the edges of the process, proximally and below. The sigmoid cavity is deeply sculpt, and its supero-anterior angle in some positions of the humerus will pass into the intercondylar foramen of that bone.

For rather more than its superior third the shaft of the ulna is obliquely flattened, so that its anterior surface looks forward and outward. It gradually contracts as it approaches the above-described articulation with the radius in the narrow "interosseous space." Below this point the shaft of the ulna is very slender and straight, and exhibits upon its inner aspect a fine, deep, longitudinal groove, which runs nearly to its distal end. Among all the carnivora we meet with this large compressed olecranon on the ulna, and observe that its shaft tapers gradually from above downward in the direction of the wrist.

In the *manus* we have the *carpus*, *metacarpus* and *phalanges*. According to Flower, "In the carnivora, the scaphoid and lunar bones always coalesce into a single *scapho-lunar* [as in *Ursus americanus*], with which the *centrale* is united, the latter never appearing[8] as a distinct bone, except sometimes in very young animals. The radial accessory ossicle or sesamoid is generally present. All have five digits, with the complete complement of phalanges, except the *Hyæna*, in which genus the pollex is represented only by a rudimentary metacarpal. This digit is usually much reduced in size, and often, as in the dog, does not reach the ground in walking. It is best developed in the bears and allied forms. The first metacarpal is never more freely movable than any of the others. As a general rule the middle digit is somewhat the longest, the second and fourth nearly equal to it, the fifth shorter, and the first the shortest.

"As the toes are nearly always armed with long, strong, curved, and sharp claws, the ungual phalanges are large, strongly compressed, and pointed, and they develop from their base a broad, thin lamina of bone, which is reflected over the root of the horny claw, and holds it more firmly in place."[9]

In *Vulpes macrotis* the *radial accessory ossicle* of the carpus is very small and rudimentary, while the pisiform on the ulnar side of the wrist is powerfully developed, and articulates with a distinct facet upon the outer side of the *cuneiform*. This latter bonelet, together with *scapho-lunar*, forms the convex proximal facet for articulation with the radius and ulna of the antibrachium, the last named affording about four-fifths of the surface, and articulating entirely with the radius. For the distal row we have four carpal bones, the largest of which is the unciform, which articulates with the proximal ends of the fourth and fifth metacarpals—the first, second and third metacarpals each having a small bone to itself. Of these

[8] B. G. Wilder, "On the Composition of the Carpus in Dogs." *Bull. Cornell University*, Vol. I, p. 301, 1874.

[9] *Osteology of the Mammalia*, pp. 287–289.

the outer one on the radial side is the *trapezium*, the next, the *trapezoid*, and the one next to the unciform, the *os magnum*.

Agreeing in the main with the vulpine Canidæ generally, the joints of the *metacarpus* present nothing of special note. As in the majority, if not in all true canines, the *pollex* metacarpal is much reduced in size, short and straight. Proximally, its end is somewhat enlarged, but in its extreme length this bone is not over 1.3 cms. in length. Its single phalanx and ungual joint are likewise greatly reduced, and it is more than probable that it plays but a feeble part in the locomotory functions of the fore-foot or paw, as it is doubtful that it reaches the ground in running, walking, or standing. The remaining four metacarpals are straight, stout and strong. At their distal ends each and all present the usual trochlear joints for the proximal articular extremities of the first row of phalanges. Their upper ends are much compressed from side to side, and they fit so firmly against each other, that they are capable of scarcely any motion at all. *Second* and *fifth metacarpals* are about of a length, each being about 2.8 centimetres long, and the last named is the stouter bone of the two. *Third metacarpal* has a length of about 3.2 cms, and the fourth is very slightly shorter. These bones appear almost alike and both are slenderer than the fifth metacarpal.

Free *sesamoids* do not appear to exist in any of tendons in the sole of the fore-foot of this little fox. Digits II–V each possesses two *phalanges* and a terminal ungual joint. The upper row of the former is composed of stout, short, straight bones, each presenting the usual articular ends as seen among the Canidæ generally. The phalanges to the second and fifth digits are shorter and stouter than those to the third and fourth—the first averaging 1.3 cms in length, and the latter 1.7 cms. (II–V being nearly of a length, as are III and IV.) The distal row of phalanges is proportionately shorter and slenderer than the proximal row, but their general comparisons are about the same. Finally, the terminal row or *ungual joints* are each armed with a strong compressed osseous claw, which latter is curved and pointed. They have the thin basal lamina spoken of by Flower, but not as strongly developed as we find them in the Felidæ. A minute tubular canal longitudinally pierces the core of each one of the bony claws of the fore-foot, apparently for the passage of the vessels to its apex, where it opens, for the horny sheath covering it during life. As in other small Canidæ, the middle digit is rather longer than any of the others, the second and fourth being somewhat shorter than it, fifth still shorter, and pollex, as already stated, shorter than any of them by far. Indeed, the entire length of this digit is not sufficient to carry the apex of its ungual joint past the distal end of the second metacarpal bone alongside of it.

The Pelvic Girdle and the Skeleton of the Hinder Limb.

Sir Richard Owen, in his *Comparative Anatomy and Physiology of the Vertebrata* does not give us a dozen lines upon the *pelvis* in the carnivora; and Flower in the last edition of the *Osteology of the Mammalia* hardly does more, and neither of these distinguished authorities refer to the pelvis of the genus *Vulpes*. On speak-

ing of the carnivora as a group, Flower says in the work just cited, that "the pelvis is generally elongated and narrow, the ilium and ischium being in a straight line, and of nearly equal length. In most species the ilia are straight, flattened, and not everted above [makes reference to his figure of the pelvis of a dog, Fig. 115, p. 317], the iliac surface is very narrow and confined to the lower part of the bone, as the acetabular and pubic borders meet in front above; the gluteal surface looks directly outwards and is concave; the sacral surface forms a broad flat plane above the attachment to the sacrum, the crest being formed by the united edges of the sacral and gluteal surfaces, instead of the iliac and gluteal surfaces, as in man. The symphysis is long; it includes part of both pubis and ischium, and commonly becomes completely osseous in adult animals. The thyroid foramen is oval, with its long axis parallel to that of the whole bone. The ischia are wide and divergent posteriorly.

"In the Hyæna the pelvis is shorter and wider than in most other carnivora, both the upper ends of the ilia and lower ends of the ischia being considerably everted."

Now in *Vulpes macrotis* the *pelvis* is by no means unlike that part of the skeleton as we find it in some of the more fox-like species of the domesticated dogs. Flower figures the "ventral surface of right innominate bone of dog ($\frac{1}{2}$)" in his *Osteology of the Mammalia* and in its general features it very closely resembles the same surface of the pelvis of the fox now being considered, and the description above quoted likewise answers very well in describing the same. There are plenty of half-breed Indian dogs in the Indian camps of the northwestern parts of the United States that doubtless possess pelves with characters almost identical with those of *Vulpes*.

The ilia of this pelvis have the sacrum of the vertebral column wedged in between them quite as firmly as we find it in man and many other animals, and the articular surface for the articulation with the sacrum is of the same roughened character. Above this surface the blade of an *ilium* rises for more than a centimetre, its superior crest being convex, while its external surface is markedly concaved. The posterior borders of the ilia are very nearly in the same plane with the ischia, and in fact the pelvis as a whole is much compressed in the antero-posterior direction. Scarcely any indication of a "greater sacro-sciatic notch" or a "lesser sacro-sciatic notch" is present, though on the anterior rim of the basin of this pelvis, a rudimentary anterior superior spine is seen, the anterior inferor spine being well-marked and conspicuously developed. Either acetabulum is a hemispherical concavity with an average width of nine millimetres. Its base is not perforated by a foramen, while the *cotyloid notch* at its lower part is distinctly marked. The *symphysis pubis* is very firmly co-ossified for its entire length, the suture being almost obliterated upon its dorsal aspect. It has a length of 2.3 cms. and the *pubic arch* is wide and much concaved. Each *obturator foramen* is very large and of a subcircular outline, with an average diameter of eleven millimetres. In the middle line at the narrowest place their peripheries are but 3.5 millimetres

apart. Below, and to the outer side of one of these foramina, the surface of the *ischium* is broad, flat and quite extensive, with its outer angle thickened and prominent. This last is the "tuberosity of the ischium," and it is far more conspicuous than it is in *Homo* and the apes. Laterally, an ischium is concaved on its border, while inferiorly it is convexed and rimmed. The *inlet* of this pelvis has a median longitudinal diameter of 2.5 centimetres, and a transverse diameter of 2.3 cms. at its widest part—in other words the inlet is nearly circular in outline.

Passing to the skeleton of the thigh, leg and pes, we find the *femur* of the first-named division of this limb to be a very interesting bone, with well-pronounced characters. Viewing it upon its anterior aspect its more or less slender subcylindrical shaft appears to be nearly straight from one extremity to the other, but seen on lateral view, there is a gentle curvature backward to be recognized, especially at the distal half, and this is here enhanced by the remarkable manner in which the large condylar end is produced posteriorly. This part is massive and profoundly channeled by the intercondyloid notch behind, to a lesser degree below, and rather faintly in front. The condyles are nearly equal in size, the external one being rather the larger, while both are situated on the same level distally. Their external surfaces are more or less smooth, the tuberosities above the external condyle alone being in evidence to break the general smoothness of the surface of this distal end of the femur.

Proximally, the bone presents for examination the head, neck and the greater and lesser trochanters. Head and neck are almost exact miniatures of those we find on the femur in a man, the former being quite hemispherical in form, and the latter constricted and proportionately a little shorter. A distinct depression for the *ligamentum teres* is present, and the axis of the neck makes an obtuse angle of some 135° with the longitudial axis of the shaft. Rising no higher above the summit of the bone than the head, the *trochanter major* is strongly developed, and has a deep excavation on its postero-internal aspect. Standing between this and the neck, and two or three millimetres below both, we meet with the *trochanter minor*, here very distinctly developed as a small but conspicuous tuberosity. Passing just to the inner side of this, and running down the shaft obliquely to the junction of upper and middle thirds, and from thence straight down to the smooth and flat "popliteal space," is a "muscular line" or ridge, best marked in the upper third of its course. A similar line (linea aspera) passes from the base of the trochanter major, its outer aspect, to run down in nearly a straight line to the tuberosity above the external condyle, where it stops. These two muscular lines are parallel and quite close together for the whole middle third of the femoral shaft. Nutrient foramina occur on the anterior aspect of the trochanter major, in the intercondyloid notch, and on the side of the internal condyle, a fact that inclines me to think that there is no regular site for these openings.

Fabellæ are also present at the back of the knee-joint of this fox, a small ossicle or fabella being found in the ligament posterior to either condyle; but the sesamoid spoken of by Flower as "a wedge-shaped bone within the joint, lying on

the articular surface of the tibia, an ossification of the internal inter-articular semi-lunar cartilage," does not appear to be present. A *patella* of some size, however (8 mm. long), and of an oval form, exists in its usual place in the common extensor tendon at the front of the knee-joint. Its anterior surface is convex and roughened, while posteriorly it presents an articular facet for each femoral condyle.

Morphologically, the *tibia* and *fibula* of the leg are interesting bones. Viewing the former upon its anterior aspect it will be noticed that the upper moiety of the shaft is gently curved in such a manner that it is concave on its outer side and correspondingly convex upon its inner side. Below the middle of the bone it is nearly straight, with a slight inclination, however, to exhibit a curvature the reverse of what has just been described as being found in the upper half. Again the upper half of the tibia is massive and strong, the crest upon its anterior aspect being prominently developed. This feature is most conspicuous above, gradually disappearing as the middle of the shaft is approached, after which this part of the bone is compressed in the antero-posterior direction. A horizontal section made first below the summit would be distinctly triangular, and a similar one made in the lower third would be elliptical. Seen from above the summit of the tibia has a cordate outline, the apex being to the front, and the figure completed by a median notch behind. In this latter locality the margins are curled downward, and particularly so where the fibular articulation is found, so that this facet is *beneath* this projecting part of the summit of the tibia, and consequently the fibula is shorter than the former bone proximally.

The tibial shaft is wonderfully smooth, and exhibits longitudinal muscular ridges only at its upper third at the posterior aspect. Distally, its extremity is but moderately enlarged, and compressed from before backward. Its basal aspect is peculiarly concaved in order to articulate with the astralagus of the tarsus. This concavity would not be suspected simply by viewing the bone directly from in front, from behind, or from the side, so completely is it on the basal end of the shaft. It is marked by a distinct and deep little notch anteriorly, close to the *internal malleolus.*

The *fibula* is an exceedingly slender bone of uniform calibre, being markedly compressed from side to side, including its extremities, which are rounded and dilated. The upper one of these articulates with the tibia in the manner described above, while the lower one projects beyond the end of the former, where it becomes the *external malleolus* of the ankle-joint. Owing to the aforesaid curvature of the upper half of the tibial shaft, the fibula stands far apart from its companion in that part of the skeleton of the leg, but below the middle of the shaft, these two bones come in contact, and from this point to the distal fibular enlargement (external malleolus) they are in extremely close contact, probably actually co-ossified in very old individuals. Flower says the "fibula is slender, and in dogs curved towards the tibia, the lower half being closely applied to that bone." This is true only in part, as proximally it is the tibia that is curved *away* from the fibula, the latter, as has been said, being almost perfectly straight from one end to the other.

Vulpes macrotis, in common with other terrestrial carnivores, has the skeleton of *pes* divided into three parts, namely, the *tarsus*, the *metatarsus*, and the digits or *phalanges*. The *tarsus* is composed of seven distinct bones articulating with each other in a manner similar to what is known to occur in the tarsi of other representatives of this group. These bones are the *astralagus*, the *os calcis* or *calcaneum*, the *scaphoid* or *navicular bone*, the three *cuneiform bones* (internal, middle and external), and the *cuboid*.

Morphologically, the astralagus is composed of the *tibiale* and the *intermedium*, the internal cuneiform is the first tarsal (tarsale I), the middle the second, the external the third, and the cuboid the united fourth and fifth tarsals (tarsale IV and V).

The *metatarsus* of *V. macrotis* consists of four much elongated metatarsal bones, of a very rudimentary, hook-like *hallux*, only 4.5 mm. long, and freely articulating with the anterior facet upon the internal cuneiform. On the under side of each distal trochlear extremity of the fully developed metatarsal bones we find a pair of large *sesamoids*. Each pair of these sesamoids is so disposed as to give the appearance of being but a single one, deeply grooved in the longitudinal direction, both on the dorsal as well as the ventral aspects. They are in the plantar tendons of pes. The podal phalanges closely resemble those of the manus, and have bones of the same number, and nearly of the same form and size. Great beauty of adaptation and movement characterizes the ankle-joint of this fox, especially in its articulation with the bones of the leg.

The *astragalus* is a very irregularly formed bone, consisting of a trochlear portion and head. The latter is a cuboidal projection that extends forward from the antero-internal aspect of the former, and has its distal, vertical face entirely occupied by a slightly convex, smooth facet for articulation with the navicular bone or scaphoid. Seen from above, the trochlear part of the astragalus has a most perfect articulation of that character, reminding one at once of the distal end of a phalanx in the manus of *Homo*, or in the pes of any large true raptorial bird. Its median groove is longitudinal, and extends from the head of the bone backward clear around and under for some distance, making in all a beautiful curved surface. The lateral margins are somewhat sharp, especially the inner one, which in the articulated ankle fits into the little narrow and deep notch which was described above as being found on the anterior distal margin of the basal part of the tibia. This admirable arrangement prevents to a great degree the danger of the lateral dislocation of the bones of the leg and the tarsus from any violence or sudden sprain in running.

On the under side of the astragalus there is a somewhat irregular trochlea for articulation with the os calcis. Its convexity is transverse or just the reverse of the one on the upper side of the bone. Furthermore we find here a minute longitudinal groove passing toward the head of the bone, but with its posterior extemity terminating in a deep pitlet. Internally, the surface of the astragalus is extensive and undulating; externally, it is narrow and markedly curved, the curve corre-

sponding to the curve of the internal trochlea of the superior aspect. When normally luxated, the astragalus rests upon the supero-internal aspect of the os calcis and articulates with it by two facets. Above, it articulates with the tibia and fibula; the former monopolizing all of the trochlear surface, while the infero-internal aspect of the distal end of the latter articulates with the greatly curved and narrow facet, described above as composing the outer surface of the tarsal bone under consideration.

The *os calcis* or calcaneum has an extreme length longitudinally of 2.4 cms., and a width of one centimetre, measured at its widest part across the articulation for the astragalus. This latter occupies the anterior half of the bone superiorly, while its anterior face is occupied by a vertical facet devoted to the articulation with the cuboid. The posterior half of the calcaneum is rather deep, compressed from side to side, with the free upper extremity enlarged, and bears a smooth, vertically convexed, laterally concaved surface for the insertion of the distal end of the tendo Achillis. The "lesser process" of the os calcis is well developed, and beneath it is plainly to be seen the groove for the passage of the tendon of the flexor longus pollicis muscle. Flower says[10] that the recent researches of Baur, *On the Morphology of the Tarsus in the Mammals*, "American Naturalist," January, 1885, make it probable that a certain bone on the tibial side of the tarsus of *Hyrax*, many Edentates, *Ornithorhynchus* and rodents,—and hitherto looked upon as a sesamoid bone,—is the rudimentary tarsale tibiale, whilst the astragalus is the intermedium representing the lunare of the hand. This tibiale is frequently fused with the centrale, the navicular bone in such cases containing the elements of the centrale and tibiale." Again, in the same work, on page 342, he says, "In addition to these constant tarsal bones, there may be supplemental or sesamoid bones; one situated near the middle of the tibial side of the tarsus, largely developed in many carnivora and rodents; another, less frequent, on the fibular side; and a third often developed in the tendons of the plantar surface of the tarsus, especially large in the armadillos. There is also usually a pair of sesamoid bones opposite each metatarso-phalangeal articulation on its plantar aspect." In carefully examining these parts in *Vulpes macrotis* it becomes clear that the first-mentioned bone (or sesamoid?), considered in the above footnote to be the *tibiale*, is fused with the *centrale* or *navicular bone* on its plantar side. The smaller one, on the fibular side, if present at all, must be either extremely rudimentary or else co-ossified with some other tarsal element. It was not found in this fox. In a former paragraph, the paired sesamoids on the plantar aspect of each metatarso-phalangeal articulation, have already been described.

Passing to the *cuboid* we meet with a large strong bone having a length equal to that of the scaphoid and external cuneiform combined. It articulates with both of these bones as well as with the proximal extremities of the fourth and fifth metatarsals anteriorly and the os calcis behind. Dorsally, the bone is comparatively smooth, while on its ventral side in front it presents a deep groove, which crossing

[10] *Osteology of the Mammalia*, Third edition, p. 340.

this surface obliquely, is intended to lodge the tendon of the peroneus longus muscle. On the external aspect the commencement of this groove is indicated by a deep notch, which in life is converted into a foramen by the ligament stretching across it from the fifth metatarsal to the cuboid itself.

The *scaphoid* is a short, subcylindrical segment of some size, with a round concave facette for the astragalus, and, anteriorly, facettes for the three cuneiform bones, and it articulates with all of these elements. Below, it fuses with a large plantar sesamoid.

Having a very regular appearance, the three *cuneiform bones* are wedged in between the scaphoid behind, and the rudimentary hallux, and the second and third metatarsals in front. In point of size, the external cuneiform is the largest, the internal the next biggest, and the middle one the smallest of the three. The internal one develops a conspicuous plantar process for the attachment of ligaments. Anteriorly, it articulates with hallux and second metatarsal. The middle or shortest cuneiform, articulates anteriorly, only with the second metatarsal, while the longer *external cuneiform* articulates with the proximal end of the third metatarsal.

Apart from the rudimentary *hallux*, all of the four remaining *metatarsals* are long, rather stout, and subcylindrical bones. Proximally, they are crowded close together, practically firmly moulded upon each other for at least one-third of this part of their lengths, and this in such a manner that from side to side they offer dorsally a marked *convex* surface as compared with the far shallower concave surface on their plantar aspects when similarly considered. As they extend forward toward the toes, the two middle ones very slightly part company, and so their shafts keep nearly straight, but the second and fifth each somewhat curve away from the longitudinal median plane, and thus their shafts exhibit this curvature.

The *second metatarsal* is the stoutest of the four, and the third the slenderest. Third and fourth each have a length of 4.6 centimeters, while second and fifth measure but 4.2 cms. Distally, they present the usual trochlear heads for the articulations of the posterior extremities of the corresponding *podal digits*. These last each possess two phalangeal joints, and terminate with a freely articulated osseous ungual claw, all morphologically similar to what we find in the digits of manus.

The character of the articulation between the metatarsal joint and the phalanx in the case of any toe is different from what is found between the two joints of the toe itself. In the first instance the head of the metatarsal bone has a convex, subellipsoidal articulation dorsad, and a sharp, median longitudinal keel on the plantar aspect. The rounded surface articulates with a corresponding facet on the proximal end of the phalanx, but below this, the articulation is deeply notched in the median line in order to admit the aforesaid keel on the end of the metatarsal, and this is kept in place in life by the paired sesamoids and the plantar tendons. The interarticulation between the phalangeal joints themselves is of the simpler trochlear type, such as we find in the case of the joints in the manus or pes of *Homo*, and between the last phalanx in any toe and its ungual joint the plan is

even still simpler, the trochlear head being less evidently defined. *Vulpes macrotis* has the skeleton of its second toe equal in length to that of the fifth, and that of the third equal to that of the fourth,—the bones all being strong, stoutish and well-proportioned. The second toe has a length of about 3.4 centimeters, and the third 4.0 centimeters. These measurements include the ungual joints, and all the bones normally articulated. In the case of any digit, its proximal joint is about one-fourth longer than the next one beyond. For example, the length of the proximal joint of the fourth digit is 1.8 cms., the next joint in the same toe being 1.4 cms., and their calibres vary in proportion. The sharp-pointed angular joints exhibit but little curvature, and at their articulations their basal portions extend plantar-wards as a process, in each case, for the insertion of the plantar tendon of the flexor longus digitorum.

EXPLANATION OF PLATES.

All the figures are of natural size, except fig. 12 of Plate XXIII, and from photographs made direct from the specimens by the author.

Plate XXII.

Fig. 1. Left lateral view of the skull and lower jaw of *Vulpes macrotis*.

Fig. 2. Dorsal aspect of the skull of *Vulpes velox*, the mandibles having been removed.

Fig. 3. Lower jaw or mandible of *Vulpes macrotis*, viewed from above.

Fig. 4. Right ramus of mandible of *Vulpes velox*, seen from above, and rotated inward. Tip of canine tooth, and the incisors broken off; molars and other teeth complete and in position.

Fig. 5. Ventral aspect of the skull of *Vulpes velox* (same specimen as is shown in fig. 2). The lower jaw has been removed.

Fig. 6. Ventral aspect of the skull of *Vulpes macrotis*.

Fig. 7. Dorsal aspect of the skull of *Vulpes macrotis*. Same specimen as is shown in fig. 6.

Plate XXIII.

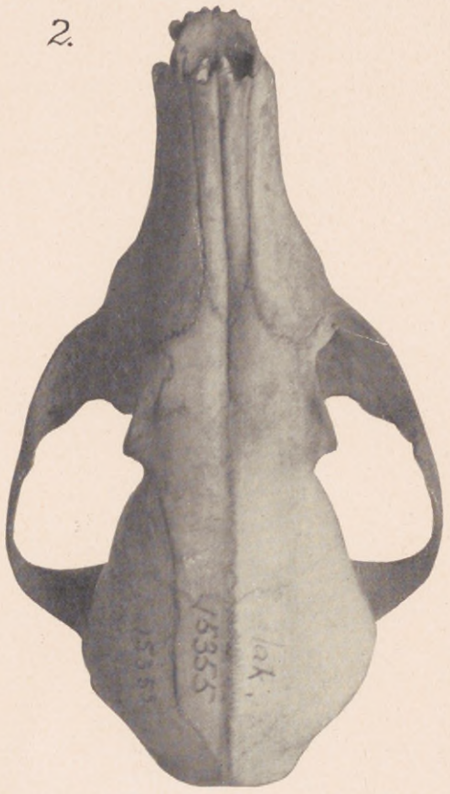
Fig. 8. Left scapula of *Vulpes macrotis*, external surface.

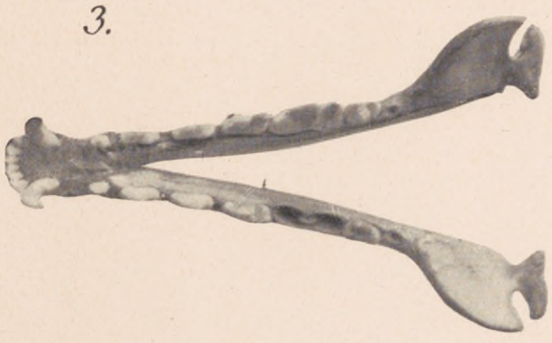
Fig. 9. Dorsal surface of the left humerus of *Vulpes macrotis*, showing the preaxial border, greater tuberosity, and the external condyle.

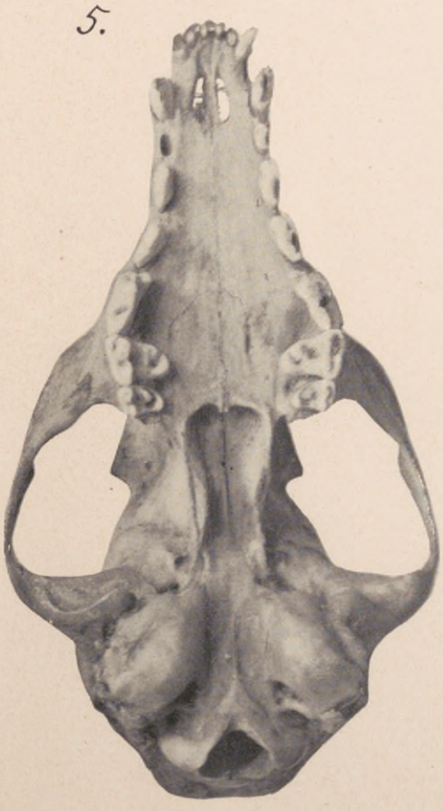
Fig. 10. Anterior view of the left femur of *Vulpes macrotis*.

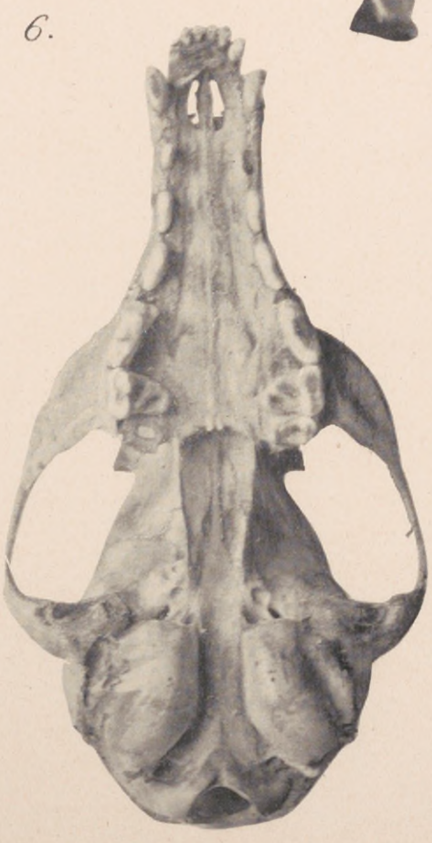
Fig. 11. Left tibia and fibula of *Vulpes macrotis*, normally articulated, and viewed upon external aspect. (All the bones, except those shown in figs. 2, 4, and 5, of Pl. XXII, belong to the one and same individual in author's collection, the ramus of the jaw in fig. 4, Pl. XXII, belonging to the specimen of *V. velox* of the U. S. Nat. Museum, No. 15,355.)

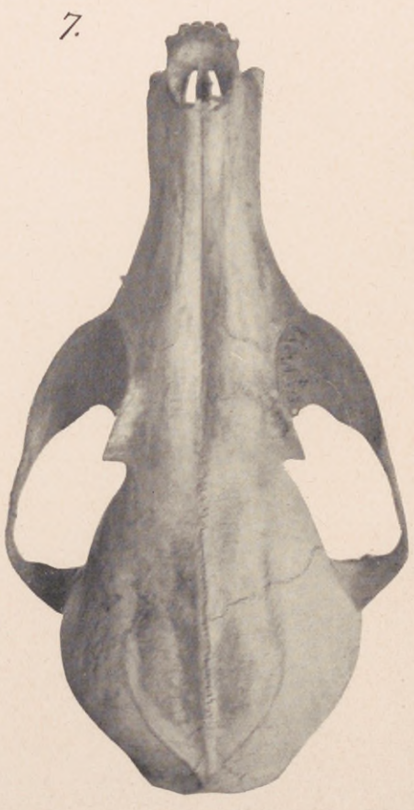
Fig. 12. Right lateral aspect of the skeleton of the trunk of *Vulpes macrotis*. (Reduced rather less than one-half.) Naturally articulated, and the dried ligaments and cartilaginous costal ribs not removed. Exhibits the normal relations of the bones of the trunk.











SHUFELDT. OSTEOLOGY OF VULPES MACROTUS.

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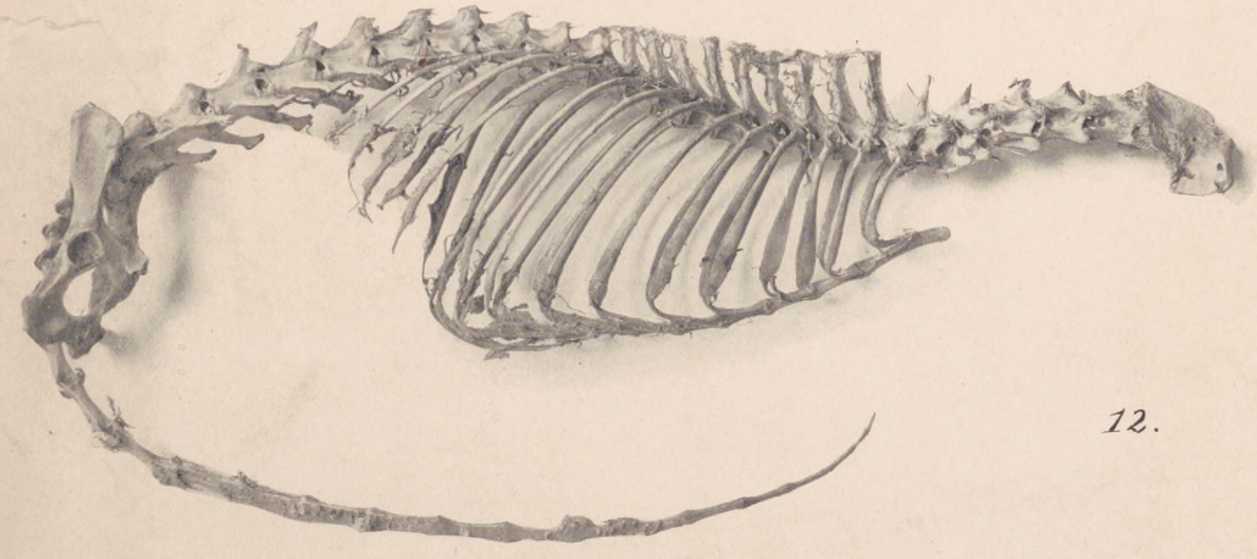

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