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XXVI.—On the Course of the Internal Carotid Artery and the Foramina connected therewith in the Skulls of the Felidæ and Viverridæ. By R. I. Pocock, F.R.S., Superintendent of the Zoological Society's Gardens.

[Plates X. & XI.]

THE skulls upon which the observations made in this paper are based belong mainly to the Zoological Society's collection; but I am indebted to Mr. H. C. Beck, F.Z.S., for the kind loan of the skull of the rare Madagascan genus *Cryptoprocta*, and to Mr. E. Gerrard for that of a species of *Galidictis*. The facts recorded have been checked as far as possible upon the skulls in the British Museum placed at my disposal by Mr. Oldfield Thomas; but in these examples I was unable to lift the bullæ or cut away the parts concerned for the purpose of laying bare the foramina.

For classifying the Æluroid Carnivora both Flower and Mivart made use of the foramina in the base of the skull connected with the course of the internal carotid artery. The former\* wrote:—"In the Felidæ the carotid canal is very minute. In the Viverridæ it is distinct as a groove on the side of the bulla." According to Mivart†, "in the Felidæ there is no carotid foramen anywhere visible on the surface of the basis cranii, and no carotid foramen perforates or notches the sphenoid, whereas in the Viverridæ there is a carotid foramen, or two carotid foramina, visible on each side of the basis cranii, and there may be a conspicuous carotid foramen (deeply notching the sphenoid) in the basis cranii for the entrance of the carotid into the cranial cavity."

No excuse need be sought for restating the facts, since neither of the quoted authors, who have inspired subsequent writers on the subject, seems to have investigated them very carefully, judging from certain inaccuracies and defects contained in their statements.

The Viverridæ, as understood by Flower and Mivart, are a heterogeneous group including all the Æluroids which are not obviously cats or hyænas. They may be considered first.

It may be recalled that in *Canis* the canal for the internal carotid begins by an orifice on the inner side and in front of the space that leads to the *foramen lacerum posticum*—the

\* 'Mammalia,' pp. 502 & 525 (1891).

† P. Z. S. 1882, pp. 144-145, 197-198.

posterior orifice between the periotic and the basioccipital. Posteriorly the canal lies between the tympanic bulla and the periotic. Anteriorly it is a tube in the tympanic itself, and its anterior orifice opens at the antero-internal angle of the bulla on the admedian side of the adjacent orifice of the eustachian tube, and just above the *foramen lacerum medium*, the anterior space between the periotic and the basisphenoid, through which the artery, after leaving the canal, enters the cranium.

Except that the posterior orifice of the canal is always situated further forwards and that the anterior orifice, even when the canal is complete, opens into a space beneath the bulla common to it and the eustachian tube, the arrangement found in the *Viverridæ* does not differ much from that of the *Canidæ*. But within the *Viverridæ* there are some interesting variations in detail worth putting on record.

The facts observed in most of the dominant types may be described before a general summary is attempted.

In an example of the African civet (*Civettictis civetta*) the posterior orifice of the carotid canal is situated about halfway along the inner wall of the bulla further in advance of the *foramen lacerum posticum* than in the *Felidæ* and *Canidæ*. Throughout its length it is an open channel, and not a closed tube. It passes nearly vertically between the tympanic and the adjacent edge of the basioccipital. It then turns, and ceases at the edge of the inturned tympanic. Thence the artery runs forwards beneath the anterior part of the tympanic, and enters the *foramen lacerum medium*, which forms a small semicircular notch in the basisphenoid and is just visible at the antero-internal angle of the bulla when the skull is viewed from below, although it is partially overlapped by a small bridge of bone jutting inwards from the bulla to the antero-lateral angle of the basioccipital. Behind this bridge the periotic appears for a small space on the surface of the skull between the bulla and the basioccipital.

In examples of the Oriental civets (*Viverra zibetha*, *V. tangalunga*, and *Viverricula malaccensis*) the arrangement is similar in all essential respects, except that the periotic does not reach the surface of the basis cranii, the *foramen lacerum posticum* is usually narrow, and the *foramen lacerum medium* much deeper and more apparent on the base of the skull\*.

\* In properly cleaned skulls a bristle can be passed through the carotid canal from back to front when the canal is tolerably straight; but where it makes a sharp bend, as in the African civet examined, this cannot be done.

In examples of *Genetta pardina* and *felina*, on the contrary, the posterior orifice of the canal lies much further in advance of the *foramen lacerum posticum*—that is to say, about one-fourth of the distance from the anterior end of the posterior chamber of the bulla. It is formed by two juxtaposed grooves, one on the bulla, the other on the periotic, a narrow strip of which reaches the surface at this point between the basioccipital and the bulla; but the deeper, anterior half of the groove is a complete bony tube formed by the bulla alone. The anterior end of this tube opens just above the *foramen lacerum medium*, which deeply notches the sphenoid and is almost concealed from view superficially.

In an adult skull of *Paguma larvata* the canal begins as a groove on the anterior half of the inner side of the bulla, and becomes a definite tube quite at the anterior end of the posterior chamber of the bulla up against the basioccipital; and as in *Genetta felina* the concealed anterior part of the canal is a short but completely bony tube formed by the bulla alone. The *foramen lacerum medium*, notching the basisphenoid, is just visible at the antero-internal angle of the bulla. The two bones forming the bulla are not fused together.

In an adult skull of *Paradoxurus niger* the canal resembles that of *Paguma larvata*, except that the concealed anterior portion is not a complete bony tube in the tympanic. Here also the two bones of the bulla are not co-ossified.

In an example of *Arctictis binturong* the posterior orifice of the canal is about halfway along the wall of the bulla, and therefore much closer to the *foramen lacerum posticum* than to the *foramen lacerum medium*. The canal is a deep groove on the tympanic. It descends nearly vertically at first, where it passes alongside the basioccipital. The artery thereafter turns forwards and completes its course on the underside of the tympanic. In the specimen examined the canal is nowhere a complete tube, although just above the point where it ceases the bones of the tympanic almost meet and close it in. Since this specimen is immature, as shown by the persistence of the occipito-sphenoidal fissure, although the permanent dentition is just in place, it is possible that in the adult the tube is closed at the place above indicated. The *foramen lacerum medium* deeply notches the sphenoid, the anterior part of the notch being almost cut off from the posterior by bony growths.

In a skull of Hose's palm-civet (*Diplogale hosei*) the carotid canal is set close to the *foramen lacerum medium*, and is a very short and simple passage lying between adjacent

portions of the tympanic, periotic, and basioccipital; and the *foramen lacerum medium* is a rather short constricted notch in the basisphenoid, and is visible to a great extent upon the surface of the skull. It may be added that the two bones composing the tympanic bulla are completely separated in the adult skull, as they are in the examples of *Paguma larvata* and *Paradoxurus niger* examined.

In a subadult skull of *Arctogalidia* with the tooth-change just completed, but with the basisphenoidal suture still visible, the posterior orifice of the carotid canal lies approximately midway between the *foramen lacerum posticum* and the *foramen lacerum medium*. It leads into a groove in the tympanic, which is bordered on the admedian side by the basioccipital; but anteriorly it is continued by a complete bony tube formed by the tympanic, as in *Genetta felina* and *Paguma larvata*. But, unlike the other species hitherto discussed, the orifice by which the carotid artery enters the skull is entirely cut off from the periotic, and pierces the sphenoid as a round hole, which is exposed on the base of the skull just in front of the antero-internal angle of the tympanic bulla. The two bones of the bulla are completely fused together, as in *Arctictis*, *Genetta*, *Viverra*, *Viverricula*, and *Civettictis*.

In *Cynogale* the course of the carotid canal is peculiar. It runs from a notch-like orifice in the wall of the bulla obliquely across the posterior chamber as a very distinct crest to the septum and periotic, and itself forms a low partition to that chamber. The *foramen lacerum medium* simply notches the basisphenoid.

In *Cryptoprocta ferox* the features presented by the carotid canal combine those of *Genetta* and *Arctogalidia*. The canal slants as a groove on the tympanic near the middle of the inner wall of the bulla; but where it dips beneath the surface it is converted into a complete cylindrical tube formed by the tympanic alone, and is thus cut off from the basioccipital and the periotic. It terminates in front beside the eustachian aperture. The artery enters the brain by a hole, not a notch, in the basisphenoid, and this hole, as in *Arctogalidia*, is visible on the base of the skull in front of the antero-internal angle of the bulla, and is completely severed from all connection with the periotic.

Approximately the same condition appears to obtain in *Eupleres* and *Fossa*—at all events, so far as the distinctness of the carotid foramen in the sphenoid is concerned.

In the skulls of mongooses (*Mungos*) the posterior orifice of the canal is a small round hole, not a long groove, perfo-

rating the wall of the bulla above the basioccipital bone. The canal itself throughout its length is a narrow cylindrical bony tube formed by the tympanic, so that the artery is nowhere in contact with the basioccipital or the periotic. The artery issues from this tube alongside the eustachian aperture, and enters the skull by a conspicuous foramen on the base of the skull, piercing the basisphenoid in advance of the antero-internal angle of the bulla, as in *Cryptoprocta*.

Within the limits of the genus *Mungos* the position of the posterior orifice of the canal varies. In a skull of *Mungos ichneumon* it lies about midway between the *foramen lacerum posticum* and the anterior termination of the canal; but in a skull of *Mungos smithii* the posterior orifice is only a short distance in front of the *foramen lacerum posticum*, so that the canal in this example is relatively much longer than in the other.

Judging from a superficial examination of the skulls of mongooses of other genera, the structure of the carotid canal is the same as that described above. The position of the posterior orifice, which always apparently pierces the bulla just behind the inner portion of the partition of the bulla, varies in accordance with the length of the two chambers. In *Cynictis*, for example, where the posterior chamber is very short and the anterior very long, the orifice in question is only a little way in front of the *foramen lacerum posticum* and the canal is long, whereas in *Ichneumia albicauda*, where the anterior chamber is small and the posterior large, the posterior orifice of the canal is set far forwards, and the canal itself is short.

In *Galidictis* and related genera the structure of the carotid canal appears to be the same as in the mongooses.

The condition of the canal in the mongooses and *Galidictinae* may be derived from that seen in *Cryptoprocta* by the growth and subsequent union of the upper and lower margins of the carotid groove on the bulla, to form a cylindrical tube continuous with the osseous tube, which forms the anterior portion of the canal in that animal.

In the African palm-civet (*Nandinia binotata*) the bulla, as is well known, has the wall of the posterior chamber permanently cartilaginous. In a fresh example of this species I found the carotid artery entering the cartilaginous bulla a little way in front of the *foramen lacerum posticum*, and running over a groove on the periotic close to the basioccipital and entering the small *foramen lacerum medium*, which lies deep down and is entirely concealed by the bony tympanic bone, when the latter is left in place. This

foramen, moreover, is cut off from the periotic by bone, a short straight suture alone indicating its original continuity with the space between the periotic and the basisphenoid.

In her paper upon *Nandinia* Miss Albertina Carlsson marks the carotid groove as running between the antero-internal portion of the tympanic bone and the basioccipital. This must, I think, be a mistaken inference. At all events, the artery did not take that course in the fresh example of *Nandinia* that I examined (see Zool. Jahrb. Syst. xiii. pp. 509-528, pl. xxxvi. fig. 1, 1900).

It may be added that there is no partition, either cartilaginous, membranous, or osseous, in the bulla of *Nandinia*. When the tympanic membrane is cut away, a probe can be passed in the uncleaned skull through the external auditory meatus to the posterior wall of the cartilaginous portion of the bulla.

In the Felidæ, in conformity with the homogeneity of the family, the carotid canal is much less variable than in the Viverridæ\*. The canal is almost always apparent as a short shallow groove notching the tympanic bulla close to the basioccipital, and not infrequently set so far back that it lies within the depression which leads to the *foramen lacerum posticum*. Occasionally, however, the notch or groove lies just in front of that depression, as in a skull of *Felis jaguarondi* I possess; but it is never set nearly so far forward as the middle of the inner surface of the bulla. Only quite exceptionally, and as an individual peculiarity, is the notch converted into a bony tube, with a rounded orifice, by the extension and fusion of its edges, so that the basioccipital forms no part of the carotid canal. This is the case on one side, but not on the other, in a skull of *Felis uncia*, in which the posterior orifice of the canal is, as in *Mungos*, a round hole in the bulla. In this skull, as in that of *F. jaguarondi*, the canal is placed in front of the *foramen lacerum posticum*.

In all cases the canal descends† to the edge of the concealed intumed portion of the tympanic above the periotic, where it ceases. From that point the artery apparently runs along the periotic close to the basioccipital and the adjacent portion of the tympanic, and in some cases this portion of the tympanic is longitudinally grooved‡; but I

\* In this paper the significance applied to the term Viverridæ by Mivart and Flower is, without prejudice, adopted.

† From the point of view of the spectator, when the skull is examined with its base uppermost.

‡ I have not, however, traced the course of the artery within the bulla of any of the Felidæ.



do not know whether or not this groove marks the course of the artery, although the similarity of this groove to that of the Viverridæ suggests that it does so. The canal frequently shows on the inside of the bulla as an upstanding ridge resembling, but relatively smaller than, that of *Cynogale*.

The artery enters the skull by a small narrow foramen, notching the basisphenoid where it touches the periotic. This orifice, visible in all the skulls of Felidæ examined, is the *foramen lacerum medium*, and it corresponds exactly with that of *Viverra* and *Genetta*; but to discover it the bulla has to be removed, because it lies deep beneath the anterior end of the bulla, which at that point is immovably fused to the basisphenoid, and the only orifice at the antero-internal angle of the bulla is the internal orifice of the eustachian tube.

In this connection it may be recalled that Mivart ('The Cat,' p. 208, 1881) said that the minute internal carotid artery enters the *foramen lacerum posticum*, and passes along a slender canal between the basioccipital, basisphenoid, and the periotic, and enters the cranial cavity at the inner side of the anterior end of the periotic. This appears to be perfectly correct, but it is difficult to reconcile with his subsequent statement (P. Z. S. 1882, p. 145) that it is distinctive of the Felidæ as compared with the Viverridæ to have no carotid foramen perforating or notching the sphenoid. Nevertheless, as has been shown above, the basisphenoid is penetrated by a notch by which the carotid enters the skull close to the periotic in the Felidæ and all the typical Viverridæ. In fact, there does not appear to be any material difference between *Felis* and *Nandinia* with respect to the course of this artery and the foramina connected therewith.

### Conclusion.

The above-mentioned facts have been described in some detail to show, first, the variation in the structure of the carotid canal and in the situation of the foramina connected with the artery in the genera referred by Mivart, Flower, and others to the Viverridæ, and, second, the impossibility of logically drawing a line, based upon the characters under notice, between the Viverridæ, as understood by those authors, and the Felidæ. The facts may be briefly summarized as follows:—

(1) In the Viverridæ the posterior orifice of the canal may be far forwards and only a short distance behind the *foramen lacerum medium* (*Paguma*, *Diplogale*), or near the

middle of the inner wall of the bulla (most of the genera), or set far back only a little way in advance of the *foramen lacerum posticum* (*Cynictis*). In some Felidæ (e. g., a skull of *F. jaguarondi*) it is only a little closer to the *foramen lacerum posticum* than in *Cynictis*. In others it lies back so as to open within that fossa.

(2) In the Viverridæ the canal itself may be a long completely bony tube traversing the wall of the bulla (*Mungos* and allied genera), or it may be a complete bony tube only at its anterior end and an open channel in the bulla posteriorly (*Genetta*, *Paguma*), or it may be an incomplete tube or an open channel throughout its length in the bulla (*Civettictis*, *Viverricula*, *Viverra*), or it may form a very distinct ridge running obliquely across the cavity of the bulla (*Cynogale*). In the Felidæ it is, as a rule, an open channel, only exceptionally being a closed bony tube in its posterior half.

(3) In the Viverridæ the orifice by which the artery enters the base of the skull after leaving the tympanic canal may be entirely cut off from the rest of the *foramen lacerum medium* and fully exposed on the basisphenoid (*Mungos*, *Cryptoprocta*, *Fossa*, *Galidictis*, *Arctogalidia*), or it may be continuous with the *foramen lacerum medium* behind and form a deeper or shallower notch in the basisphenoid, the anterior end of this notch being sometimes plainly visible in front of the bulla (*Arctictis*, *Diplogale*, *Paradoxurus*), sometimes overlapped by it and only visible by looking beneath the bulla (*Genetta*, *Viverricula*, *Nandinia*). In the Felidæ the orifice always notches the basisphenoid, as in the genera just mentioned, but it is never visible from the surface, because the overlying portion of the bulla forms here a bony contact or fusion with the basisphenoid.

The combination of these characters—namely, the fusion of the bulla to the basisphenoid and the consequent complete concealment of the *foramen lacerum medium* by which the internal carotid enters the skull after leaving the bulla—is apparently the only positive feature that can be substantiated between the Viverridæ and the Felidæ so far as the structures under notice are concerned.

## EXPLANATION OF THE PLATES.

### PLATE X.

*Fig. 1.* Base of cranium of *Viverricula malaccensis*, with bulla of left side removed and bristles passed through the eustachian tube and the carotid canal of the right side. *ov.*, foramen ovale; *gl.*, glenoid foramen; *fm.*, foramen lacerum medium running from the petrotic and deeply notching the basisphenoid; *st.*, stylomastoid foramen with the fenestra rotunda on its inner side and the fenestra ovalis just in front; *per.*, petrotic pierced by these two

fenestræ and on the inner side abutting against the basioccipital; *fp.*, foramen lacerum posticum with the condyloid foramen just behind it; *pocc.*, paroccipital; *tb.*, tympanic bulla, the position of the partition shown by a dotted line.

*Fig. 2.* Base of cranium of *Cryptoprocta ferox* with the two bullæ in place. Lettering and arrows as in *fig. 1*; *fm.*, the foramen lacerum medium piercing the sphenoid as a round hole entirely separated from the periotic.

*Fig. 3.* Base of cranium of *Mungos ichneumon* with the antero-internal portion of the bulla of the left side cut away to show the bony carotid canal (*cc.*) running alongside the basioccipital and terminating in front a little behind the part of the foramen lacerum medium (*fm.*) which is separated from the periotic (*per.*), the rest of it being represented by the smaller, more external orifice behind; *co.*, the posterior orifice of the carotid canal. Other lettering and arrows as in *figs. 1* and *2*.

*Fig. 4.* Base of cranium of *Nandinia binotata* with the cartilaginous portion of the bullæ missing from both sides and the osseous anterior portion, marked *tb.* on the left side, removed from the right. The stylomastoid foramen (*st.*) is remote from the margin of the prominent mastoid (*m.*) and the fenestra rotunda on the periotic (*per.*) is on its inner side; the foramen lacerum medium (*fm.*) is a small orifice in the basisphenoid lying deeply beneath the tympanic (*tb.*) and touching the periotic by a very narrow cleft. Other lettering as in preceding figures.

# PLATE XI.

*Fig. 1.* Left auditory bulla of *Civettictis civetta*, and seen obliquely from the underside to show the course of the carotid canal (*car.*), represented by a dotted groove. The canal comes to an end at the edge of the inturned portion of the tympanic bulla; *ea.*, external auditory meatus formed by tympanic ring.

*Fig. 2.* Left auditory bulla of *Arctictis binturong* from the same aspect. The carotid groove is almost converted into a bony tube inferiorly; *eu.*, eustachian tube. The large groove behind the carotid groove leads to the foramen lacerum posticum.

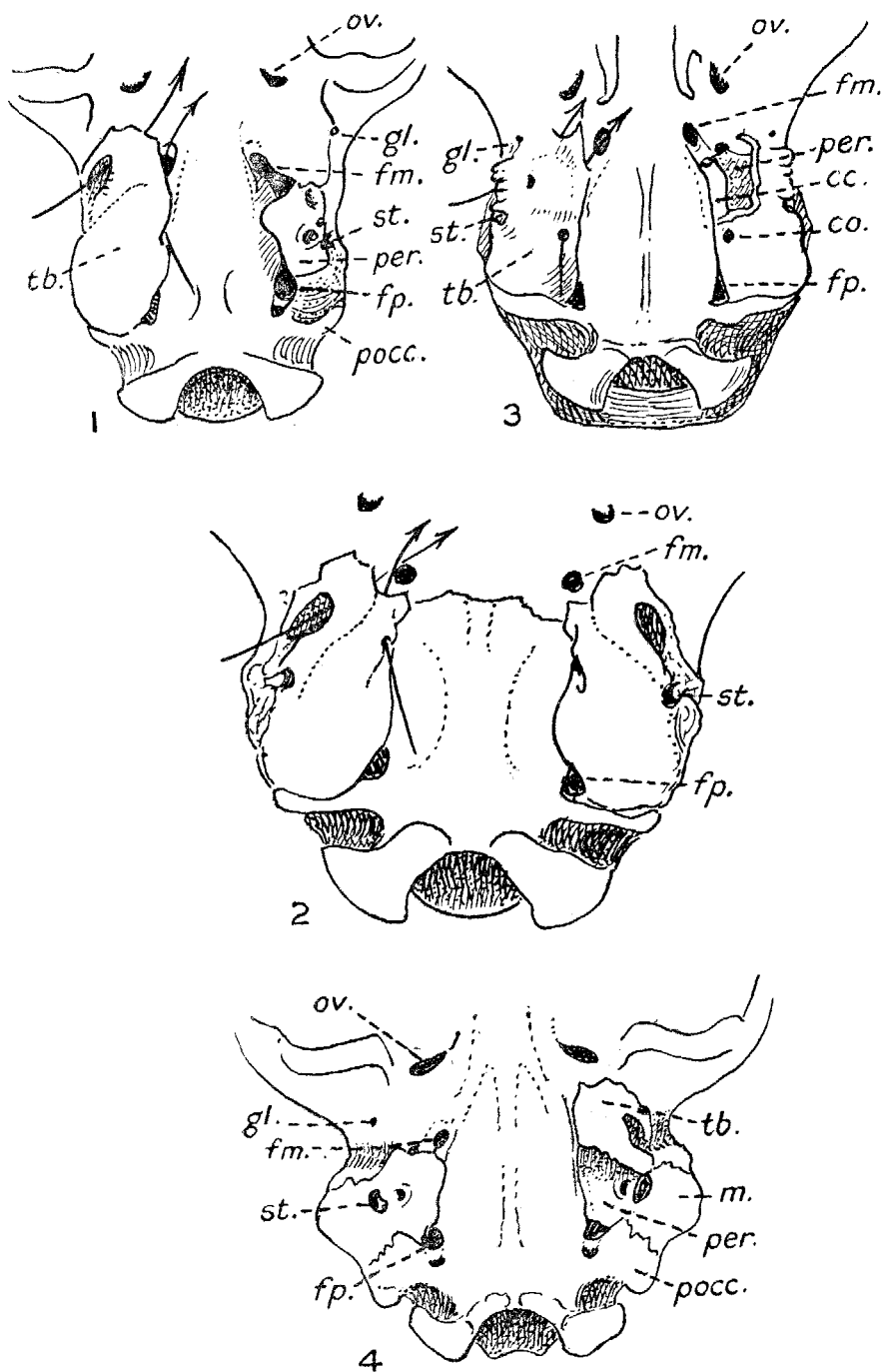
*Fig. 3.* Anterior portion of the left bulla of *Paguma larvata*, to show the carotid groove passing anteriorly into a bony tube, the arrow indicating a bristle traversing the canal.

*Fig. 4.* The same in *Genetta felina*.

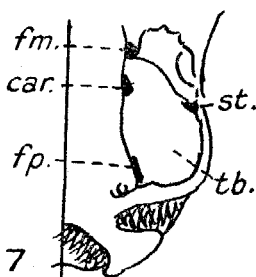
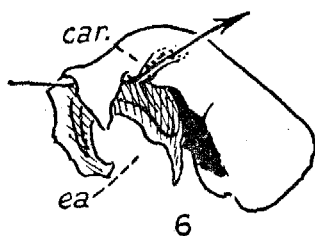
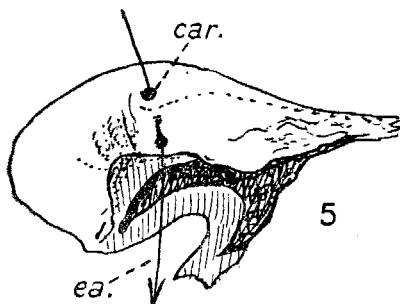
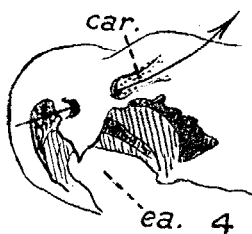
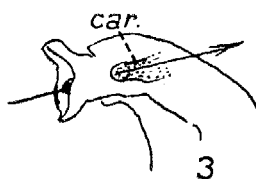
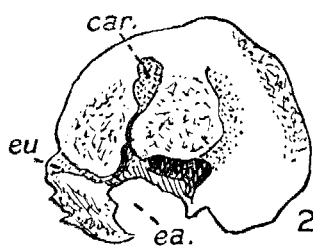
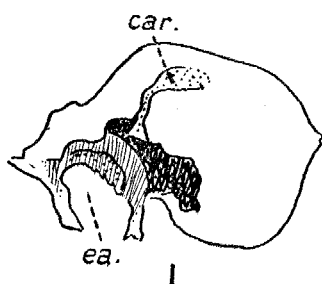
*Fig. 5.* Right bulla of *Felis uncia* from the same aspect as represented in the foregoing figures. The arrow indicates a bristle passed through the carotid canal (*car.*), part of which is a complete bony tube. In all Felidæ the canal apparently takes the same course, which is practically the same as that of *Civettictis* and *Arctictis*, but the canal is almost always an open groove, and not a bony tube.

*Fig. 6.* Right bulla of *Viverricula malaccensis*, with arrow indicating the course of the carotid artery anteriorly beneath the triangular flange of bone, which is not united beneath the artery to the adjacent bone of the tympanic ring to form a tube such as is seen in *Genetta*.

*Fig. 7.* Left half of base of skull of *Diplogale hosei*, showing the very short carotid canal beginning at *car.*; *fm.* and *fp.*, foramen lacerum medium and posticum; *st.*, stylomastoid foramen; *tb.*, tympanic bulla, with the line showing the separation between the two portions.



The Internal Carotid Canal in the Viverridae.



The Internal Carotid Canal in the Viverridæ and Felidæ.